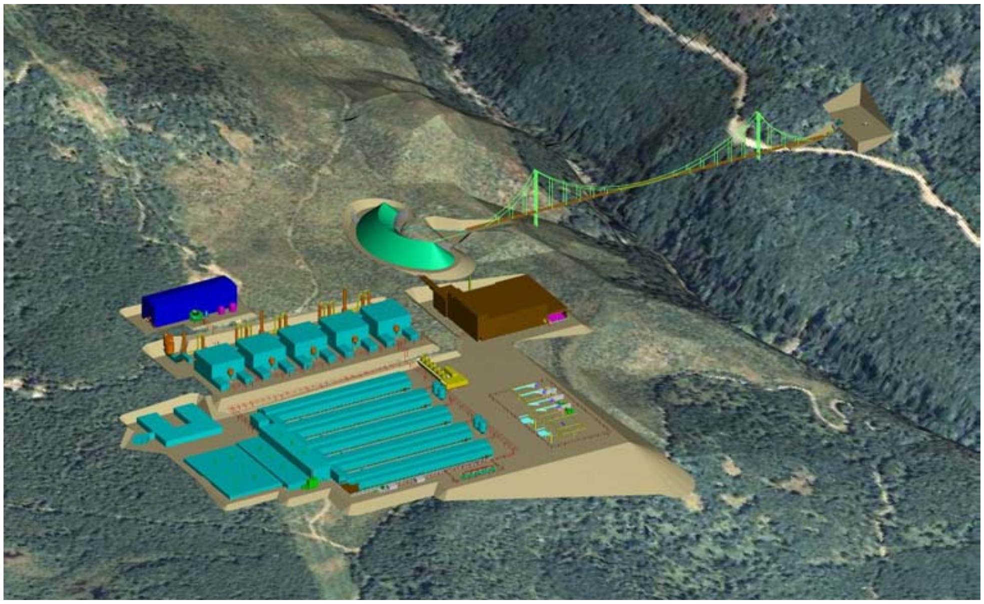
LEADER MINING INTERNATIONAL

BINDER NO. 1
PROJECT SUMMARY

FOR

PRODUCTION FEASIBILITY STUDY FOR COGBURN MAGNESIUM PLANT



HATCH

May 14, 2003

ISO 9001-94

5 Place Ville Marie, Bureau 200
Montréal, Quebec, CANADA H3B 2G2
Tel: (514) 861-0583 ◆ Fax: (514) 397-1651 ◆ www.hatch.ca

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5 Place Ville Marie, Bureau 200
Montréal, Quebec, CANADA H3B 2G2
Tel. (514) 861-0583 ◆ Fax: (514) 397-1651 ◆ www.hatch.ca

April 30, 2003

Mr. Jasi Nikhanj
Leader Mining International
#810, 400-5th Avenue S.W.
Calgary, Alberta
T2P 0L6

Dear Sir:

Subject: Cogburn Project Magnesium Metal Production Feasibility Study

In February 2002, Leader Mining International awarded Hatch the mandate to complete a Production Feasibility Study on the Cogburn Magnesium Project. The Cogburn Magnesium Deposit is a large ultramafic intrusive body containing consistently high-grade magnesium silicate (+24% magnesium). The discovery is located 120 kilometres east of Vancouver, British Columbia, Canada near the town of Hope. The location has a significant infrastructure advantage in that electric power, natural gas, mainline rail, provincial highways and barge access to nearby deep-sea ports are all adjacent to the property. In addition, the project is located in a mining and forest products extraction region with extensive supporting skilled labour and a broad spectrum of service industries.

The enriched Emory Zone has been subjected to an intensive drilling and sampling program. Under the direction of HATCH, Process Research ORTECH has pilot tested a composite sample, for hydrochloric leach extraction of magnesium. In addition, leach solution was tested at Messo in Germany to define evaporation and crystallization parameters for the preparation of cell feed for the STI/VAMI magnesium electrolysis technology. In April 2002 Leader signed an option with STI/VAMI for the use of the magnesium electrolysis technology for the Cogburn Project. Successful testing has resulted in preliminary design parameters for development of the Cogburn Project flowsheet. The Cogburn deposit because of its large size, high magnesium grade, low impurity levels, favourable metallurgy, and proximity to infrastructure has the potential to be developed into a world-class, environmentally friendly, long-life magnesium operation. Process information generated during the Study was used to develop capital and operating costs for the project at the selected site location. Following discussions with BC Hydro and Duke Energy, energy costs have been established for the Cogburn Project.

A market evaluation has been completed by Hatch and Leader Mining International proposes an aggressive entrance into the magnesium market. Total plant capacity is 131,000-t/a magnesium metal and alloys. The choice of proven technology will minimize risk for the implementation of the Cogburn project. Hatch has determined cost objectives of US$1.24 billion for the construction of the plant facilities and a magnesium cash cost of US$0.70/lb magnesium, providing an internal rate of return in the range of 6.5 to 18.1% based on sensitivity analysis. The test-work and the engineering completed to-date indicate that the Cogburn Project is technically feasible and economically viable. Hatch looks forward to the opportunity of assisting Leader Mining International in the development of this Project and we thank you for your forthright assistance in this study.

Yours truly,

Roger C. Urquhart

Dr. Roger C. Urquhart
Director – Light Metals

RCU:rcu

Project Report

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May 14, 2003

Leader Mining International
Cogburn Magnesium Feasibility Study

DISTRIBUTION

John Chapman – Leader
Yves Dessureault – Hatch

Project Summary Report

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If you disagree with any information contained herein, please advise immediately.

1. EXECUTIVE SUMMARY

1.1 Background

In 2002, Leader Mining International Inc. initiated actions to conduct a Production Feasibility Study for the development of its olivine bearing ultramafic rock deposit near the town of Hope in south-western British Columbia, Canada, approximately 120 km east of Vancouver. The project consists of quarry development and the construction of a magnesium plant, producing pure magnesium metal and magnesium alloy products.

Several magnesium production technologies were evaluated during previous phases of the project and the STI/VAMI carnallite-based process was recommended for implementation at the plant. The STI/VAMI process is proven technology with existing magnesium production plants operating in the former Soviet Union and Israel.

The complete plant flow sheet was modelled using METSIM metallurgical modelling software. Process flow diagrams (PFD) of the plant were produced based on the results of METSIM modelling. Plant layout and equipment general arrangement drawings were developed to enable producing capital and operating cost estimates. The capital cost estimate was generated jointly by Hatch and other consultants chosen by Leader Mining International Inc. The operating cost estimate was generated using plant operating parameters and Hatch in-house information.

The summary of the Production Feasibility Study of the project is presented in this document.

1.2 Plant Capacity and Life of Study

The nameplate capacity for the proposed plant is 125,000 tonnes per year of electrolytic magnesium metal. This electrolytic magnesium capacity will be used to produce 131,000 tpa of both primary magnesium metal and magnesium alloy products with a ratio of 23% primary magnesium and 77% magnesium alloys. The magnesium resource is very large, but only 25 years was selected for modeling in this Study.

1.3 Project Scope

The proposed Cogburn Magnesium production facility includes the following:

- ore quarrying and transportation;
- ore receiving, storage and preparation;
- ore leaching and brine purification;
- crystallization of synthetic carnallite;
- fluid bed dehydration of the carnallite;
- electrolytic reduction of magnesium metal;
- gas handling;
- spent electrolyte granulation;
- metal refining, alloying and casting;
- residue management;
- appropriate process utilities, plant services, administration and maintenance facilities.

1.4 Project Objectives

The main objectives of the Production Feasibility Study were as follows:

- Reserve characterization, ore requirements and quarry planning;
- Site selection and characterization;
- Process testwork;
- Process definition and flowsheets;
- METSIM process modelling;
- Utility requirement, availability and cost.
- Equipment sizing and selection;
- Environmental planning;
- Local communities consultation
- Plant layout;
- Capital and operating cost estimation;
- Marketing support for potential off-take agreements;
- Financial evaluation.

1.5 Capital Costs

The total capital cost estimate for the plant is US$1,237,000,000, or US$9,440 /installed tonne of capacity (Table 1). All costs in 2003 US$.

Table 1. Primary summary of the Capex estimate

Defined		**US$m Feb 2003**
	Direct	800
	Indirect	234
	Subtotal	1,034
Undefined	Provisions	202
	Total CAPEX Estimate	**1,237**
Production Capacity Unit Cost		
Based on target output	*(131,000 tpa)*	*9,440 /t*

1.6 Operating Costs

The operating costs have been calculated based on the plant operations (ore, residue management, reagents, etc.), utilities (electrical, natural gas, water), maintenance and indirects.

Table 2. Summary of operating costs

Description	**Annual Cost US$/year**	**Cost per Mg Unit Mass US$/kg**	**US$/lb.**	**Comments**
Directs				
Plant Operations	$68,950,897	$0.53	$0.239	
Utilities	$81,251,462	$0.62	$0.281	
Maintenance	$40,512,695	$0.31	$0.140	
Indirects	$12,165,049	$0.09	$0.042	
TOTAL	**$202,880,103**	**$1.55**	**$0.703**	For 131,000 mtpa of product mix
Analysis - Alloying				
Total Production Costs for Pure Mg	*$47,985,195*	*$1.55*	*$0.702*	*For 31,000 mtpa of pure Mg*
Total Production Cost for Alloyed Mg	*$154,894,908*	*$1.55*	*$0.703*	*For 100,000 mtpa of Mg Alloy*

1.7 Project Schedule

The project master schedule is attached in the next figure. It shows the next steps to full production of the plant. Basically, the first metal will be produced 30 months after project approval.

1.8 Market

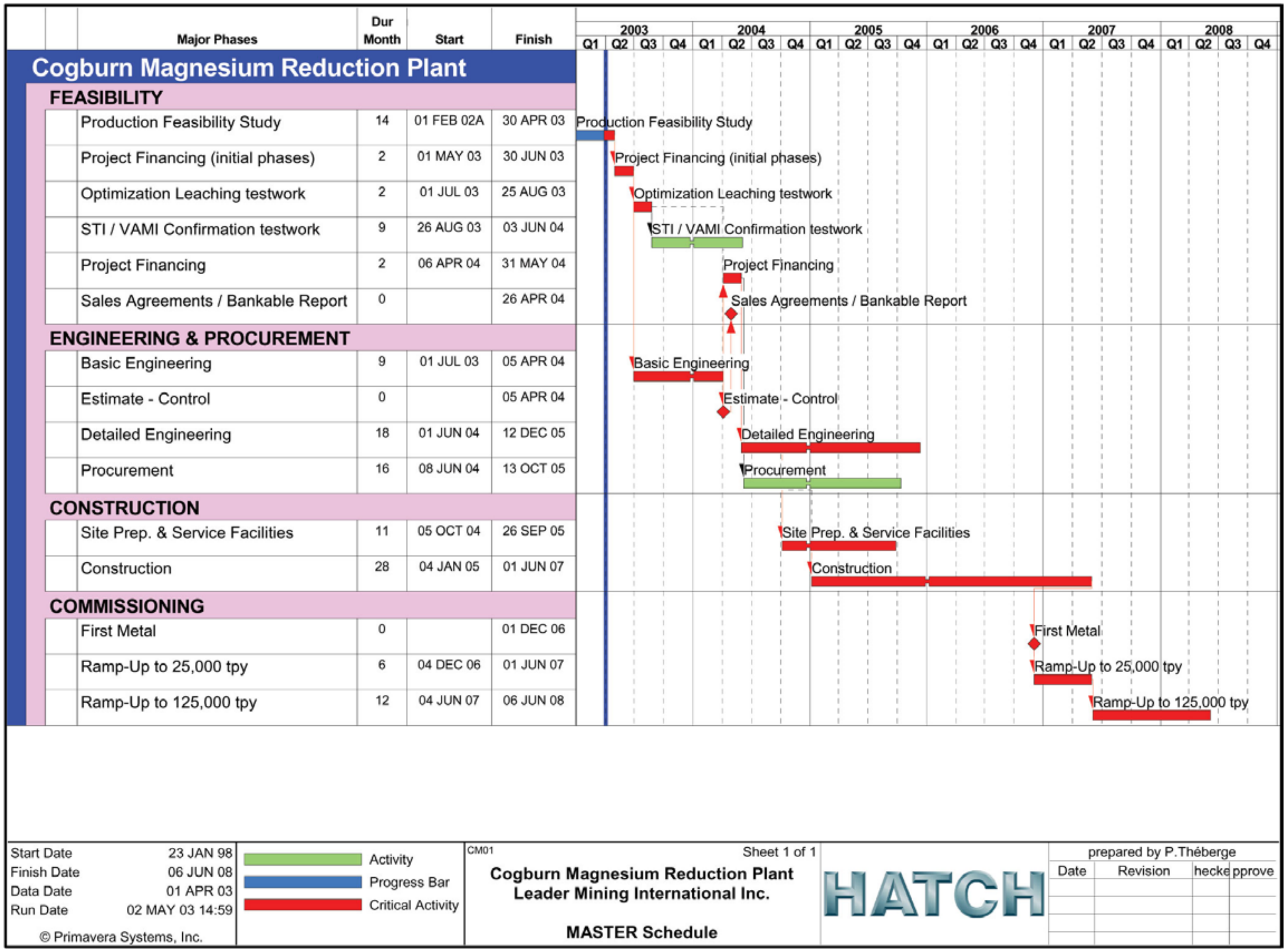
Magnesium metal is best known for its lightweight and high strength-to-weight ratio, making it suitable for a wide range of applications. The global market has shown excellent potential for growth, mainly in automotive die cast applications. The automobile users of magnesium are currently seeking stable long-term supplies to meet their increasing requirements. Well situated geographically, the Cogburn Project would be poised to meet this growth with economically competitive production.

The magnesium market has been highly volatile in recent years with major changes on the supply side. China has become the biggest player and has brought the metal prices to record lows. As a consequence, most of the western world producers have closed their plants. However, at the published market prices for magnesium of early 2003, no producers, including the lowest cost Chinese, can make a profit on a full cost basis. Hatch believes that the current prices are unsustainable, and further capacity reductions are inevitable unless prices increase. Also, if the growth in the automobile demand continues, there will be a shortfall in the magnesium capacity of more than 100,000 tons by 2012.

These are the main reasons why we believe that the current prices in Midwest US will climb from the today's 1.05-1.19 US$/lb to the 1.27 US$/lb that was used in the financial analysis.

1.9 Financial Analysis

A financial analysis has showed that the market price has the biggest impact on the IRR of the project. Three cases were evaluated, a base, an optimistic and a pessimistic case. The internal rate of return on the equity portion of the project varied from 6.5 to 18.1%, with the base case achieving a return of 10%.



Cogburn Magnesium Reduction Plant

Major Phases	Dur Month	Start	Finish
FEASIBILITY			
Production Feasibility Study	14	01 FEB 02A	30 APR 03
Project Financing (initial phases)	2	01 MAY 03	30 JUN 03
Optimization Leaching testwork	2	01 JUL 03	25 AUG 03
STI / VAMI Confirmation testwork	9	26 AUG 03	03 JUN 04
Project Financing	2	06 APR 04	31 MAY 04
Sales Agreements / Bankable Report	0		26 APR 04
ENGINEERING & PROCUREMENT			
Basic Engineering	9	01 JUL 03	05 APR 04
Estimate - Control	0		05 APR 04
Detailed Engineering	18	01 JUN 04	12 DEC 05
Procurement	16	08 JUN 04	13 OCT 05
CONSTRUCTION			
Site Prep. & Service Facilities	11	05 OCT 04	26 SEP 05
Construction	28	04 JAN 05	01 JUN 07
COMMISSIONING			
First Metal	0		01 DEC 06
Ramp-Up to 25,000 tpy	6	04 DEC 06	01 JUN 07
Ramp-Up to 125,000 tpy	12	04 JUN 07	06 JUN 08

Start Date	23 JAN 98
Finish Date	06 JUN 08
Data Date	01 APR 03
Run Date	02 MAY 03 14:59

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🟩 Activity
🟦 Progress Bar
🟥 Critical Activity

CM01
Sheet 1 of 1

Cogburn Magnesium Reduction Plant
Leader Mining International Inc.

MASTER Schedule

HATCH

prepared by P.Théberge

Date	Revision	hecke	pprove

Figure 1. Project Schedule

1.10 Description of Risks

Typically, the vulnerability of a new magnesium plant is determined by the following factors:

- Process technology – newly developed or used commercially;
- Market conditions;
- Efficient integrated plant design;
- Availability of operating personnel with magnesium production experience;
- Raw material and product quality control/management;
- Environmental requirements;
- Political stability and tax structure.

Most of these risks have been minimized in the Cogburn project. Indeed, the key factors tied to the viability of this project are:

- Large, long life resource of quality ore of high grade magnesium silicate mineral;
- Significant infrastructure advantage in that electric power, natural gas, mainline rail, provincial highways and barge access to nearby deep-sea ports are adjacent to the property;
- Proven STI/VAMI technology package to estimate reliable operating and capital costs. The ramp up rate and the metal quality produced are also predictable;
- Stable, globally competitive energy rates in British Columbia;
- An efficient local labour pool since the project is located in a mining and forest products extraction region with a broad spectrum of service industries;
- Permit issuing authorities which are pro-business;
- Proximity to the US and Asian markets for sales and efficient client inventories management;
- Stable social and political structures.

The biggest risk component for the economic viability of the project remains the market conditions. These will most likely vary during the course of the project. The market growth and the magnesium prices have been volatile in the past and most likely will remain so.

1.11 Conclusions

The Cogburn Magnesium Deposit is a large ultramafic intrusive body containing consistently high-grade magnesium silicate (+24% magnesium). The enriched Emory Zone has been subjected to an intensive drilling and sampling program. Under the direction of HATCH, Process Research ORTECH has pilot tested a composite sample, for hydrochloric leach extraction of magnesium. In addition, leach solution was tested at Messo in Germany to define evaporation and crystallization parameters for the preparation of cell feed for the STI/VAMI magnesium electrolysis technology. In April 2002, Leader signed an option with STI/VAMI for the use of the magnesium electrolysis technology for the Cogburn Project.

Successful testing has resulted in preliminary design parameters for development of the Cogburn Project flowsheet. The Cogburn deposit because of its large size, high magnesium grade, low impurity levels, favourable metallurgy, and proximity to infrastructure has the potential to be developed into a world-class, environmentally friendly, long-life magnesium operation. Process information generated during the Study was used to develop capital and operating costs for the project at the selected site location. Following discussions with BC Hydro and Duke Energy, energy costs have been established for the Cogburn Project.

The test-work and the engineering completed to-date indicate that the Cogburn Project is technically feasible and economically viable.

2. FINANCIAL ANALYSIS

2.1 Base Case and Main Hypotheses

The base case financial evaluation is presented in Table 3 and Figure 2. It shows that with all the standard inputs, from the operating and capital costs to the magnesium prices, the project would generate an internal rate of return of 10.0% on the equity portion.

Based on the overall project schedule, first metal production would be produced 30 months after project approval. It was assumed that

- Start-up period: The start-up of the plant was assumed to take 18 months with linear increase in production over that period. For example, after 9 months of start-up the monthly production would be equivalent to an annual throughput of 50% of nameplate capacity.
- Sales revenues: The price for pure magnesium and alloys has been kept constant at the base case price identified in the marketing analysis i.e. a delivered price to the Midwest US of US$1.27/lb in 2003 dollars with a 10% price premium for alloys. It must be noted that this is the recent spot transaction price for primary magnesium and that most magnesium is sold under contract and thus this price may be higher than is presently being realized. At the present time magnesium prices have firmed and in some markets increased, thus it is possible that this price could be realized on a contractual basis three or four years hence when the plant is operational. The freight cost for delivery to the Midwest US was estimated at US$70/tonne, based on rail prices from Hope to Chicago and local delivery to end users by trucks.
- Fixed and variable costs: The operating costs were separated in fixed and variable costs. These represent respectively US$0.586 and US$0.116 per pound of saleable products at the full capacity of the plant. The additional costs related to the plant start-up were included in the owner's costs.
- Capital costs: The base case capital costs for the plant were utilized for the financial analysis of the project. It represents the total cost of the plant including the direct, the indirect and the owner's costs.
- Working capital: The working capital was assumed at 5% of the total project capital cost.
- Debt Financing: Generally, the debt/equity ratio depends on the type of industry and the evaluated commercial risk of a project. Based on the marketing report, it is clear that the main clients of the Cogburn project would be the auto makers (magnesium alloys) and aluminium producers (primary magnesium). Based on the above and taking into account the specifics of the light metals industry, the commercial risk was assumed to be similar to that of the aluminium industry. A survey of the annual reports of world largest aluminium producers: Alcoa and Alcan indicated that an assumption of debt to equity ratio of 0.50 for long-term assets appears reasonable. This ratio was utilized for the base case scenario. It was assumed that this ratio will remain constant for the duration of design and construction period which means that the design and construction was financed one third by financing and two thirds by equity

- Cost of borrowing and debt retirement: The interest on the long-term debt was based on 2003 long-term bond corporate rates, at 8%. It was assumed that the term of debt retirement would be equal to the selected project life of 25 years.

- Sustaining capital: Some sustaining capital will be needed to design and implement the capital projects for maintaining the plant capacity, for reducing the operating costs, for complying with new environmental standards, for improving health and safety practices, etc. This sustaining capital was taken at 1.2% of the capital cost of the plant, a reasonable assumption based on other metallurgical plants of this nature that such sustaining capital expenditures will be required starting from the 4th year of the project's life and until the 25th.

- Corporate taxes: The corporate tax rate was assumed at 35%, typical for a mining operation. It includes federal and provincial taxes. All the pre-production capital costs were classified in class 41 for the capital cost allowance. The digressive rate for that class was put at a conservative 25%. Indeed, certain portion of the plant could qualify for rates of up to 100%

- Depreciation charges: All sustaining capital expenditures were classified in the class 8 (machinery) for the capital cost allowance. The digressive rate for that class is 20%.

- Closing the project: At the end of the project's life, the remaining value of the plant and the working capital are recovered.

Table 3. Base case financial evaluation.

COGBURN MAGNESIUM PROJECT - COST MODEL - 18 MONTHS RAMP UP TO FULL PRODUCTION												
PROJECT LIFE, YEAR			0	1	2	3	4	5	10	15	20	25
Internal Rate of Return (IRR)							-18.2%	-10.6%	4.5%	7.8%	9.2%	10.0%
REVENUES												
ANNUAL PRODUCTION				47,306	121,903	131,000	131,000	131,000	131,000	131,000	131,000	131,000
ANNUAL REVENUES				$ 139,601,429	$ 359,742,143	$ 386,588,572	$ 386,588,572	$ 386,588,572	$ 386,588,572	$ 386,588,572	$ 386,588,572	$ 386,588,572
Variable costs				$ 55,157,376	$ 142,136,316	$ 152,743,504	$ 169,349,468	$ 169,349,468	$ 169,349,468	$ 169,349,468	$ 169,349,468	$ 169,349,468
OPERATING MARGIN				$ 84,444,052	$ 217,605,827	$ 233,845,068	$ 217,239,103	$ 217,239,103	$ 217,239,103	$ 217,239,103	$ 217,239,103	$ 217,239,103
Fixed costs				$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634
EBITDA				$ 50,913,418	$ 184,075,193	$ 200,314,433	$ 183,708,469	$ 183,708,469	$ 183,708,469	$ 183,708,469	$ 183,708,469	$ 183,708,469
INTEREST CHARGES ON LONG TERM DEBT				$ 40,226,184	$ 39,745,086	$ 39,110,580	$ 38,423,931	$ 37,680,916	$ 32,948,351	$ 25,960,215	$ 15,753,255	$ 1,923,076
interest coverage				1.27	4.63	5.12	4.78	4.88	5.58	7.08	11.66	95.53
EBTDA				$ 10,687,234	$ 144,330,106	$ 161,203,853	$ 145,284,538	$ 146,027,553	$ 150,760,118	$ 157,748,254	$ 167,955,214	$ 181,785,393
DEPRECIATION CHARGES				$ 154,590,000	$ 270,532,500	$ 202,899,375	$ 155,291,066	$ 119,740,660	$ 39,398,546	$ 20,938,951	$ 16,756,965	$ 15,829,625
INCOME BEFORE TAXES				$ (143,902,766)	$ (126,202,394)	$ (41,695,522)	$ (10,006,528)	$ 26,286,893	$ 111,361,572	$ 136,809,303	$ 151,198,249	$ 165,955,768
Accumulated Losses from operation				-	(143,902,766)	(270,105,160)	(311,800,681)	(321,807,209)	-	-	-	-
Taxable Income				$ -	$ -	$ -	$ -	$ -	$ 111,361,572	$ 136,809,303	$ 151,198,249	$ 165,955,768
TAXES				$ -	$ -	$ -	$ -	$ -	$ 38,976,550	$ 47,883,256	$ 52,919,387	$ 58,084,519
NET INCOME				$ (143,902,766)	$ (126,202,394)	$ (41,695,522)	$ (10,006,528)	$ 26,286,893	$ 72,385,022	$ 88,926,047	$ 98,278,862	$ 107,871,249
FINANCING SCENARIO		DESIGN & CONSTRUCTION PERIOD		COMMISSIONING								
item	Construction Financing	$ (211,709,747)	$ (440,991,299)									
	Working Capital		$ 61,836,000									
	Loss from previous year			-	-	-	-	-	-	-	-	-
	Financing - Long Term Debt		$ 502,827,299	$ 502,827,299	$ 502,827,299	$ 495,383,805	$ 487,326,758	$ 478,606,041	$ 422,996,668	$ 340,610,821	$ 219,148,722	$ 42,818,171
	total annual payment				$ 47,188,579	$ 47,167,627	$ 47,144,648	$ 47,119,413	$ 46,948,825	$ 46,658,697	$ 46,108,647	$ 44,696,225
	annual interest charges			$ 40,226,184	$ 39,745,086	$ 39,110,580	$ 38,423,931	$ 37,680,916	$ 32,948,351	$ 25,960,215	$ 15,753,255	$ 1,923,076
	borrowed capital repayment				$ 7,443,493	$ 8,057,048	$ 8,720,717	$ 9,438,497	$ 14,000,474	$ 20,698,482	$ 30,355,392	$ 42,773,150
	Sustaining Capital			$ -	$ -	$ -	$ 15,582,672	$ 15,582,672	$ 15,582,672	$ 15,582,672	$ 15,582,672	$ 15,582,672
CASH FLOW FROM OPERATION												
	EBITDA			$ 50,913,418	$ 184,075,193	$ 200,314,433	$ 183,708,469	$ 183,708,469	$ 183,708,469	$ 183,708,469	$ 183,708,469	$ 183,708,469
	Interest Charges			$ (40,226,184)	$ (39,745,086)	$ (39,110,580)	$ (38,423,931)	$ (37,680,916)	$ (32,948,351)	$ (25,960,215)	$ (15,753,255)	$ (1,923,076)
	Taxes			$ -	$ -	$ -	$ -	$ -	$ (38,976,550)	$ (47,883,256)	$ (52,919,387)	$ (58,084,519)
	Borrowed capital repayment			$ -	$ (7,443,493)	$ (8,057,048)	$ (8,720,717)	$ (9,438,497)	$ (14,000,474)	$ (20,698,482)	$ (30,355,392)	$ (42,773,150)
	Royalty payments	$ (50,000)	$ (1,125,000)	$ (681,952)	$ (1,899,553)	$ (2,066,334)	$ (1,900,274)	$ (1,900,274)	$ (1,900,274)	$ (1,900,274)	$ (1,900,274)	$ (1,900,274)
	Sustaining capital			$ -	$ -	$ -	$ (15,582,672)	$ (15,582,672)	$ (15,582,672)	$ (15,582,672)	$ (15,582,672)	$ (15,582,672)
	Selling assets and recovering WC			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 140,622,194
NET CASH FLOW FROM OPERATION		$ (414,351,200)	$ (415,426,200)	$ 10,005,281	$ 134,987,060	$ 151,080,472	$ 119,080,875	$ 119,106,110	$ 80,300,148	$ 71,683,570	$ 67,197,489	$ 204,066,973
CUMMULATIVE CASH POSITION		$ (414,351,200)	$ (829,777,400)	$ (819,772,119)	$ (684,785,058)	$ (533,704,586)	$ (414,623,711)	$ (295,517,601)	$ 252,947,074	$ 625,228,312	$ 969,712,997	$ 1,434,541,287

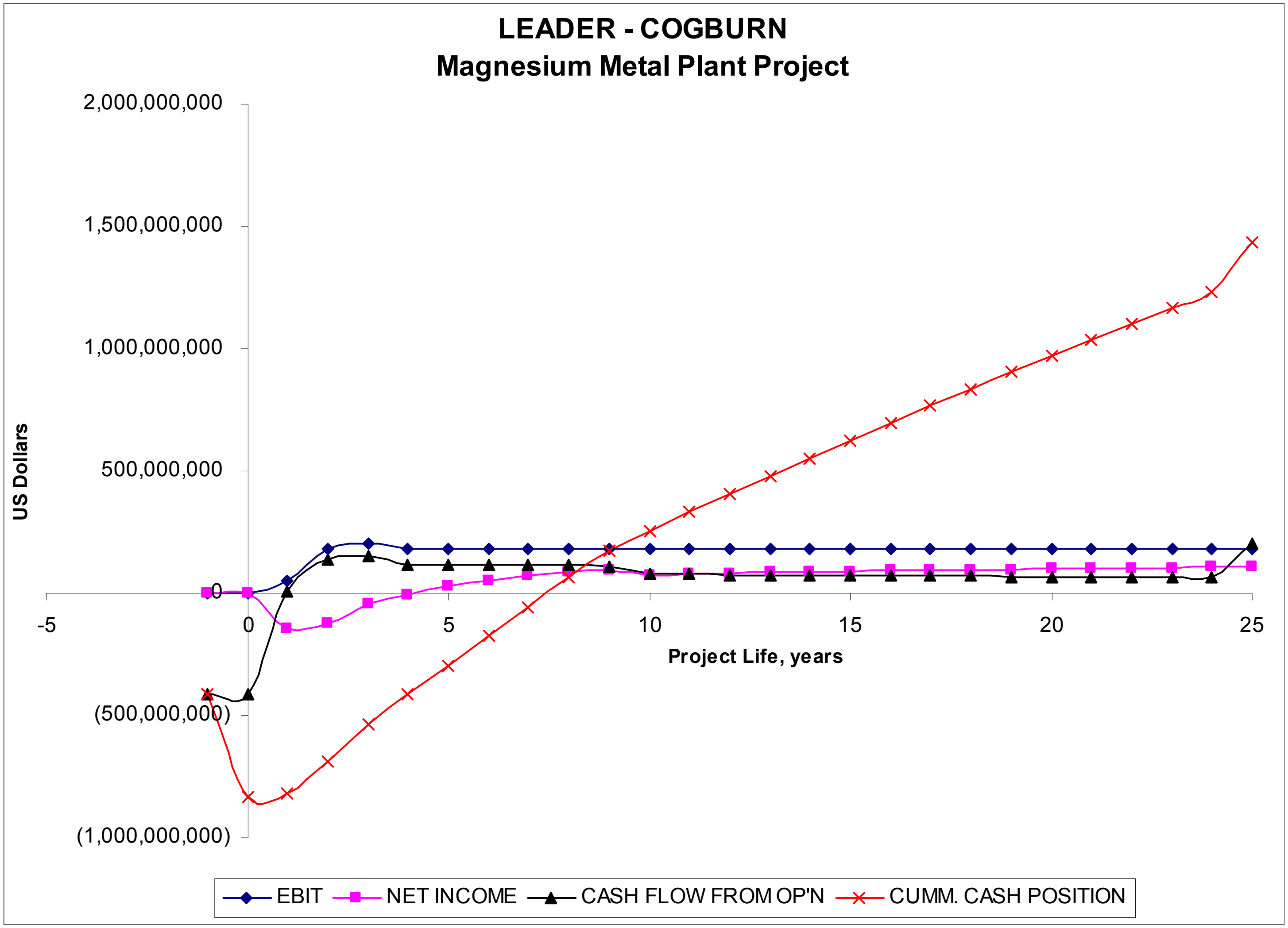

Figure 2. Project cash flow

2.2 Scenarios

A number of upside and downside scenarios have been evaluated in order to quantify their impact on the Cogburn project.

2.2.1 Operating Costs

The Cogburn plant operating cost will be influenced by the following factors.

- Electricity prices: The electricity cost information used in this study was provided by Intuit Strategies. While BC Hydro's power prices will remain regulated for the foreseeable future, the influence of the northwest electricity market will remain. The prices provided by Intuit Strategies indicate a potential for a 15% over the next 10-year period. An increase in the electricity prices will directly impact the operating cost of the plant. For example, a 15% increase in the price of electricity would add 2.5 US cents/pound of produced magnesium.

- Natural gas prices: The pricing was provided by Intuit Strategies and it indicates that there is a potential for ± 10% natural gas price fluctuation over the period of the next 10 years. The corresponding impact on the operating cost of the plant would total at ± 1.5 US cents/pound. The prices used in the base case scenario were somewhat higher than the long-term average.

  MgO Sourcing: In the base case scenario, it is assumed that the magnesia (MgO) is shipped from China, a source that is less expensive than the high-purity magnesia from Baymag, Alberta. The Chinese magnesia has an MgO content higher than 95%. In the Cogburn project, the magnesia is used to neutralize the brine at the end of the leaching process of the plant. As an option, magnesia can potentially be supplied from an alternative source in California (Halaco Engineering. Co.). The magnesia produced at Halaco is a waste stream of their magnesium dross recovery process and its MgO content (84%) is lower than that of magnesia derived from magnesite processing (China). It is likely that this alternative material would be suitable for Cogburn process, but some minor testing is still required. It is anticipated that cost of this alternative material will only include the costs of handling and transport. If confirmed suitable, usage of this alternative magnesia source will allow decreasing operating cost of the plant by over 2.5 US cents/pound of produced magnesium. In addition, there are known occurrences of magnesite in southern British Columbia that should be investigated as a possible low-cost supply for MgO.

- Improved leaching flow sheets: While some test work has been done for this phase of the project, additional test work could allow to further improve and simplify the process and operations in the ore leaching sector of the plant. As an example, the inclusion of a magnetic separation step after crushing and before leaching could well reduce the magnetite bearing components in the ore. Assuming a two thirds reduction in magnetite content, the iron content of the feed to the leach circuit would be reduced by about 50%, which will reduce the MgO and the HCl-acid consumption by 25%. Also, further improvements in the filtering section of the leaching plant would allow the removal of the residue drying stage. Thus, the natural gas consumption would be reduced by approximately 8%. The overall potential savings of the operating cost would exceed 2.5 US cents/pound of magnesium.

By taking into account all of these different scenarios, a sensitivity analysis was performed with an increase/decrease of 3.0 US cents/pound in the operating costs compared to the base case scenario.

2.2.2 Capital Costs and Plant Capacity

- Capital costs: From our analysis of the STI/VAMI technology package, the engineering factor utilized by STI/VAMI is high. Based on our knowledge of the technology, it is believed that both the electrolysis and the fluid bed dehydrators could operate at 20% above their published design capacity. Thus, it would be possible to reduce the number of installed electrolytic cells and fluid bed dehydrators, reducing the capital cost by an order of magnitude 120 millions US dollars without affecting the plant capacity.

- Plant capacity: While the engineering factor utilized in the STI/VAMI package could be used to reduce the capital costs as indicated above, it could also allow to achieve a higher production capacity. As indicated above, electrolytic cells and fluid bed dehydrators would have spare capacity that could be utilized to achieve higher production. In the carnallite crystallization section, Messo has specified 5 crystallizers with only 4 continuously operating. With some minor investment in the leaching, grinding and cast house sector, the overall capacity of the plant could be increased. With such investment and some optimization in other sectors, the plant operating capacity could be increased to 150,000 metric tonnes within a five-year period.

2.2.3 Selling Prices

- Alloys production: By increasing the alloys production, the Cogburn project would obtain a higher premium on the products sold. This scenario would have to be confirmed by off-take agreements.

- Sales price: The magnesium prices have the highest impact on the financial return of the Cogburn project. Three price scenarios were analyzed, the optimistic given in the marketing analysis, and the 2003 actual prices seen in the Midwest (US$ 1.05-1.19/lb).

2.2.4 Financing

- Debt to equity ratio: Financing strategies in the metals sector tend to be conservative due to high capital requirements. While aluminium producers Alcan and Alcoa have a debt to equity ratio of 0.5 (33% debt, 67% equity), it is reasonable to assume that the Cogburn project could be financed with a higher ratio.

- Interest on debt: Some companies with a good credit rating are presently able to obtain some long term bond issues at 7% rather than 8% used in the base case scenario.

The impact of these scenarios on the internal rates of return as compared to the base case in is provided in Table 4.

Table 4. Impact of scenario changes on the internal rate of return

Change	**Impact on IRR**
Operating cost	Increase of 3.0 US cents/lb, -0.7%
	Decrease of 3.0 US cents/lb, +0.7%
Reduction of Capex based on STI/VAMI performance	+1.6%
Increased production based on STI/VAMI performance	+2.2%
Impact of prices on products	Optimistic case, +1.6%
	Today's price, - 1.0%
All production in alloys	+0.7%
Debt/equity ratio	50% debt/50% equity, + 1.8%
	0% debt/100 % equity, - 1.5%
Interest rate at 7%	+0.3%

The combined impacts of the scenarios are not purely additive. The net impact of the combined changes is always higher than the sum of their respective impacts.

2.2.5 Detailed Scenarios

Two detailed scenarios were defined based on the results of the preceding section. Optimistic and pessimistic cases were identified. These cases are presented in the next table.

Table 5. Optimistic and pessimistic scenarios.

	Optimistic market case	Pessimistic market case
Magnesium sales price	Base case prices (1.27 US$/lb.)	Average spot price in early 2003 (1.15 US$/lb.)
Production	150,000 metric tonnes/year	131,000 metric tonnes/year.
Debt/Equity ratio	67% debt and 33% equity	33% debt and 67% equity
Operating cost	A decrease of 3 US cents/lb vs. the base case	the base case operating costs

The details of the optimistic and pessimistic scenarios are presented in Table 7 and Table 8. The internal rate of return of the three cases is shown below.

Table 6. Internal rates of return for different scenarios.

Scenario	Internal Rate of Return
Base Case	10.0%
Optimistic Case	18.1%
Pessimistic Case	6.5%

This analysis shows how much impact the market price of magnesium has on the financial return of the project. It also indicates that the Cogburn Project is economically viable.

Table 7. Optimistic case financial evaluation

COGBURN MAGNESIUM PROJECT - COST MODEL - 18 MONTHS RAMP UP TO FULL PRODUCTION												
PROJECT LIFE, YEAR			**0**	**1**	**2**	**3**	**4**	**5**	**10**	**15**	**20**	**25**
Internal Rate of Return (IRR)							**-7.4%**	**0.9%**	**15.0%**	**17.1%**	**17.8%**	**18.1%**
REVENUES												
ANNUAL PRODUCTION				47,306	121,903	131,000	150,000	150,000	150,000	150,000	150,000	150,000
ANNUAL REVENUES				$ 139,601,429	$ 359,742,143	$ 386,588,572	$ 442,658,670	$ 442,658,670	$ 442,658,670	$ 442,658,670	$ 442,658,670	$ 442,658,670
Variable costs				$ 52,028,114	$ 134,072,447	$ 144,077,854	$ 183,989,105	$ 183,989,105	$ 183,989,105	$ 183,989,105	$ 183,989,105	$ 183,989,105
OPERATING MARGIN				$ 87,573,315	$ 225,669,696	$ 242,510,718	$ 258,669,565	$ 258,669,565	$ 258,669,565	$ 258,669,565	$ 258,669,565	$ 258,669,565
Fixed costs				$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634
EBITDA				$ 54,042,680	$ 192,139,061	$ 208,980,083	$ 225,138,931	$ 225,138,931	$ 225,138,931	$ 225,138,931	$ 225,138,931	$ 225,138,931
INTEREST CHARGES ON LONG TERM DEBT				$ 77,007,980	$ 76,086,979	$ 74,872,296	$ 73,557,793	$ 72,135,384	$ 63,075,482	$ 49,697,573	$ 30,157,629	$ 3,681,487
interest coverage				0.70	2.53	2.79	3.06	3.12	3.57	4.53	7.47	61.15
EBTDA				$ (22,965,299)	$ 116,052,083	$ 134,107,787	$ 151,581,138	$ 153,003,547	$ 162,063,448	$ 175,441,357	$ 194,981,301	$ 221,457,443
DEPRECIATION CHARGES				$ 155,465,000	$ 272,063,750	$ 204,047,813	$ 156,170,034	$ 120,418,408	$ 39,621,547	$ 21,057,468	$ 16,851,812	$ 15,919,223
INCOME BEFORE TAXES				$ (178,430,299)	$ (156,011,667)	$ (69,940,025)	$ (4,588,896)	$ 32,585,138	$ 122,441,901	$ 154,383,889	$ 178,129,490	$ 205,538,220
Accumulated Losses from operation				-	(178,430,299)	(334,441,967)	(404,381,992)	(408,970,888)	(22,050,496)	-	-	-
Taxable Income				$ -	$ -	$ -	$ -	$ -	$ 100,391,405	$ 154,383,889	$ 178,129,490	$ 205,538,220
TAXES				$ -	$ -	$ -	$ -	$ -	$ 35,136,992	$ 54,034,361	$ 62,345,321	$ 71,938,377
NET INCOME				$ (178,430,299)	$ (156,011,667)	$ (69,940,025)	$ (4,588,896)	$ 32,585,138	$ 87,304,909	$ 100,349,528	$ 115,784,168	$ 133,599,843
FINANCING SCENARIO		DESIGN & CONSTRUCTION PERIOD		COMMISSIONING								
item	**Construction Financing**	$ (432,267,864)	$ (900,413,747)									
	Working Capital		$ 62,186,000									
	Loss from previous year			-	-	-	-	-	-	-	-	-
	Financing - Long Term Debt		$ 962,599,747	$ 962,599,747	$ 962,599,747	$ 948,350,114	$ 932,925,908	$ 916,231,190	$ 809,774,026	$ 652,056,662	$ 419,532,720	$ 81,970,014
	total annual payment				$ 90,336,612	$ 90,296,502	$ 90,252,511	$ 90,204,202	$ 89,877,632	$ 89,322,218	$ 88,269,217	$ 85,565,313
	annual interest charges			$ 77,007,980	$ 76,086,979	$ 74,872,296	$ 73,557,793	$ 72,135,384	$ 63,075,482	$ 49,697,573	$ 30,157,629	$ 3,681,487
	borrowed capital repayment				$ 14,249,633	$ 15,424,206	$ 16,694,718	$ 18,068,818	$ 26,802,149	$ 39,624,645	$ 58,111,588	$ 81,883,826
	Sustaining Capital			$ -	$ -	$ -	$ 15,670,872	$ 15,670,872	$ 15,670,872	$ 15,670,872	$ 15,670,872	$ 15,670,872
CASH FLOW FROM OPERATION												
	EBITDA			$ 54,042,680	$ 192,139,061	$ 208,980,083	$ 225,138,931	$ 225,138,931	$ 225,138,931	$ 225,138,931	$ 225,138,931	$ 225,138,931
	Interest Charges			$ (77,007,980)	$ (76,086,979)	$ (74,872,296)	$ (73,557,793)	$ (72,135,384)	$ (63,075,482)	$ (49,697,573)	$ (30,157,629)	$ (3,681,487)
	Taxes			$ -	$ -	$ -	$ -	$ -	$ (35,136,992)	$ (54,034,361)	$ (62,345,321)	$ (71,938,377)
	Borrowed capital repayment			$ -	$ (14,249,633)	$ (15,424,206)	$ (16,694,718)	$ (18,068,818)	$ (26,802,149)	$ (39,624,645)	$ (58,111,588)	$ (81,883,826)
	Royalty payments	$ (50,000)	$ (1,125,000)	$ (713,245)	$ (1,980,192)	$ (2,152,990)	$ (2,323,743)	$ (2,323,743)	$ (2,323,743)	$ (2,323,743)	$ (2,323,743)	$ (2,323,743)
	Sustaining capital			$ -	$ -	$ -	$ (15,670,872)	$ (15,670,872)	$ (15,670,872)	$ (15,670,872)	$ (15,670,872)	$ (15,670,872)
	Selling assets and recovering WC			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 141,418,134
NET CASH FLOW FROM OPERATION		$ (205,263,800)	$ (206,338,800)	$ (23,678,545)	$ 99,822,258	$ 116,530,591	$ 116,891,805	$ 116,940,113	$ 82,129,692	$ 63,787,736	$ 56,529,776	$ 191,058,759
CUMMULATIVE CASH POSITION		$ (205,263,800)	$ (411,602,600)	$ (435,281,145)	$ (335,458,887)	$ (218,928,296)	$ (102,036,491)	$ 14,903,622	$ 565,382,220	$ 902,463,996	$ 1,199,485,934	$ 1,602,056,668

Table 8. Pessimistic case financial evaluation

COGBURN MAGNESIUM PROJECT - COST MODEL - 18 MONTHS RAMP UP TO FULL PRODUCTION											
PROJECT LIFE, YEAR		**0**	**1**	**2**	**3**	**4**	**5**	**10**	**15**	**20**	**25**
Internal Rate of Return (IRR)							**-17.9%**	**-0.8%**	**3.8%**	**5.3%**	**6.5%**
REVENUES											
ANNUAL PRODUCTION			**47,306**	**121,903**	**131,000**	**131,000**	**131,000**	**131,000**	**131,000**	**131,000**	**131,000**
ANNUAL REVENUES			$ 126,281,201	$ 325,416,942	$ 349,701,788	$ 349,701,788	$ 349,701,788	$ 349,701,788	$ 349,701,788	$ 349,701,788	$ 349,701,788
Variable costs			$ 55,157,376	$ 142,136,316	$ 152,743,504	$ 169,349,468	$ 169,349,468	$ 169,349,468	$ 169,349,468	$ 169,349,468	$ 169,349,468
OPERATING MARGIN			$ 71,123,825	$ 183,280,626	$ 196,958,284	$ 180,352,320	$ 180,352,320	$ 180,352,320	$ 180,352,320	$ 180,352,320	$ 180,352,320
Fixed costs			$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634	$ 33,530,634
EBITDA			$ 37,593,190	$ 149,749,991	$ 163,427,650	$ 146,821,685	$ 146,821,685	$ 146,821,685	$ 146,821,685	$ 146,821,685	$ 146,821,685
INTEREST CHARGES ON LONG TERM DEBT			$ 40,226,184	$ 39,745,086	$ 39,110,580	$ 38,423,931	$ 37,680,916	$ 32,948,351	$ 25,960,215	$ 15,753,255	$ 1,923,076
interest coverage			0.93	3.77	4.18	3.82	3.90	4.46	5.66	9.32	76.35
EBTDA			$ (2,632,993)	$ 110,004,905	$ 124,317,070	$ 108,397,754	$ 109,140,769	$ 113,873,334	$ 120,861,470	$ 131,068,431	$ 144,898,610
DEPRECIATION CHARGES			$ 154,590,000	$ 270,532,500	$ 202,899,375	$ 155,291,066	$ 119,740,660	$ 39,398,546	$ 20,938,951	$ 16,756,965	$ 15,829,625
INCOME BEFORE TAXES			$ (157,222,993)	$ (160,527,595)	$ (78,582,305)	$ (46,893,311)	$ (10,599,891)	$ 74,474,788	$ 99,922,520	$ 114,311,465	$ 129,068,984
Accumulated Losses from operation			-	(157,222,993)	(317,750,588)	(396,332,893)	(443,226,205)	(281,374,914)	-	-	-
Taxable Income			$ -	$ -	$ -	$ -	$ -	$ -	$ 99,922,520	$ 114,311,465	$ 129,068,984
TAXES			$ -	$ -	$ -	$ -	$ -	$ -	$ 34,972,882	$ 40,009,013	$ 45,174,144
NET INCOME			$ (157,222,993)	$ (160,527,595)	$ (78,582,305)	$ (46,893,311)	$ (10,599,891)	$ 74,474,788	$ 64,949,638	$ 74,302,453	$ 83,894,840
FINANCING SCENARIO	DESIGN & CONSTRUCTION PERIOD		COMMISSIONING								
item **Construction Financing**	$ (211,709,747)	$ (440,991,299)									
Working Capital		**$ 61,836,000**									
Loss from previous year			**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Financing - Long Term Debt		**$ 502,827,299**	**$ 502,827,299**	**$ 502,827,299**	**$ 495,383,805**	**$ 487,326,758**	**$ 478,606,041**	**$ 422,996,668**	**$ 340,610,821**	**$ 219,148,722**	**$ 42,818,171**
total annual payment				$ 47,188,579	$ 47,167,627	$ 47,144,648	$ 47,119,413	$ 46,948,825	$ 46,658,697	$ 46,108,647	$ 44,696,225
annual interest charges			$ 40,226,184	$ 39,745,086	$ 39,110,580	$ 38,423,931	$ 37,680,916	$ 32,948,351	$ 25,960,215	$ 15,753,255	$ 1,923,076
borrowed capital repayment				$ 7,443,493	$ 8,057,048	$ 8,720,717	$ 9,438,497	$ 14,000,474	$ 20,698,482	$ 30,355,392	$ 42,773,150
Sustaining Capital			**$ -**	**$ -**	**$ -**	**$ 15,582,672**	**$ 15,582,672**	**$ 15,582,672**	**$ 15,582,672**	**$ 15,582,672**	**$ 15,582,672**
CASH FLOW FROM OPERATION											
EBITDA			**$ 37,593,190**	**$ 149,749,991**	**$ 163,427,650**	**$ 146,821,685**	**$ 146,821,685**	**$ 146,821,685**	**$ 146,821,685**	**$ 146,821,685**	**$ 146,821,685**
Interest Charges			**$ (40,226,184)**	**$ (39,745,086)**	**$ (39,110,580)**	**$ (38,423,931)**	**$ (37,680,916)**	**$ (32,948,351)**	**$ (25,960,215)**	**$ (15,753,255)**	**$ (1,923,076)**
Taxes			**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ (34,972,882)**	**$ (40,009,013)**	**$ (45,174,144)**
Borrowed capital repayment			**$ -**	**$ (7,443,493)**	**$ (8,057,048)**	**$ (8,720,717)**	**$ (9,438,497)**	**$ (14,000,474)**	**$ (20,698,482)**	**$ (30,355,392)**	**$ (42,773,150)**
Royalty payments	**$ (50,000)**	**$ (1,125,000)**	**$ (548,750)**	**$ (1,556,301)**	**$ (1,697,466)**	**$ (1,531,406)**	**$ (1,531,406)**	**$ (1,531,406)**	**$ (1,531,406)**	**$ (1,531,406)**	**$ (1,531,406)**
Sustaining capital			**$ -**	**$ -**	**$ -**	**$ (15,582,672)**	**$ (15,582,672)**	**$ (15,582,672)**	**$ (15,582,672)**	**$ (15,582,672)**	**$ (15,582,672)**
Selling assets and recovering WC			**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 140,622,194**
NET CASH FLOW FROM OPERATION	**$ (414,351,200)**	**$ (415,426,200)**	**$ (3,181,744)**	**$ 101,005,111**	**$ 114,562,557**	**$ 82,562,960**	**$ 82,588,194**	**$ 82,758,783**	**$ 48,076,029**	**$ 43,589,947**	**$ 180,459,431**
CUMMULATIVE CASH POSITION	$ (414,351,200)	$ (829,777,400)	$ (832,959,144)	$ (731,954,033)	$ (617,391,476)	$ (534,828,517)	$ (452,240,322)	$ (38,821,376)	$ 287,837,199	$ 514,284,177	$ 861,074,759

3. MARKET AND USINESS ASSESSMENT

The following section represents a high-level summary of the more elaborate marketing report that can be found in the second binder[1]

3.1 Demand Overview

As reported by United States Geological Survey (USGS), in 2001, world production of primary magnesium was estimated at 426,000 metric tonnes. Between 1997 and 2001, the global production of primary magnesium grew by 42,000 metric tonnes.

According to CRU International Limited, global demand for primary magnesium metal have grown during the period 1990-2000 at an annualized rate of 3.1%, substantially faster than the more mature metals such as aluminium or steel. According to CRU, 83% of this global demand comes from the western word (excluding China and the CIS).

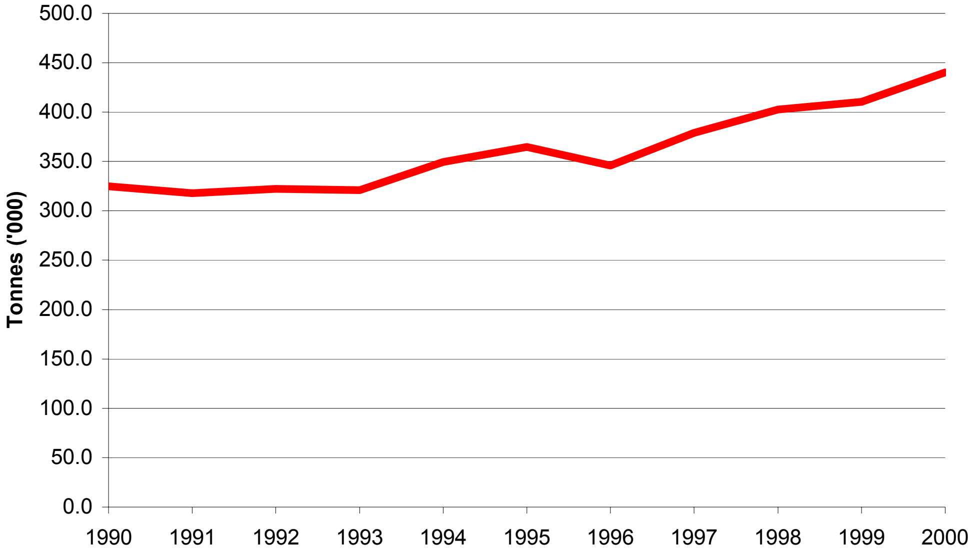

Figure 3. Estimated world demand for primary magnesium (CRU).

Source: CRU International Limited, 2001

As per CRU, the major markets for primary magnesium are North America, Western Europe and Asia, which account for approximately 40%, 28% and 18% of total global demand, respectively. In these economies, magnesium demand is very broadly based in consumer durables through aluminium consumption, steel making, castings for autos and other transportation equipment, and in high technology as castings for electronics and aerospace components.

There are four components of demand seen by a magnesium producer:

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[1] Hatch Consulting, “Magnesium Market Study”, February 25th 2003

- **Aluminium Alloys** - 40% of 2002 demand. Almost all aluminium is sold with some magnesium as an alloy. Magnesium is generally purchased by aluminium producers and sold as a small but critical alloy in castings, extrusions and wrought aluminium. This is the largest demand for magnesium. On average, magnesium makes up 0.8% of aluminium consumed; given its low content and use in alloys, which are industry standards, this demand has limited price sensitivity.

- **Die-casting** - 36% of 2002 demand. Magnesium auto parts are a rapidly growing segment of the market. These castings are 97% or more magnesium. Demand is, however, very price sensitive to competition from aluminium castings, steel and plastics. Automakers speak of magnesium price in terms of price ratio with aluminium, its main competitor. There are, however, non-price advantages to the use of magnesium. This demand is also conditioned by security of supply and investment in technical developments in applications. Castings are also used in smaller volumes in aerospace and other end user industries.

- **Desulphurisation** - 15% of 2002 demand. Desulphurisation is a standard element of the steel making process. Magnesium is one option in a selection of reagents to use. Under normal market situations, post-consumer magnesium scrap is the most cost effective source. Chinese magnesium has displaced this at times due to it being heavily discounted. Countervailing duties and trade agreements specifying minimum prices have somewhat restored the normal order to the market. Magnesium is granulised or formed as wire and introduced into hot metal (liquid iron) to remove sulphur. Magnesium competes with calcium carbide primarily, but also calcium silicate and soda ash. Magnesium is not the cheapest means, but is very effective if used with the right technology in conjunction with other reagents. This use is very price sensitive, but its penetration has been growing as a result of increasing demand for lower sulphur levels in steel plus declining supplies of low sulphur coking coal.

- **Other** - 9% of 2002 demand. A mixture of historic uses including the production of nodular iron, electrochemical, reagents and wrought products and castings. This is a declining category, many of the uses involving old technologies. These are generally not price sensitive as they are very specialized chemically with limited substitutes.

The western world demand by category between 1983 and 2002 is presented in the next figure.

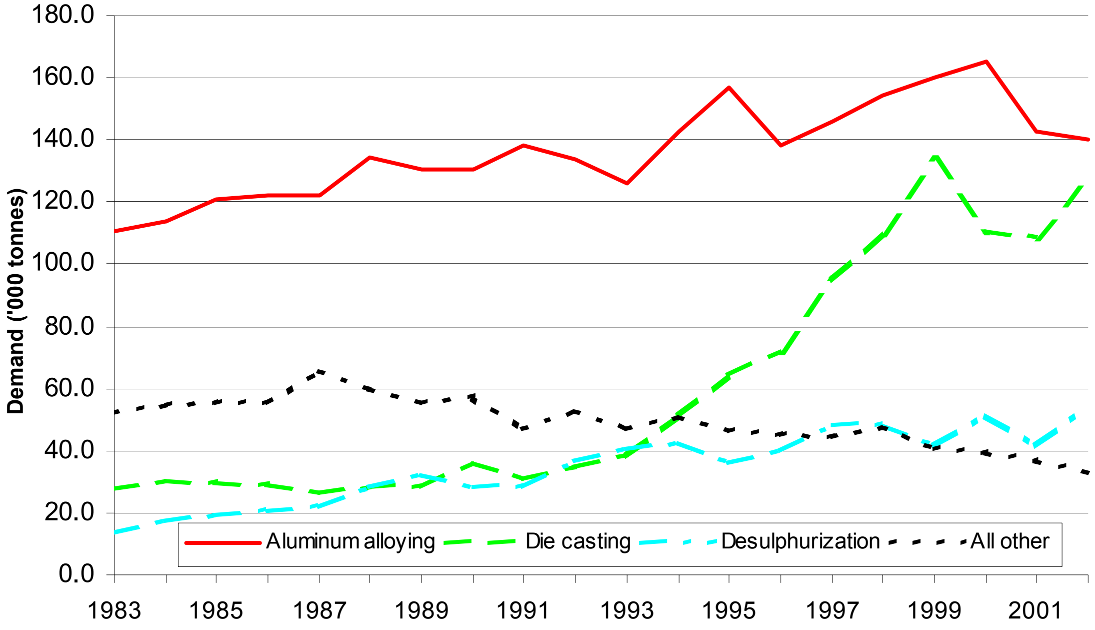

Figure 4. Western world demand for primary magnesium by use

Source: International Magnesium Association

The market fundamentals of each category were analyzed and the outlook for future growth is particularly strong in the automotive die-casting sector, where the unique combination of magnesium's lightweight strength and castability make it ideal for production of complex parts that save weight and simplify assembly. The rate of penetration of magnesium into these applications will depend in part on the relative prices of magnesium and aluminium, developments in fabrication technologies that impact the final component complexity and cost, and the impetus for weight saving and fuel economy improvements from energy prices and government actions. Growth of magnesium use in other markets is projected to be low, as these sectors are either mature or declining.

3.2 Production Capacity Overview

The world supply of primary magnesium is small compared to industrial metals such as aluminium. Western world primary supply of 355,000 tonnes in 2002 is only about 1.7% of that of aluminium, its most important competitor. Primary magnesium is produced by only five western-world companies, the largest of which has a capacity of approximately 45,000 tonnes per year (or, at current market prices, about US$ 100 million in product value). For all except one of the large western producers, magnesium is a minor part of their overall corporate activity

There has been a dramatic change in the primary magnesium supply sources in the last decade. Starting in the early 1990's, magnesium from Russia and China, which had never previously played any role in the Western markets, arrived on the markets at low prices. Initially, western producers believed that this was a temporary phenomenon, fuelled by the need for hard currency and the existence of inventories of metals on hand for which the local market, especially in Russia, had disappeared. However, the supplies from Russia and China have continued to increase, and a number of the important traditional western magnesium producers who were facing the need to make substantial investments to upgrade their old plant decided instead to exit the business. As a result, by 2002 magnesium metal supplied to the western markets was only 60% from western producers and 40% was from Russia and China.

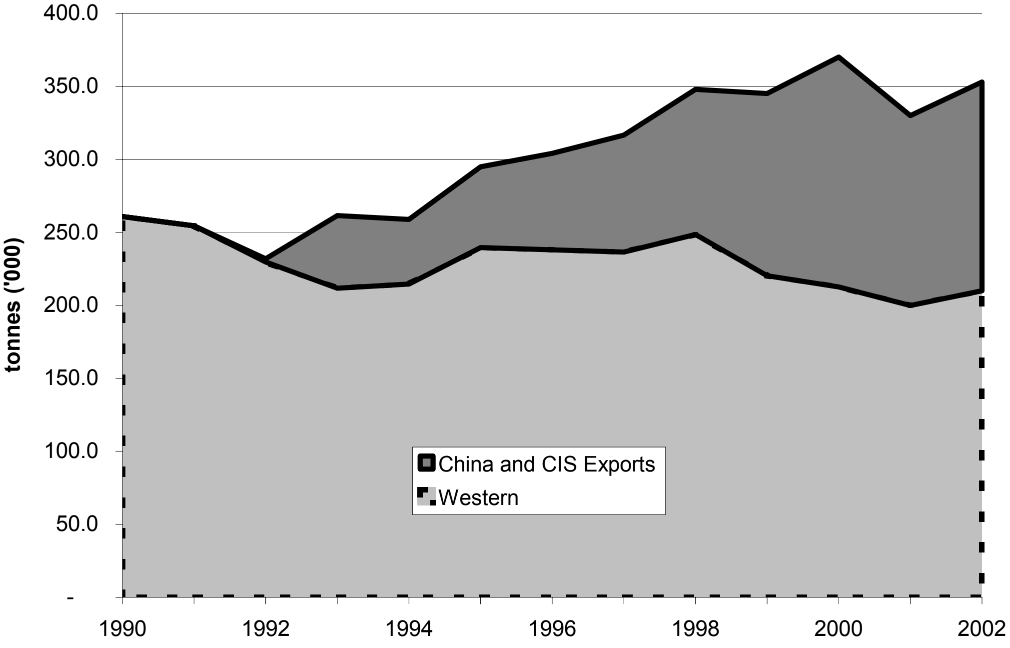

Figure 5. Reported western world supply of magnesium.

Sources: USGS, CRU, Hatch Estimates

Since the early 1990's there has been considerable movement in plant closures and openings for such a small industry. Driving the closures has been economic collapse in the CIS and unsustainably high production costs and pollution problems at older Western plants. Many of these reductions were in the early 1990's recession and manifest themselves in the drop in total production from 1991 to 1993. The largest losses of capacity, however occurred in the period 1994 to 2002 with the closure of Dow Chemical's US plant, plants in Norway, France, and the US, and specific plants in the CIS. In addition to the above, in February 2003 Magnola metallurgy Inc. announced the mothball of its 58,000 tpy magnesium production facility in Quebec, Canada. Of all the major Western primary magnesium plants active in 1990, only two continue to operate, and these were built in the late 1980s.

In 2003 western world primary magnesium capacity fell to only 200,000 annual tonnes, compared to western demand of 355,000 tonnes in 2002. Western European capacity has been completely eliminated by plant closures. North American capacity, which was reduced by approximately 50% by the closure of Dow in the 1990's, was in the process of being increased back to near the earlier levels by the start-up of the new Noranda Magnola plant (mothballed in 2003) and incremental expansions

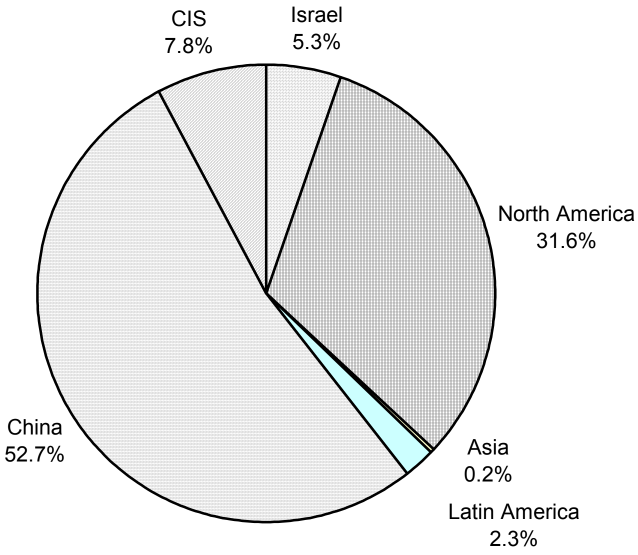

Figure 6. Regional distribution of magnesium capacity, 2003

Source: Hatch Estimates

Today, China has the largest primary magnesium capacity, and based on available statistics, is also the largest producer and supplier to the western markets The major increase in primary magnesium supply from China has been the result of a large number of capacity additions at many relatively small plants using an old technology which is considered obsolete and uneconomic in the west. The silico-thermal process (Pidgeon Process) is labour intensive and small scale. On the other hand, it has the advantages of great simplicity, direct utilisation of low cost thermal energy (coal in China) rather than electricity, and very low capital cost for expansion or new plants, both in terms of cost per unit capacity and absolute dollars.

In the future, it is likely that some of the existing capacity may be removed from the industry.

In terms of future capacity addition in the western world, there is currently only one new magnesium plant in the early stages of construction - the AMC facility in Australia, with a planned capacity of 90,000 tonnes per year (some capacity increases may be achievable at other existing plants through incremental changes). While other magnesium projects have been discussed in many locations, none are near coming to fruition today.

In the Chinese industry, it is believed that the higher cost segment of the Chinese industry will be unable to compete, or will be simply replaced by the more cost-effective capacity being built. While actual capacity of the magnesium facilities in China is somewhat speculative, it can be reasonably estimated that functional capacity there will remain in the 300,000 to 350,000 tonnes range.

Based on the demand forecasts discussed earlier, the magnesium supply-demand situation in circa 2010 is presented in Table 9:

Table 9. Magnesium supply/demand circa 2010.

	Hatch Most Likely Case (mtpy)	Hatch Optimistic Case (mtpy)
Western World Demand	600,000	900,000
Western World Production	270,000	270,000
China, CIS, and FCC Demand	100,000	100,000
China, CIS Production	315,000	315,000
Total World Demand	700,000	1,000,000
World Production	585,000	585,000
Additional Capacity Required, World	115,000	415,000

Without the construction of any new western plants except for the AMC facility, by 2012 there would be a shortfall in magnesium capacity of nearly 115,000 annual tonnes using the Hatch Base Case demand forecast. Under the more speculative Hatch Optimistic Case demand, the shortfall would increase to over 400,000 annual tonnes.

In order for even the base case demand to be satisfied, new primary magnesium plants will have to be constructed between now and the latter half of this decade.

In addition to the assessment of future primary magnesium supply for the purpose of evaluating the likely supply-demand conditions for a new entrant in the middle of this decade, it is also important to examine the estimated production costs of the various existing and likely producers. In an industry such as primary magnesium, this is no easy task. However, Hatch, with inputs from a wide variety of published and unpublished sources has made estimates of production costs for major producers and producing locations. In each case, these estimates are based on an understanding of the processes being utilised, the input requirements per unit of production (e.g. raw material, process materials, energy, manpower, maintenance materials, etc.) and the unit costs of these inputs.

While we believe that the estimates are useful for setting the industry's costs in perspective, it should be noted that the degree of confidence one can have in the absolute costs vary significantly. Costs of producers in the US and Canada are likely to be more accurate than costs in Russia or China. These cost assume facilities are operating at near full capacity levels, and are not in a start-up situation. There are significant costs, especially in the large, modern electrolytic plants that are fixed over a substantial range of volumes, and unit costs at reduced output and during start-up are significantly higher. In addition, these cost reflect exchange rates of 2001, and major change in exchange rates would affect relative costs in a significant manner.

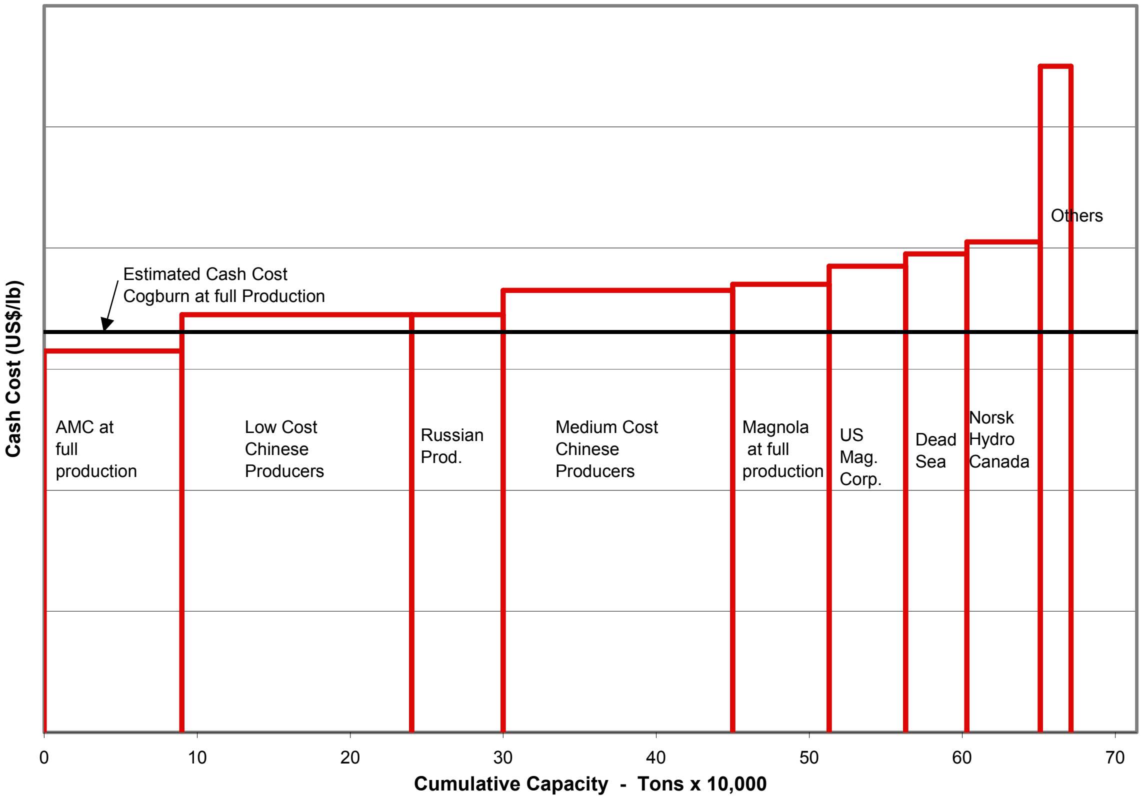

Figure 7. Primary magnesium capacity and cost curve (actual cost numbers on Y axis are not shown for confidentiality reasons).

The capacity and cost graph presented in Figure 7 is based on estimated cash costs of production in 2001 US dollars per pound, in the 2005 time frame. The producers included are those currently in place, with incremental capacity increases in some cases, plus the Australian Magnesium Corporation facility, and with the highest cost portion of the current Chinese industry replaced by the lower cost capacity currently being built or starting up

Based on the preliminary Opex cost estimate for the Cogburn Project, its cash operating cost at full production can be estimated to be in the lower half of industry costs, somewhat above the costs of AMC, the lowest cost Chinese producers and the Russian producers, but below the costs of the medium cost Chinese producers and the other western world (Canadian, US, Israeli) producers.

3.3 Price Overview

The following graph shows the US price for magnesium, as published by the USGS, from 1980 to 2002. In nominal (dollars of the day) terms, magnesium prices showed a steady, slow, increase from 1980 to 1990, a modest decline in 1991, steady until 1994, when prices, now transaction based instead of producer list based, surged to an historic peak in 1997. This peak was driven by both strong real demand and short term concerns. Interestingly, other metal commodities such as pig iron, aluminium ingot and copper cathode also peaked in this period.

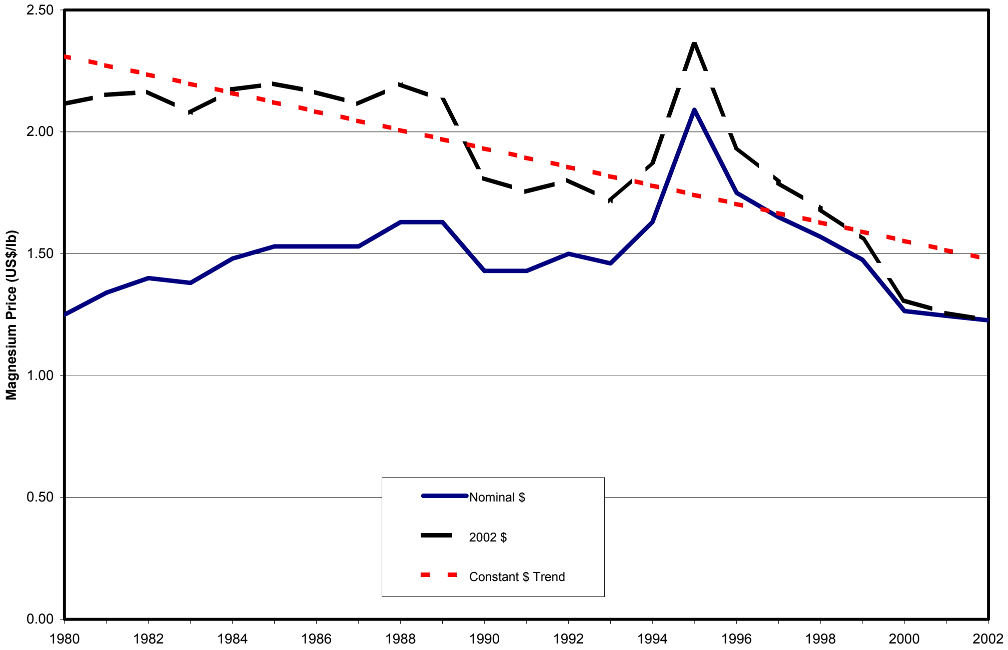

Figure 8. U.S. Magnesium price history (Source: USGS).

In constant 2002 dollar terms, the US magnesium price was essentially flat in the 1980’s, and has been highly cyclical in the 1990’s and the first three years of the new century. The steep decline in both current and constant dollar terms since 1996 has brought magnesium prices to a low point in 2002, which is below even the nominal dollar price in 1980.

In constant dollar terms, the long-term trend in magnesium prices over the period shown in the graph is a decline of 1.9% per annum. While the extreme volatility in price over the last decade is, perhaps, the characteristic of the magnesium price that stands out, this longer-term trend is not unusual for metal commodities.

It should also be noted that the 2002 trend-line price, based on the constant dollar trend, is US$ 1.48/lb, substantially higher that the actual price of US$1.23/lb. At the published market prices for magnesium of early 2003, no producers, including the lowest cost Chinese, can make a profit on a full cost basis. The current prices are unsustainable, and further capacity reductions are inevitable unless prices begin to increase soon. . It should also be noted that over the period of the last few months, magnesium prices including those of Chinese producers are under steady increase. It is believed that with further improvements in the world political and economic situation, further increase in magnesium prices is likely.

Existing plants represent sunk investment cost, and many have either been written down in value or depreciated to the point where there is little in the way of financial cost or depreciation to be covered. The Chinese plants have small investment levels, as the technology has a very low capital requirement. On the other hand, new large electrolytic plants, such as the AMC plant under construction now have large investments, and will have large financial costs to cover.

Magnesium production costs in the middle part of this decade (2005-2007) were estimated on a cash cost basis. Adding other corporate costs, freight, duties as appropriate, trader margins, and return on capital employed (interest and profit) gives a range of minimum acceptable selling prices for different producers.

We have examined the prices at which the projected suppliers to the US market achieve, on average, their full costs and some profit margin, and, the price at which the highest cost supplier achieves coverage of its costs, but no profit margin. This was done for each of the Base Case demand and the Optimistic Case demand.

The result of this analysis is that under the base case conditions, the anticipated weighted average cost plus profit, and the high cost without profit are both at a price of US$1.27/lb (2003 dollars), and under the optimistic conditions (which includes higher production and lower average costs for the producers), the average cost plus profit and the high cost, with less profit, are both at US$ 1.34/lb. These prices are delivered to the Midwest US markets, and represent an average over time in a market, which will be cyclical, and will vary above and below these figures from year to year.

As indicated in the prior section, growth in demand for magnesium will require construction of new capacity, and major production facilities using modern technology at large scale will be necessary to satisfy sophisticated users such as the auto industry in the future, as such users are not likely to be willing to rely on production from small scale facilities such as those in China for major segments of their requirements. Based on recent experience, the production costs at such new, large scale facilities must be significantly lower than those of existing western capacity in order to offset their high capital-related costs and still be successful in the market environment expected.

We recommend that for planning purposes, a magnesium price, delivered to the Midwest US, of US$1.27/lb in 2003 dollars be utilised in the base case for the life of the project, with the recognition that in reality the price will decline slowly, and that the projects operating costs will need to be reduced over time in order to maintain operating margins. For the optimistic case, the average price would be US$1.34/lb.

Examination of recent price differentials between pure metal and specification casting alloys shows a consistent premium of about 10% for the alloy material. This difference has held in China (export, fob port), in Europe (fob warehouse, Rotterdam) and in the US (spot market). Therefore, we recommend using this 10% premium to determine the alloy prices in both the base and optimistic cases.

The following table contains the prices used in the financial analysis.

Table 10. Long-term magnesium prices, 2003 US dollars per pound, delivered to US Midwest.

	99.8% Metal	**Die Casting Alloys**
Base Case	$1.27	$1.40
Optimistic Case	$1.34	$1.47

4. RAW MATERIALS

4.1 Location

The Emory Zone is located near the southern end of a large (10-kilometer long by 2-kilometer wide) ultramafic body lying in the Talc Creek drainage basin 23 kilometres north-west of Hope, British Columbia, Canada (Figure 9).

4.2 Core Drilling

The core drilling program was carried out by Crest Geological Consultants Ltd. The purpose of the 2002 definition drill program at the Emory Zone was to define sufficient magnesium bearing silicate (>24% Mg) to supply a processing plant.

Definition core drilling started April 26 and was completed June 3, 2002. Thirty-four vertical holes were diamond drilled for a total of 1904.22 meters. A 50m (maximum spacing) square drill pattern was designed using four 2001 drill holes as guides along eight northeast orientated (037°-217°), 45m to 50m spaced section lines defining an area some 350m by 250m.

Drill core logging shows that the Emory Zone is underlain by steeply dipping, variably serpentinized dunite with only minor changes in primary modal mineralogy.

Of the 38 core holes (2001 & 2002) drilled in the Emory Zone, five holes located in the south-east corner of the Emory Zone contain average magnesium values (average over the entire length of drill hole) ranging from 26.10% Mg to 26.81% Mg. Twenty-two of the holes through the central and northern part of the Emory Zone contain average magnesium values ranging from 24.29% Mg to 25.80% Mg including three holes with average magnesium values ranging from 26.05% Mg to 26.24% Mg. The southern and south-western part of the area drilled intersected significant intervals of listwanite and variably altered dunite that has negatively affected the average magnesium content, which ranges from 20.23% Mg to 23.42% Mg. However, one hole (CR02-45) within this area contains 29.47% Mg over 18m (9.0 m to 27.0 m) which is the highest-grade magnesium intersection from the Emory Zone.

Deleterious elements that affect the processing/recovery of magnesium metal are considered to be below tolerance. Moderate to low values of Fe, Ca, S, B and Ni are located throughout the central and northern part of the Emory Zone while the southern area contains moderately “anomalous” values of Ni (up to 3343 ppm Ni), Zn (up to 4852 ppm Zn), Cd (up to 54.9 ppm Cd), As (up to 374 ppm As) and Mn (up to 2482 ppm Mn) all of which are contained in listwanite, listwanitic fault/fracture zones or open breccia zones.

Generally, the 2001 and 2002 core drilling has defined a near surface deposit that is amenable to quarrying, containing a significant magnesium silicate resource (>24% Mg) with low concentrations of deleterious elements. In conjunction with the 2001 reconnaissance style drill program covering some seven kilometres of strike length, indicates that the main ultramafic complex contains a remarkably uniform magnesium grade (>24% Mg), which adds to the long term viability of the project.

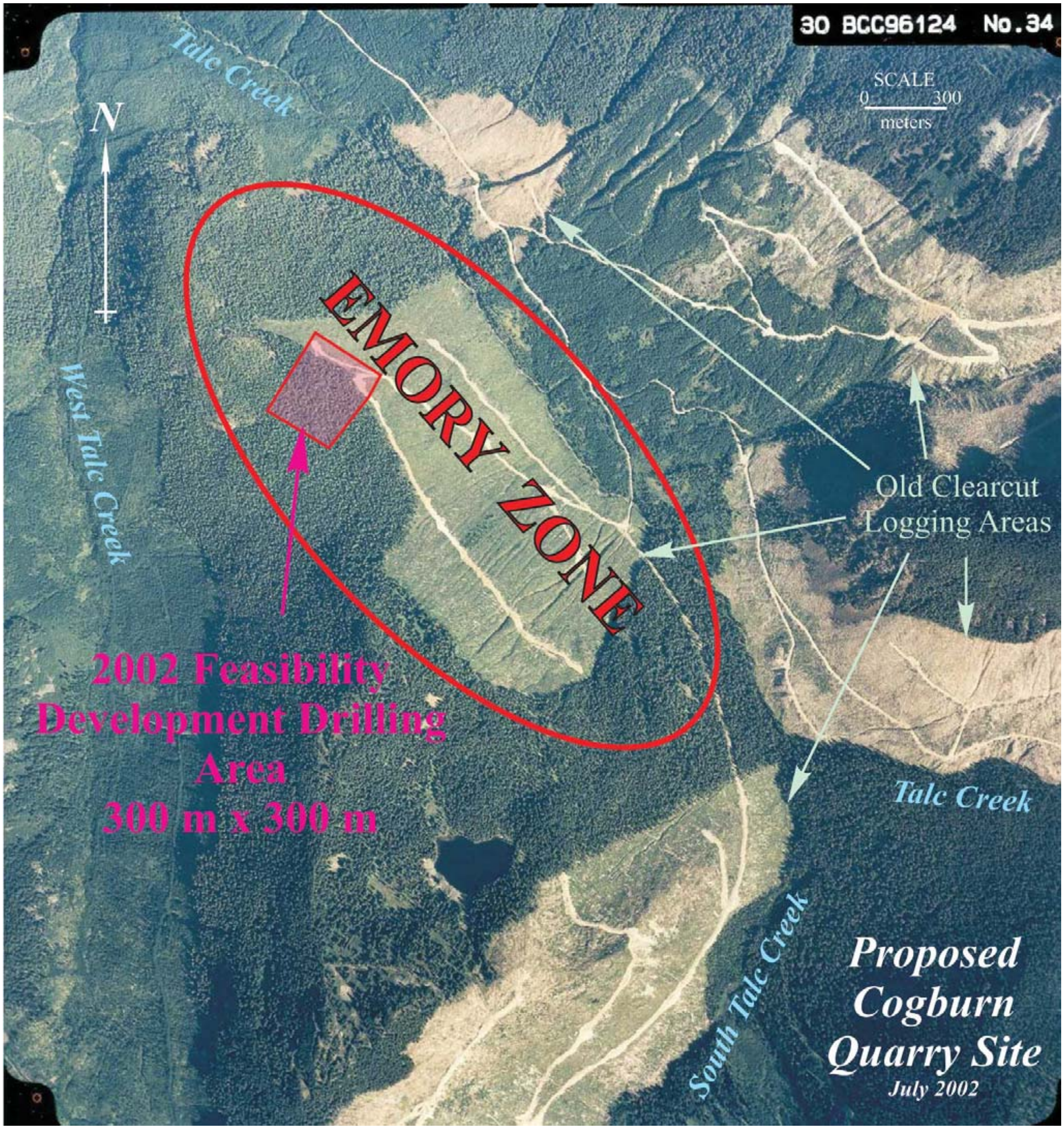

Figure 9. Cogburn quarry site

4.3 Mineral Resource Estimate

The mineral resource estimate was performed by Geospectrum Engineering[2].

The purpose of the estimate was to determine the size of the resource based upon core drill program carried out by Crest Geological Consultants Ltd.

Golden Software Inc.'s SURFER (32) V7.0 was utilized for developing the grid, geostatistics, volume calculations and mapping of the data (Figure 10). The calculations are summarized in Table 11.

Table 11. Mineral resource estimate

Description	Value
"Thickness" Volume	8,958,828 m3
"Thickness Grade" Volume	220,155,193 m3*%Mg
Grade of Emory Zone	24.57 %Mg
Specific Gravity	2.85 tonnes/m3
Tonnage	25.5 M tonnes

The Emory Zone has been drilled off at a 50-meter square spacing and is uniform enough in grade and geology to comply with the National Instrument 43-101 and CIM definition for a Measured Mineral Resource. Therefore the Emory Zone has a Measured Mineral Resource of approximately 25.5 million metric tonnes at 24.57 % magnesium using an SG of 2.85.

4.4 Quarry and Haul Road Design

4.4.1 Quarry

The quarry and haul road conceptual design was performed by Geospectrum Engineering and Emil Anderson Construction Co. Ltd[3].

A conceptual quarry plan has been developed with the various infrastructure required through the 25-year quarry life cycle. The plans are for years one, two, five, ten, fifteen, twenty and twenty-five (Figure 11 and Figure 12). Topsoil will be removed and stored for reclamation. It is anticipated that there will be no waste dump or low-grade stockpile. All rock will be quarried and hauled to the processing plant. Excavation of the quarry will be done between break-up and freeze-up each year (approximately 6 months operation).

The initial excavation will be started at the 960-meter level. A new road will be constructed at this level and will connect with the existing roads southeast of the quarry. Each bench will be 6 meters in height. It is anticipated that two benches can be mined before a crest and toe needs to be left for safety reasons. Initially the high walls will be mined at 45° until the overall

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[2] Geospectrum Engineering: "Emory Zone Resource Estimate Report", D. Makepeace, July 3 2002.

[3] Geospectrum Engineering and Emil Anderson Construction: "Quarry and Haul Road Preliminary Design and Assessment Report", D. Makepeace, F. Jacobs and S. Wilson, August 16, 2002.

competency of the rock has been tested over time. It is anticipated that the high walls can be steepened to approximately 60° when the testing is completed.

4.4.2 Haul Road

The connecting quarry-plant road will be an upgraded industrial forest road that will utilize the existing logging road network. The use of the existing roads will require six-wheel drive 40-ton articulated trucks due to the steep grades and tight road radii.

The total length of the upgraded industrial forest road is 24 kilometres from the proposed Emory Zone quarry to the primary crusher located 1.7 kilometres north of the community of Ruby Creek. There will be no ore haulage on provincial highways.

The majority of the road system is in good shape and sufficiently wide to accommodate the 40 ton articulated trucks. However, minor modifications are required, including:

- ➤ clearing of vegetation to improve line-of-site on corners;
- ➤ road realignment;
- ➤ grading of the road;
- ➤ modifications to bridges;
- ➤ modifications to culverts;
- ➤ addition of turnouts.

The only major modification is the addition of a 300 m long one-lane wide tunnel to bypass an existing single-lane road located on a steep cliff face.

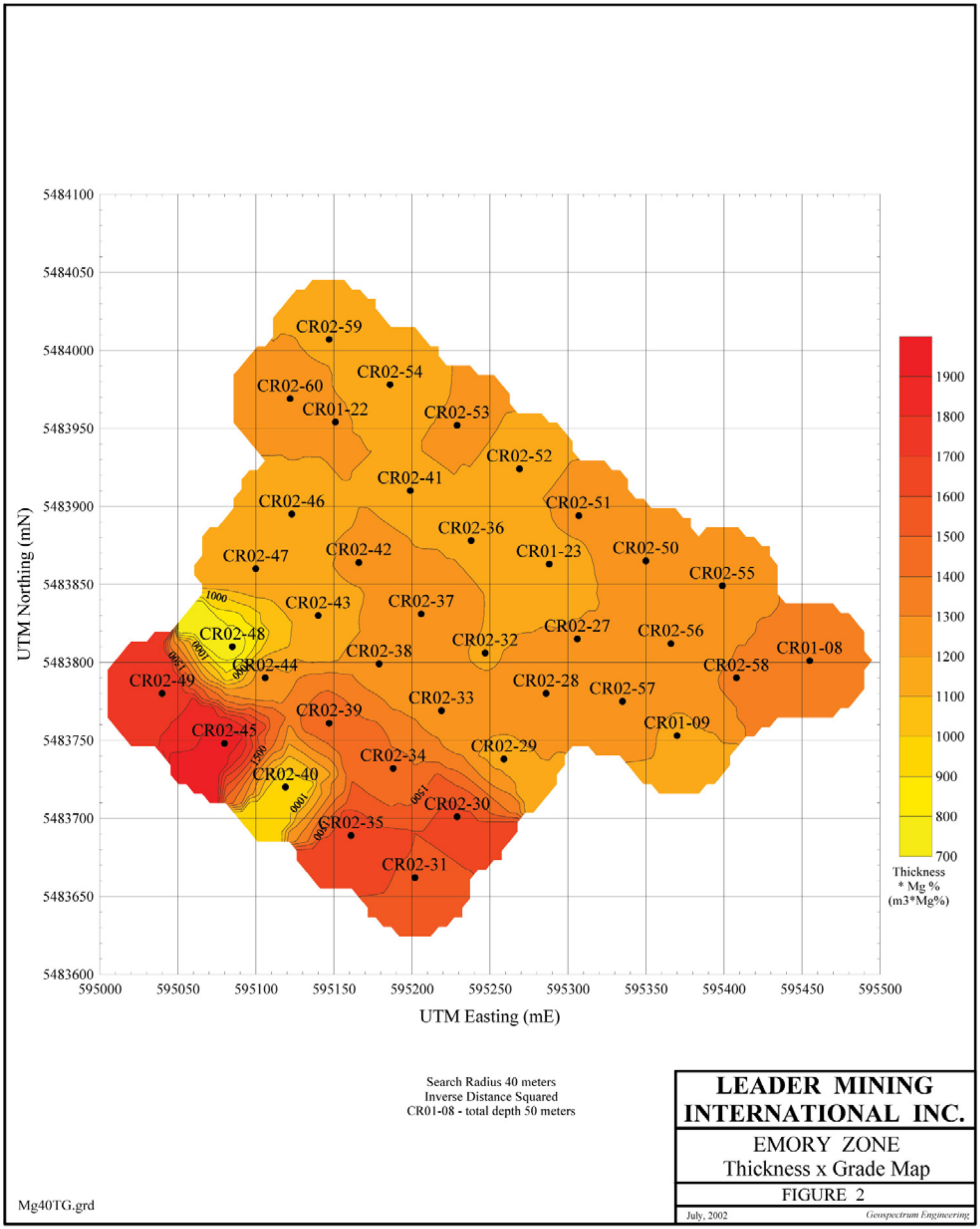

Figure 10. Thickness x grade map

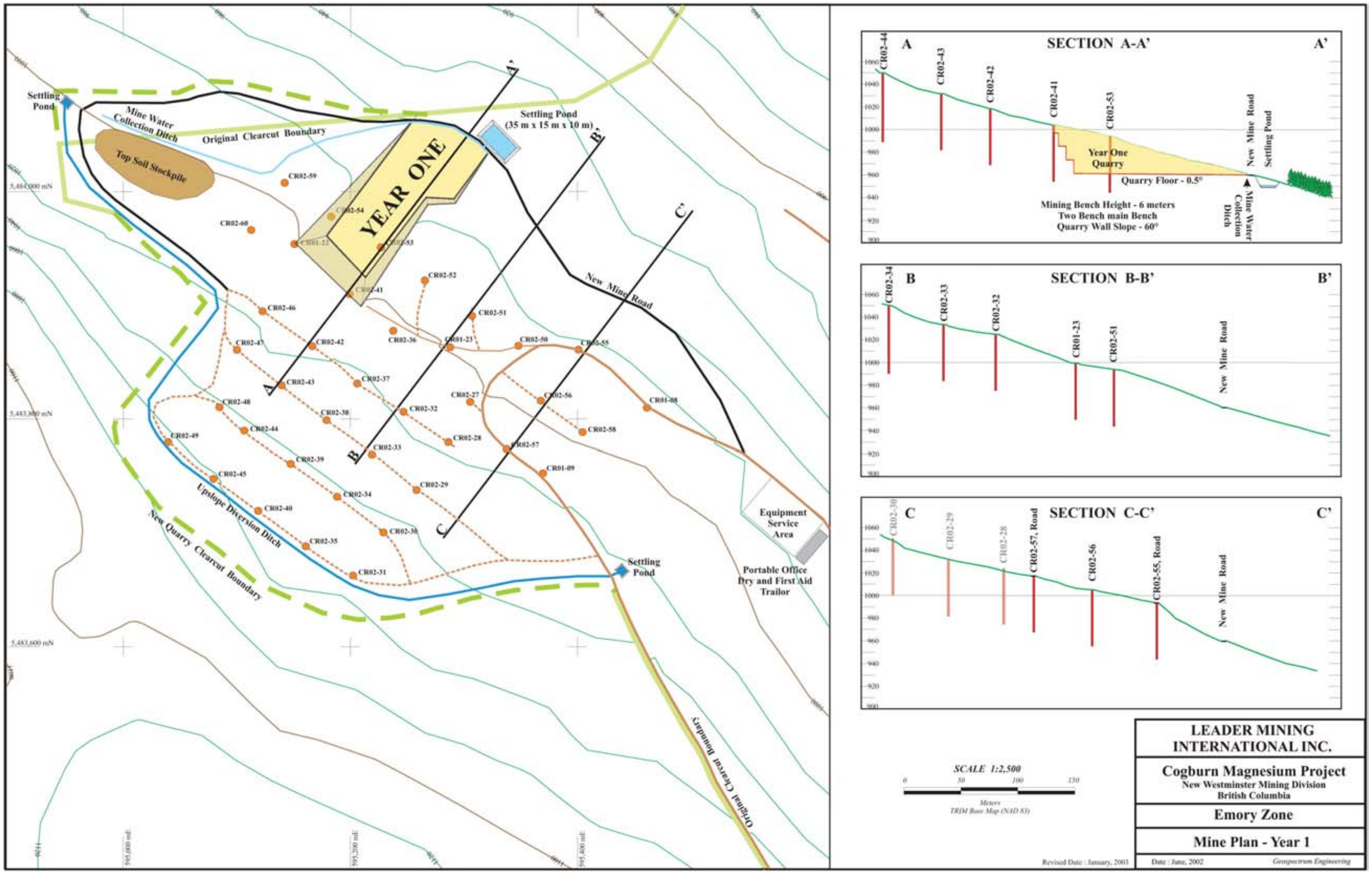

Figure 11. Mine plan for Year 1.

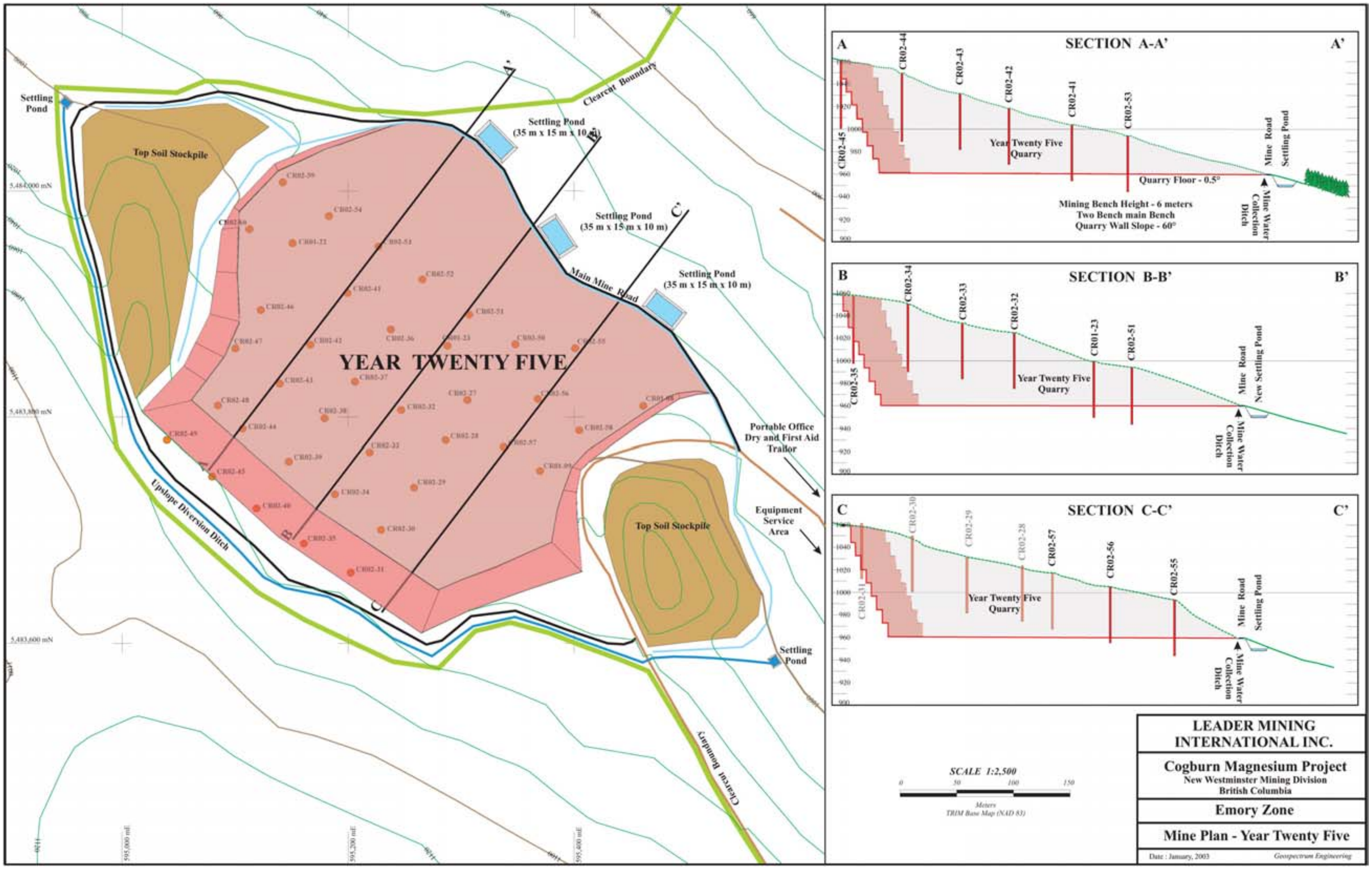

Figure 12. Mine plan for Year 25

5. PROCESS TECHNOLOGY REVIEW

This section of the report presents an overview, description and comparison of the various magnesium metal production technologies.

5.1 Processing Options

There are two major process routes utilized for production of magnesium metal, namely:

- Electrolytic route
- Thermal route

A brief description of these process routes is provided below.

5.1.1 Electrolytic Route

The technologies for the production of magnesium by electrolysis are characterized by three essential steps. These are the following:

- Production of magnesium rich brine (usually MgCl2 or MgCl2/KCl)
- Brine drying or crystallization followed by dehydration
- Electrolytic reduction of $MgCl_2$ or MgCl2*-KCl for production of Mg-metal and chlorine gas

The $MgCl_2$ brine is produced by leaching of magnesium oxide or magnesium carbonate minerals such as magnesite or serpentine with hydrochloric acid, or can be concentrated from seawater, lake brines or underground salt deposits. The concentration of $MgCl_2$ in the produced brine is generally greater than 25%. The produced brine is also purified in order to remove such impurities as boron, sulphate ions, and heavy metals.

Alternatively, carnallite (MgCl2*-KCl*-6H2O) may be used. The carnallite is either a by-product of other processes or is mined from natural deposits.

The pure magnesium rich brine is then evaporated to produce dehydrated $MgCl_2$ or MgCl2*-KCl crystals suitable for electrolytic cell feed. Process equipment design and parameters of dehydration technology utilized by different producers vary significantly. This is due to specific requirements to the quality of feed (content of MgO and H_2O) of the electrolytic cells employed at the producer facility.

The electrolytic reduction area of a magnesium production facility is the most important and critical process area of the plant. There are 5 electrolytic cell technologies utilized in the world today.

Presently in the magnesium industry, the decomposition of $MgCl_2$ to magnesium metal and chlorine gas by electrolysis is done largely in mono-polar diaphragm-less electrolytic cells.

An evolution of the original I.G. Farben (Germany) mono-polar cell is used by the STI/VAMI (Former Soviet Union) technology, by Magcorp - US Magnesium (USA) and by Norsk Hydro (Norway and Canada). The Norsk Hydro facility in Norway is now closed.

The STI/VAMI technology is based on a flow through design in which all the cells in the cell hall are linked together. Each cell is fed individually. The magnesium and electrolyte flow from one cell to the next via a system of enclosed launders. The magnesium if collected at the end of the flow line in a separator cell, and is siphoned out for casting at the casthouse. This system is currently utilized at the Dead Sea Magnesium plant in Israel.

Dow Chemical's magnesium electrolytic cell is unique in that it is the only cell designed to accept partially dehydrated $MgCl_2$ feed.

Finally, Alcan (Canada) together with Sumitomo SiTix (Japan) have developed a multi-polar electrolytic cell, which is distinguished from the mono-polar cells by a higher operating voltage, lower current, and a smaller physical size per annual production capacity. This multi-polar cell requires a high quality feedstock. The Magnola Metallurgy Inc. (Quebec, Canada) was the first primary magnesium production facility built to use the Alcan multi-polar cell for commercial production of magnesium metal.

Performance of the electrolysis cell is a function of its current efficiency defined as the ratio of magnesium actually produced to the theoretical amount predicted by Faraday's Law. The specific energy performance of the cell depends on the dimensions of the cell including electrode separation. All electrolytic cells employ graphite anodes that are subject to corrosion by any oxides (MgO, etc.) present in the cell feed. The design of the Dow magnesium cell, as well as the majority of mono-polar cells, allows for the replacement of graphite anodes as they are consumed. Other cells depend on the dehydration process to provide low MgO containing feed. In these cells, the anode life is equivalent to the life of the cell. All electrolysis cells have a finite life that varies with the technology.

5.1.2 Thermal Reduction Route

Non-electrolytic methods of magnesium production are all based upon thermo-chemical reduction of magnesium oxide which is obtained by processing any one of a number of magnesium resources, e.g. magnesite ($MgCO_3$), dolomite ($MgCO_3$*$CaCO_3$), olivine ((Mg, Fe)SiO_2), etc., although dolomite is utilized most commonly. The prototypical reaction of the process is the following:

$$MgO + R = Mg + RO$$

Where, R is the reductant, and can be carbon (C), a metal, or a metallic compound such as carbide or silicide.

The process is batch, low capacity, and labour intensive.

The major process steps for the thermal reduction processes include the following:

- Calcination of raw material
- Reagent mixing

- ➤ Thermal reduction

The calcination process step is required to remove all volatile components from the raw material (CO_2, moisture, others), thus ensuring the production of high quality magnesium metal. Primary chemical reactions of the process are the following:

$$MgCO_3 = MgO + CO_2$$
$$MgCO_3{*}CaCO_3 = MgO{*}CaO + 2\ CO_2$$

If this step is not performed properly, residual volatile components of the raw material will react with magnesium metal (and form $MgCO_3$) during the reduction stage, and will cause metal loss and contamination of the product.

Calcined raw material is then mixed with a reducing agent (C, FeSi, Al, etc.) and other components to form a furnace charge. Some additional reagents are required by the process in order to react with impurities contained in the raw material and form slag.

Furnace charge is placed into an airtight enclosure and heated under vacuum to initiate thermal reduction of the raw material. Magnesium metal is evaporated in the form of gas and condensed in a cooled, airtight enclosure to form a so-called crown. Once the process is complete, the solid magnesium crown is removed, re-melted, and cast into ingots.

5.2 Assessment of Processing Technologies

5.2.1 Comparison of Electrolytic Production Technologies

Parameters and equipment design of electrolytic processes employed in the industry vary depending on the raw material, the type of dehydration technology, and the cell design used.

In all electrolytic magnesium production processes, by far the largest component of the operating cost is energy (natural gas and electricity). A typical operating cost distribution is included in Table 12.

Table 12. Generic operating cost breakdown (electrolytic technologies)

Operating Cost Item	Proportion, %
Energy	30-40
Labour	15-20
Raw Materials	2-5
Reagents	10-20
Other	Balance

Source: Hatch

The most important factor, therefore, is the choice of a process which maximizes energy efficiency, in addition to locating a plant where energy sources are not only readily available, but also at favourable rates.

The energy requirement for each process technology and the relative amount of electricity and natural gas consumption is a function of several factors:

- Electrolysis technology employed
- Dehydration technology employed
- Whether process materials are produced on site or purchased
- Whether or not co-generation is used at the producing plant
- Form of energy (gas, oil, electricity) used in the foundry for refining and melting furnaces
- Degree of heat recovery
- Plant location in terms of winter heating requirements

Table 13 provides a comparison of the electrolytic technologies by key process sector.

Table 13. Comparison of estimated parameters of electrolytic process technologies

description	Norsk Hydro 45, 000 tpa	U.S. magnesium 43,000 tpa	Dead Sea Magnesium 27, 500 tpa	Dow Magnesium 65,000 tpa	Magnola 58,000 tpa	AMC project 97,000 tpa	Cogburn project 125,000 tpa
Status	Operational	Operational	Operational	Closed	Closed	In Construction	Study
Raw Material	Magnesite imported from China or Brazil (~ 28% Mg).	Great Salt Lake Brine (0.4% Mg).	Dead Sea Brine (4% Mg).	Sea water (0.13% Mg)	Serpentine from Asbestos operations (24% Mg).	Magnesite (~28% Mg)	Magnesium silicate (~24.6% Mg)
Pure Brine Production	➤ Leach magnesite with recycle HCl acid; ➤ Solution purification.	➤ Solar evaporation; ➤ Crystallize potash; ➤ B & SO_4 removal.	➤ Solar evaporation Precipitate NaCl. ➤ Precipitate carnallite $KCl \cdot MgCl_2 \cdot 6H_2O$.	➤ Neutralized with alkali to precipitate $Mg(OH)_2$; ➤ $Mg(OH)_2$ slurry Neutralized with HCl gas to produce 34% $MgCl_2$ brine ➤ B,Ca, SO_4 removal.	➤ Leach with recycle HCl acid to 27% $MgCl_2$ brine; ➤ Solution purification.	➤ Leach with recycle HCl acid; ➤ Solution purification.	➤ Leach with recycled HCl acid; ➤ Solution purification. ➤ Cristallisation of carnallite $KCl \cdot MgCl_2 \cdot 6H_2O$.
Dehydration	➤ Concentrate $MgCl_2$ brine to 40-50% $MgCl_2$; ➤ Convert to prill in prilling tower; ➤ Multi-stage FBD to $MgCl_2$ (A); ➢ 40 GJ/t Mg.	➤ Pure $MgCl_2$ brine to Spray Dryers heated with turbine off-gases; ➤ Spray Dry Powder: ➢ 88% $MgCl_2$; ➢ 5% H_2O; ➢ 5% MgO. ➢ 38.3 GJ/t Mg (Hatch estimate without turbine); ➤ Carbo-chlorination of $MgCl_2$ (SD) in melt cells and reactor cells; ➢ 2.3 MWh/t Mg.	➤ Fluid Bed drying of carnallite to: ➢ 48% $MgCl_2$; ➢ 46% KCl; ➢ 3.7% H_2O; ➢ 1.7% MgO. ➢ 40 GJ/t Mg (Hatch estimate); ➤ Carbo-chlorination of dehydrated carnallite in chlorinators ➢ 3.2 MWh/t Mg	➤ Pure brine to fluid bed drying to $MgCl_2 \cdot 2H_2O$ ➢ 68% $MgCl_2$ ➢ 27% H_2O. ➢ 43.8 GJ/t Mg.	➤ Concentrate to 38% $MgCl_2$ Fluid bed drying of pure brine to prills ➤ $MgCl_2 \cdot 2H_2O$: ➢ 68% $MgCl_2$; ➢ 28% H_2O ➢ 0.2% MgO ➢ 34.5 GJ/t Mg ➤ Melt chlorination of prills in contact with dry HCl. ➤ Chlorination ➢ 3.2 MWh/t Mg	➤ Crystallize $MgCl_2 \cdot 6H_2O$; ➤ Dissolve in glycol; ➤ Saturate with ammonia to precipitate $MgCl_2 \cdot 6NH_3$; ➤ Fluid bed calcination to release NH_3 for recycle; ➤ Distillation of glycol to regenerate glycol for recycle; ➤ Produce $MgCl_2$ with less than 0.1% MgO; ➤ 68.4 GJ/t Mg (Hatch estimate).	➤ Fluid Bed drying of carnallite to: ➢ 48% $MgCl_2$; ➢ 38% KCl; ➢ 11% NaCl ➢ 0.2% H_2O; ➢ 0.3% MgO. ➢ 40.7 GJ/t Mg
Electrolysis[*]	Norsk Hydro Monopolar cells: ➤ 400 kA; ➤ 14.0 MWh/t Mg; Rebuild frequency: ➤ 5 years; ➤ $3 million/year.	US Magnesium Monopolar cells: ➤ 130 kA; ➤ 15.0 MWh/t Mg Rebuild frequency: ➤ 2-3 years; ➤ Reactor: 1.5 year ➤ $7.7 million/year.	STI/VAMI monopolar cells: ➤ >165 kA; ➤ 15.3 MWh/t Mg. Rebuild frequency: ➤ 3 years ➤ $4 million/year.	➤ Dow monopolar cells: ➤ 195 kA ➤ 19.2 MWh/t Mg ➤ 1.1 GJ/t Mg Natural gas ➤ 0.058 t graphite anodes/t Mg Rebuild frequency: ➤ 6 years ➤ Repair every 2½ year; ➤ $2 million/year.	➤ Alcan multipolar electrolysis cell: ➤ >140 kA ➤ 13.6 MWh/t Mg Cell and chlorination rebuild frequency: ➤ 2 years ➤ $8.6 million/year	➤ Alcan multipolar electrolysis cell: ➤ >140kA; ➤ 13.6 MWh/t Mg Cell rebuild frequency: ➤ 2 years ➤ $6.6 million/year	STI/VAMI monopolar cells: ➤ 300 kA; ➤ 15.3 MWh/t Mg. Rebuild frequency: ➤ 3.3 years ➤ $13.6 million/year.
Energy: Dehydration & Electrolysis	➤ 25.1 MWh/t Mg, or ➤ 90.4 GJ/t Mg	➤ ~27 MWh/t Mg, or ➤ 118.9GJ/t Mg	➤ 29.7 MWh/t Mg, or ➤ 106.8 GJ/t Mg	➤ 31.4 MWh/t Mg, or ➤ 112.9 GJ/t Mg	➤ 26.4 MWh/t Mg, or ➤ 95.0 GJ/t Mg	➤ 32.6 MWh/t Mg, or ➤ 117.4 GJ/t Mg	➤ 27.0 MWh/t Mg, or ➤ 97.6 GJ/t Mg

Source: Operating parameters of the major operating equipment are Hatch estimates.
**Rebuild costs are dependent on the number of cells installed and cell service life.*

5.2.2 Comparison of Thermal Production Technologies

There are several options of thermal process that are currently utilized in the industry.

These process options are essentially variations of the basic Pidgeon process distinguished by the size and design of the main production equipment, as well as by the few process details.

These main processes are the following:

- Pidgeon process – utilized by Timminco (Canada) and Chinese producers
- Brasmag – utilized by RIMA Industrial (Brazil)
- Magnetherm – utilized by Pechiney (France) and North-West Alloys (Alcoa), both plants are presently shut down

In all magnesium thermal reduction processes, by far the largest component of operating cost is the cost of reagents, in particular the ferrosilicon which can account for up to 50% of the total costs. A typical operating cost distribution is presented in Table 14.

Table 14. Generic operating cost breakdown for western facilities (Thermal Reduction Technologies)

Operating Cost Item	Proportion, %
Energy	15-20
Labour	15-25
Raw Materials	5-10
Reagents	25-50
Other	Balance

Source: Hatch

For a thermal reduction plant therefore, the most important factor, is the availability of low cost ferrosilicon, although labour and energy are also significant. It should be noted that the Pidgeon process is very difficult to mechanize or to adapt to modern process controls and automation.

Table 15 provides a comparison of selected western-world magnesium thermal reduction technologies by cost of raw materials and energy consumption.

Table 15. Comparison of selected magnesium Thermal reduction technologies

Description	North West Alloys** 40 000 tpa	Pechiney** 15 000 tpa	Bolzano** 8 000 tpa	Brasmag 12 000 tpa
Cost of Raw Materials	US$1,106/t Mg	US$1,289/t Mg	US$1,407/t Mg	US$1,240/t Mg
Energy Requirements	28.8 MWh/t Mg	28.8 MWh/t Mg	30.0 MWh/t Mg	40.0 MWh/t Mg

Source: "Magnesium at the Crossroads"; Report by Commodities Research Unit Ltd (UK).
*Note: ** These plants have been shut down.*

The Pidgeon process is particularly well adapted to the specifics of China due to relatively low cost ferrosilicon, labour and energy (coal), good quality dolomite reserves, and environmental policies that are less stringent than those of the western world (Table 16). Furthermore, the Pidgeon process has a lower capital investment per installed tonne and capacity can be added incrementally. This allows for the commissioning of many small producers, and indeed in China the majority of the producers have less than 3000 tpa capacity.

Table 16. Generic operating cost breakdown for China (Thermal Reduction Technologies)

Operating Cost Item	Proportion, %
Energy (coal)	20-30
Labour	5-10
Raw Materials	5-10
Reagents	55-65
Other	Balance

5.2.3 Product Quality Differences Between Technologies and Producers

There are no product quality differences between the western-world technologies or producers. Generally, magnesium producers comply with the requirements of ASTM standards for primary magnesium metal and magnesium alloys.

The difference between various technologies and producers rests with the diversity of products they are willing to supply to the markets and their respective economies of scale.

Typically, major producers who employ electrolytic production routes supply primary magnesium metal and alloys to large-scale, large-volume consumers (i.e. aluminium companies for aluminium alloying, producers of magnesium powder for steel desulphurisation, or magnesium die-casters). Producers who employ thermal processes are capable of supplying small quantities of higher purity primary magnesium metal and, therefore, focus on supply of high purity metal to niche markets such as the nuclear industry and producers of specialty metals.

5.3 Technology Selection

5.3.1 Overview

Choosing the appropriate process depends on the overall objectives of a specific producer and the advantages/disadvantages that the site selection offers in terms of:

- Raw material
- Cost and availability of electricity
- Cost and availability of natural gas
- Labour skill level
- Environmental regulations

Details of the overall process flow sheet are always tailored to the above constraints.

In all instances over the history of magnesium industry evolution, new plants utilizing newly developed technologies have experienced significantly longer start-up and integration periods than planned. Some of these plants were shutdown as no technical and economical solutions were found to address the problems that incurred at ramp-up.

Start-up difficulties take place due to the following:

- It is almost impossible to foresee all potential pitfalls which will be present when a newly developed technology is scaled–up for use in commercial operations; and
- Management/development/engineering personnel may not have a full appreciation of the complexity of the problems, as they tend to apply knowledge and expertise obtained during other metallurgical/mining projects usually not related to the magnesium industry.

5.3.2 Commercial Availability of Technologies

The following technologies are available for commercial license.

5.3.2.1 Electrolytic Technologies

5.3.2.1.1 Alcan International Ltd.

The Alcan technology is based on anhydrous magnesium chloride ($MgCl_2$) and can be licensed in packages as follows:

- *Dehydration of $MgCl_2$ solution via a solvent extraction route.*
  The technology is patented, and has been tested on the bench scale. Pilot test trials would be required to demonstrate scale-up and minimize risk for a commercial project.
- *Electrolytic production of magnesium metal and chlorine gas.*
  The technology is used for commercial production of magnesium metal from recycled molten $MgCl_2$ as part of the Kroll Process for the production of titanium. It should be noted that this $MgCl_2$ is 100% anhydrous due to the nature of its production. However, the technology can be used for commercial production of magnesium metal from other raw materials. Indeed, the Magnola project produced magnesium from serpentine mineral thus proving the viability of the cell, although, due to start-up difficulties at Magnola, the economic viability of the Alcan cell is still not proven.

Technology packages available from Alcan do not include the following:

- Production of $MgCl_2$ solution;
- Gas handling; and
- Refining of electrolytic magnesium metal.

5.3.2.1.2 Dow Chemical Co.

The Dow technology is based on hydrated magnesium chloride and can be licensed in packages as follows:

- *Production of pure $MgCl_2$ solution from seawater and other sources.*
  The technology was used in large-scale commercial operation and is proven.

- *Electrolytic production of magnesium metal and chlorine gas.*
  The technology was used for large-scale commercial production of magnesium metal and is proven.

- *Refining of electrolytic magnesium metal and production of pure magnesium alloys.*
  The technology was used for large-scale commercial production of magnesium metal and is proven.

Technology packages available from Dow do not include the following:

- Dehydration of $MgCl_2$ solution; and
- Gas handling.

5.3.2.1.3 STI/VAMI Group

The STI/VAMI technology is based on natural or synthetic carnallite ($MgCl_2*KCl*6H_2O$) and can be licensed in packages as follows:

- *Production of highly dehydrated carnallite $MgCl_2*KCl$ from raw carnallite crystals ($MgCl_2*KCl*6H_2O$).*
  The technology was scaled-up from a similar process used in large-scale commercial operation and is proven.

- *Electrolytic production of magnesium metal and chlorine gas.*
  The technology was used for large-scale commercial production of magnesium metal and is proven.

- *Refining of electrolytic magnesium metal and production of pure magnesium alloys.*
  The technology was used for large-scale commercial production of magnesium metal and is proven.

Technology packages available from STI/VAMI do not include the following:

- Production of pure carnallite solution; and
- Production of raw carnallite crystals.

5.3.2.2 Thermal Reduction Technologies

Over the past 15 years, there have not been any new thermal process based magnesium projects in the western world. In addition, both Pechiney and Alcoa have recently closed their plants.

5.3.2.2.1 Magnetherm Process

- Process developed by Pechiney used by Pechiney in Marignac, France and by Alcoa in Addy, Washington, USA.

➤ Both Pechiney and Alcoa have closed their plants.

5.3.2.2.2 Solid State Silicothermic Processes

Pidgeon, Bolzano (no longer operating) and Brasmag reduce calcined dolomite under vacuum to magnesium vapour, which is condensed to solid magnesium.

5.3.3 Electrolytic versus Thermal Reduction

It is believed that under current world market conditions, the economics of any size thermal process based facility utilizing one of the current technologies would be prohibitive to install in the western world. This mainly being due to the high cost of ferrosilicon, energy and labour.

However, this is not the case in China, where relatively cheap ferrosilicon, energy (in the form of coal) and labour, as well as relaxed environmental regulations, have allowed the commissioning in the past few years of a number of new small and medium sized (3,000 t/y up to 20,000 t/y) Pidgeon process based plants.

Furthermore, thermal technologies are not suitable for use with the silicate raw material found in Leader's Emory Zone. Thermal technologies use ferrosilicon as a reductant and require high purity magnesite or dolomite raw material feed. However, if a magnesium silicate raw material is used, silicon is an ineffective reducing agent. This is because the reduction of the MgO by silicon generates SiO_2 as a reaction product and the existing SiO_2 in the feed will tend to stifle the reaction. Reductants other than silicon would need to be used. These reductants would have an even higher cost than the FeSi75 generally used.

5.3.4 Choice of Electrolytic Technology

As described above there are three commercially available electrolytic reduction technologies in addition to Norsk Hydro and Magcorp technology, both of which are not available commercially.

Alcan technology has been used in the production of magnesium from pure $MgCl_2$ in Japan as well as from dehydrated $MgCl_2$ produced from serpentine tailings from the recently closed Magnola plant in Canada. The Magnola plant operated for over two years when it was shut down. It is estimated that the Magnola plant reached only 60% capacity after two years of start-up[4]. As such, the economic feasibility of the Alcan cell is not proven. In addition, the dehydration of the $MgCl_2$ has only been proven by Alcan on the lab scale.

DOW magnesium is proven technology but has a significant drawback in that there are no personnel to aid in the transfer of the technology since DOW's magnesium plant closure. Production of magnesium is complex, and it is considered that the lack of a sound knowledge base and operating skills eliminates this option.

STI/VAMI technology is proven via several installations in the former Soviet Union, and more recently at Dead Sea Magnesium.

The transferral of the technology to Dead Sea Magnesium has proven:

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[4] Magnesium Monthly Review, Vol 32, No 1, January 2003.

- the technology transfer capabilities
- that the production capabilities of the technology can be met and even exceeded
- that STI/VAMI has a strong technical base capable of assistance during start-up and troubleshooting.

Furthermore, STI/VAMI is capable of supplying not only electrolytic technology but also the important carnallite dehydration and magnesium refining technology.

It should be noted that the two sectors that are missing from the STI/VAMI scope are brine production and crystallization. Brine production is relatively straightforward and can be designed by engineering firms with hydrometallurgical experience, while carnallite crystallization can be performed by Messo-Chemietechnik (Germany), a supplier of specialized crystallization equipment.

From the above it is clear that the STI/VAMI technology has significant advantages over other available technologies and as such, was recommended as the preferred technology for the Cogburn project.

6. PROCESS DESCRIPTION

6.1 Ore composition

The raw material comes from the Emory Zone and contains roughly 24.6% magnesium. Ore chemical composition from the Emory Zone drill samples is given in Table 17. This information comes from the resources estimate[5] for the principal elements and chemical analysis for laboratory testwork for minor elements[6].

6.2 Process Description

The overall Cogburn Magnesium Reduction Plant block diagram is presented in Figure 13.

The hydro-metallurgical recovery begins with the leaching of magnesium from the ore with hydrochloric acid (HCl), as represented in reaction (1).

$$xMgO.ySiO_2 + 2xHCl \Rightarrow xMgCl_2 + ySiO_2 + xH_2O \qquad (1)$$

The unleached residue (SiO_2, etc.) is separated from the resulting $MgCl_2$ brine by thickening and filtration. The brine is neutralized with MgO to adjust the pH and to purify the solution from metallic impurities. Precipitated impurities are removed by thickening and filtration. The neutralized brine is further purified of nickel (Ni) and manganese (Mn) by means of ion-exchange.

The pure $MgCl_2$ brine is then contacted with KCl-rich molten spent electrolyte from electrolysis, to produce granulated electrolyte slurry that is then dissolved to produce a KCl and $MgCl_2$ rich brine (synthetic carnallite solution). The solution is filtered to remove a small amount of insoluble residue.

The synthetic carnallite solution is then enriched with make-up KCl. Crystals of synthetic carnallite hexa-hydrate ($MgCl_2.KCl.6H_2O$) are precipitated from the solution in crystallizers. The mother liquor is separated from the crystals by thickening and centrifugation. A portion of the recycled mother liquor from crystallization is purified from calcium by reaction with sulphuric acid as represented in reaction (2).

$$CaCl_2 + H_2SO_4 \Rightarrow CaSO_4\downarrow + 2HCl \qquad (2)$$

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[5] Geospectrum Engineering: “Emory Zone Mineral Resource Estimate Report”, D. Makepeace, July 3, 2002.

[6] Process Research Ortech, Report PRO-01-262: “Process Optimization for Magnesium Recovery Through Leaching and Solution Purification”, G. Puvvada, October 15, 2002.

Table 17. Ore chemical composition

Element	Avg. Value	Unit
Ag	0.2	ppm
Al	0.25	%
As	21.67	ppm
B	13	ppm
Ba	11.67	ppm
Be	0.5	ppm
Bi	5	ppm
Ca	0.36	%
Cd	1	ppm
Co	80.58	ppm
Cr	0.28	%
Cu	10.75	ppm
Fe	5.68	%
K	0.00013	ppm
LOI	8.26	%
Mg	**24.59**	**%**
Mn	849.6	ppm
Mo	2	ppm
Ni	2106	ppm
P	56.67	ppm
Pb	8.167	ppm
S	0.55	%
Sb	9.583	ppm
Sc	3.917	ppm
Si	18.5	%
Sn	10	ppm
Sr	1	ppm
Ti	0.01	%
V	13.17	ppm
W	10	ppm
Y	1	ppm
Zn	34.67	ppm
Zr	3.083	ppm

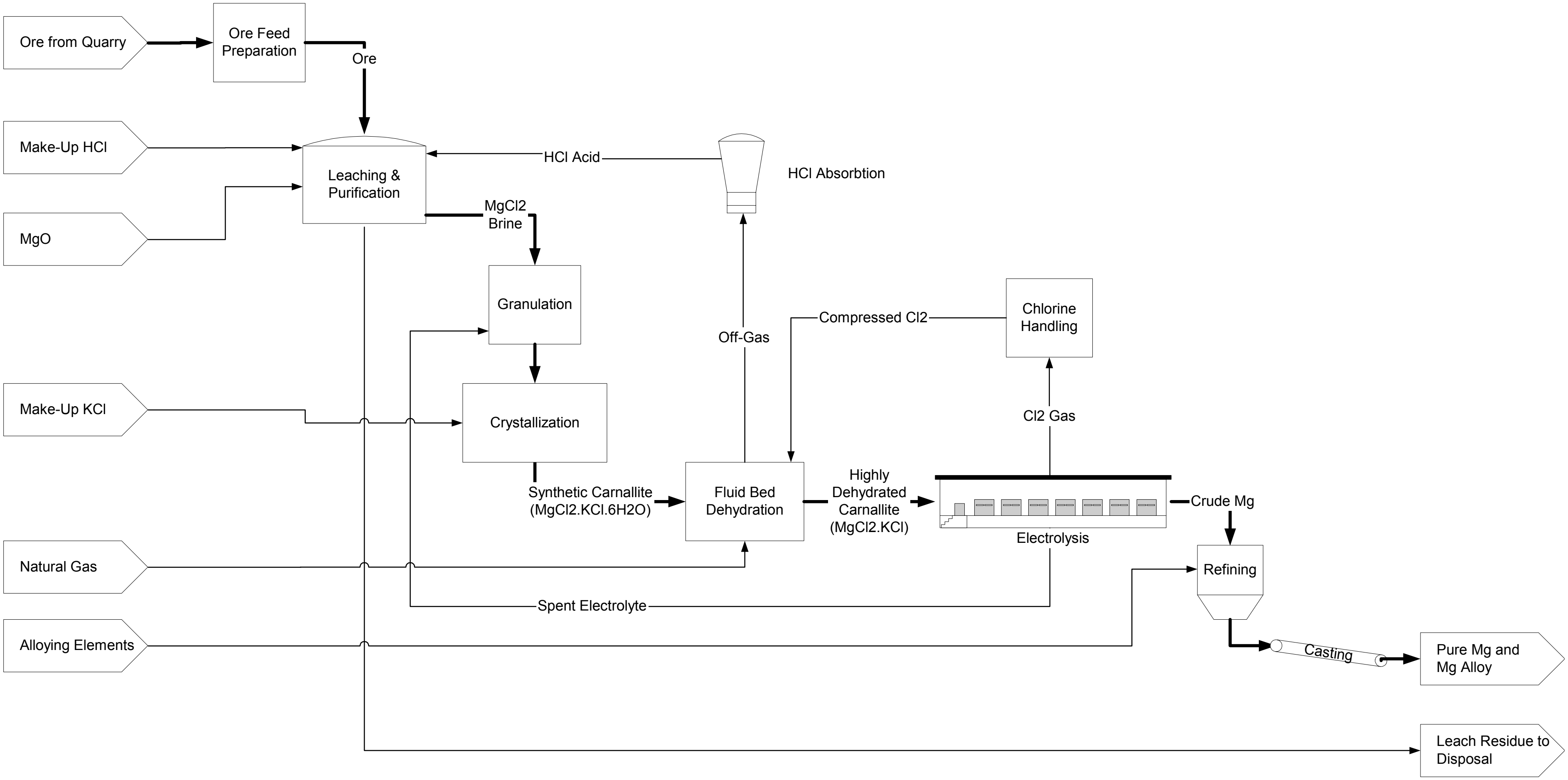

Figure 13. Cogburn Magnesium Production Plant – Simplified process flow diagram

The pyro-metallurgical section of the process begins with carnallite dehydration. Crystals of synthetic carnallite hexa-hydrate are dehydrated in fluidized bed dryers to produce highly dehydrated carnallite ($MgCl_2.KCl$) with typical MgO and H_2O contents of 0.3 and 0.2 weight percent respectively.

The dehydration process is summarized by the overall reaction (3): free moisture and crystalline water are removed by heating of the carnallite hexa-hydrate with HCl-rich burner off-gas produced by combustion of natural gas, electrolytic chlorine and steam. The HCl-gas is generated as represented in reaction (4).

$$MgCl_2.KCl.6H_2O \Rightarrow MgCl_2.KCl + 6H_2O \qquad (3)$$

$$CH_4 + 4Cl_2 + 2H_2O \Rightarrow CO_2 + 8HCl \qquad (4)$$

In the dehydration process, a portion of the $MgCl_2$ is hydrolysed and a minor amount of MgO (as MgOHCl) is produced as represented in reaction (5).

$$MgCl_2 + H_2O \Rightarrow MgOHCl + HCl\uparrow \qquad (5)$$

HCl from the fluidized bed dehydrator off-gas is recovered by absorption with water. The hydrochloric acid produced is then reused in the leaching area for the production of the $MgCl_2$ brine.

Solid highly dehydrated carnallite is used to feed the electrolytic cells. In the electrolytic cells, magnesium chloride is reduced by direct electric current (DC) to magnesium metal and chlorine gas as represented in reaction (6).

$$MgCl_2 \Rightarrow Mg + Cl_2\uparrow \qquad (6)$$

Magnesium metal is tapped from the separating cell and transferred to the casting area for refining, alloying and casting. Chlorine gas is filtered and recycled to fluidized bed dehydrators for the production of highly dehydrated carnallite.

The electrolytic cells are combined into a “Flow Through” system thus providing for tapping of Mg metal from a single point and maintaining the disruption of the cell process to a minimum. The design parameters given by STI/VAMI indicate that these cells will operate at a current of 300 kA with an average current efficiency of 79 percent.

Electrolytic magnesium metal is considered a “crude” product and requires additional refining to meet ASTM quality specifications. Refining of the crude Mg is achieved in continuous refining furnaces where non-metallic impurities (chlorides and oxides) are precipitated from the metal. The refined pure magnesium metal is cast into ingots. Magnesium ingots are stacked, strapped, wrapped and transferred to the product warehouse.

For the production of magnesium alloys, the electrolytic magnesium is transferred into alloying furnaces where it is mixed with alloying elements (Al, Zn, $MnCl_2$). The impure alloy is transferred to the alloy refining furnaces where it is refined by sedimentation of non-metallic impurities (chlorides and oxides). Excess iron is also removed by adjustment of the temperature of the melt. The refined Mg alloy is cast into ingots. Magnesium alloy ingots are stacked, strapped, wrapped and transferred to the product warehouse.

6.3 Plant Areas

The plant is divided into process areas:

- B - Feed Preparation: Ore is crushed and ground.
- C – Leaching and Purification: The ore is leached with hydrochloric acid (HCl) to extract magnesium as magnesium chloride brine. The solution is then neutralized to precipitate out impurities, filtered to remove the gangue material and impurities and passed through a final stage of purification via ion exchange to remove trace elements.
- D - Spent Electrolyte Granulation: Electrolyte is granulated and dissolved as part of the preparation for carnallite crystallization.
- E - Carnallite Crystallization: The $MgCl_2$ is converted to carnallite crystals.
- F - Carnallite Dehydration: The carnallite is dehydrated in fluid beds to produce dead-burnt carnallite.
- G - HCl Absorption: HCl gas is captured from the fluid bed dehydrators, converted to acid and recycled to leach.
- H - Electrolysis – Cells: Dead burnt carnallite is converted to magnesium via electrolysis.
- J - Electrolysis – Chlorine Handling: Chlorine produced during electrolysis is cleaned, compressed and sent to the fluid bed dehydrators.
- K - Magnesium Refining and Casting: The magnesium is alloyed, refined and cast.
- U - Utilities and Reagents.

Each plant area is schematically represented by one or more process flow diagrams (PFD's). The PFD's can be found in Binder #4.

6.4 Mass and Energy Balances

The plant mass and energy balance has been calculated with the METSIM simulation software. The basis for the calculation was 125,000 MTPY of crude electrolytic magnesium metal; this represents a nominal hourly production rate of 14.27 metric tons per hour of crude magnesium at 8760 h/year.

6.5 Technology Packages

6.5.1 STI/VAMI

STI/VAMI (Ukraine and Russia) has been selected as the principal technology suppliers for the following sectors:

- fluid bed dehydration of carnallite

- spent electrolyte granulation
- electrolysis
- magnesium refining

STI/VAMI has supplied Hatch with preliminary process know how, equipment specifications and drawings for the critical equipment designs and layouts.

The scope of supply of STI/VAMI includes the designs of the specialty equipment in the specified areas and does not include the equipment supply. The majority of the equipment within STI/VAMI scope would be fabricated off-site and shipped to site for final installation and refractory lining at site.

Scope of STI/VAMI does not include the following:

- civil or structural design
- transport systems between the different sectors (pneumatic, conveyors, etc.)
- automation and process controls
- casting equipment
- off-gas handling equipment

6.5.2 Messo-Chemietechnik

Messo-Chemietechnik (Germany) is a supplier of specialized carnallite crystallization equipment. They have previously constructed and entire carnallite crystallization plant. In addition they have performed testwork on the Cogburn Emory zone feed and on a number of similar projects worldwide. Based on this testwork they have been selected as a potential supplier of crystallization equipment. Their budgetary offer includes the engineering and construction of:

- spent electrolyte dissolution reactors
- carnallite crystallizers
- centrifuges
- miscellaneous pumps, filters, conveyors
- plumbing and wiring
- automation

The whole crystallization plant from $MgCl_2$ feed to carnallite product would be located in one building. The building structures are not included in Messo-Chemietechnik scope.

7. METALLURGICAL TESTWORK

7.1 Leach Testwork

As part of the feasibility study for the Cogburn Magnesium project, Hatch recommended to retain Process Research Ortech, Mississauga, Ontario, to perform leach testwork on the siliceous ore provided from Leader Mining International's Emory Zone deposit located in British Columbia, Canada.

The primary objectives of the testwork were to define the leach and purification flowsheet, and to generate sufficient process engineering data. The testwork programs carried out at Process Research Ortech have confirmed that the Cogburn ore can provide the feed to a magnesium process.

Both lab-scale batch testwork and pilot -scale continuous testwork were performed[7].

Batch testwork indicated that magnesium recoveries in the order of 80% are achievable (Figure 14) and that the brine produced during leaching can be partially purified via chlorination and neutralization.

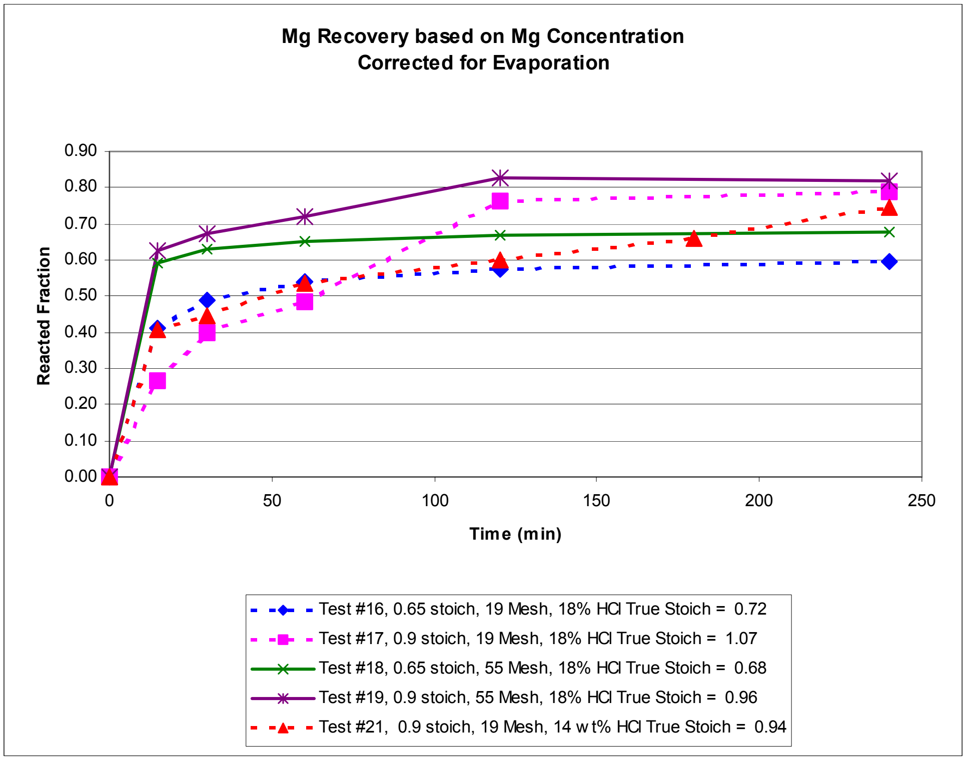

Figure 14. Batch test results showing the evolution of magnesium recovery with time. Under the correct conditions, a recovery of 80% or greater is readily achievable

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[7] Process Research Ortech Report, PRO-01-262: "Process Optimization for Magnesium Recovery Through Leaching and Solution Purification", George Puvvada, October 15, 2002.

The continuous test results provided the key engineering data for designing the leaching and neutralization circuits. These are:

- An acid stoichiometry of approximately 0.9.
- An acid concentration of approximately 18%.
- A three-tank co-current system, with a residence time of two hours per tank.
- A magnesium recovery of 80%[8].
- An ore size distribution below 20 meshes.
- An ion exchange unit for manganese and nickel.

Some optimizing testing under process conditions stated above will be done in the next phase of engineering to find the most cost effective leach process parameters. The key factors that require optimization are the following:

- Find the optimum acid stoichiometry to reduce MgO consumption
- Determine if the equipment for nickel and manganese removal can be eliminated
- Investigate the potential for ore beneficiation to reduce MgO and HCl consumption

7.2 Crystallization Testwork

As part of the feasibility study for the Cogburn Magnesium project, Hatch recommended to retain Messo-Chemietechnik Gmbh (Germany) to perform carnallite crystallization testwork on the brine produced at Process Research Ortech.

The primary objective of the testwork was to confirm that Messo's DTB turbulence crystallizers were capable of producing carnallite crystals to STI/VAMI chemical and size specifications. Production of carnallite is relatively well understood, and the concern here was the large crystal size required.

The testwork program carried out by Messo has confirmed that the brine produced from the Cogburn ore can provide the feed to the crystallization process and that the Messo DTB turbulence crystallizer is capable of producing crystals to STI/VAMI specifications[9].

Messo is the technology and equipment supplier of the carnallite crystallization section of the plant. The crystallization testwork and results alleviate the risks related to this section of the plant.

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[8] Note that recovery at Ortech was measured at 76% but this included losses at the filter. It is estimated that the losses are approximately 5% so the actual recovery in leach is 76/0.95 = 80%.

[9] Messo-Chemietechnik Gmbh, report No. M855/2002: "Crystallization of Carnallite", Christian Melches, November 26, 2002.

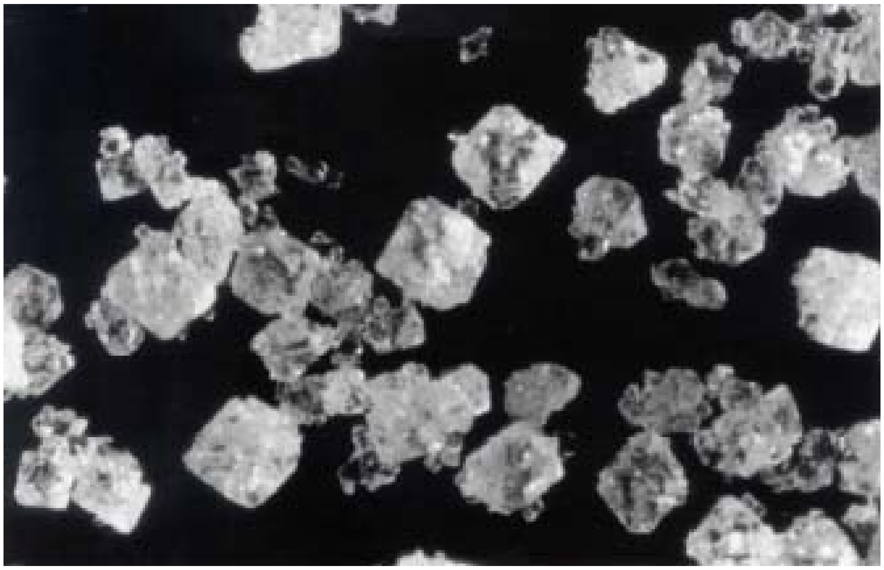


Figure 15. Carnallite crystals produced at Messo to STI/VAMI specifications (magnified, average size approximately 2 mm)

7.3 Dehydration and Electrolysis Testwork

These steps of the process have not been tested at this stage of the project. Since the crystals produce by Messo-Chemietechnik Gmbh (Germany) were in accordance to STI/VAMI specifications, the risk related to these parts of the plant is considered minimal.

In the next stage of the project, some testwork by STI/VAMI is recommended to obtain process guarantees and to allow for fine-tuning of STI/VAMI equipment designs.

7.4 Future Testwork

Although a significant amount of testwork has already been performed to date, there remains some testwork that must be done with regards to:

- process optimization
- production of material for characterization by suppliers
- obtaining process guarantees from technology suppliers

Only the leaching circuit requires significant process optimization work, as other sectors of the plant have already been built elsewhere and unlike the leach circuit, are not site specific.

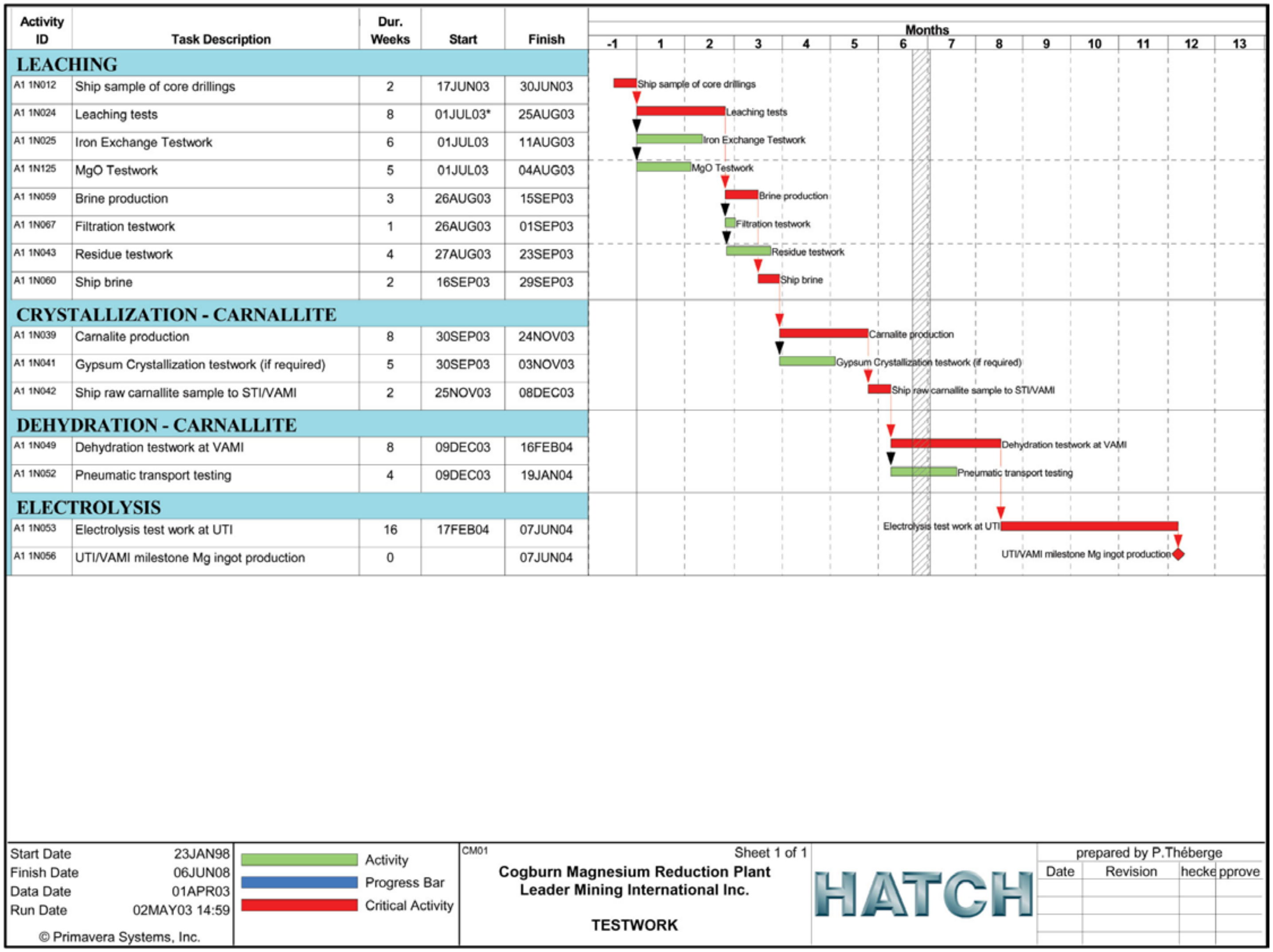
Significant economic savings can be obtained by the optimization of the leach circuit. This impacts the design of the leaching circuit but also heavily influences the size, capital and operating costs of the quarry, ore stockpile, and the residue management area. Inclusions/exclusion of certain unit operations such as ion exchange will also be determined during this testwork. Difference between suppliers of key reagents, namely MgO, will also be studied, with the objective of finding low cost alternatives.

Testing at suppliers is a key step in obtaining reliable engineering data. The following testwork is expected:

- Work index and other tests for sizing of the dry grind SAG mill.
- Filtration testwork to size belt filters.
- Ion exchange testwork to determine type and amount of ion exchange resin required (if necessary).
- Testing of leach residue for residue management area design.
- Pneumatic transport testing of both “wet” and “dead burnt” carnallite.

A large part of this testwork will be done in parallel with the pilot-scale production of brine and carnallite for STI-VAMI, whom in order to provide process guarantees, require approximately 30 kg of carnallite. This material will be used to test both the fluid bed dehydrators as well as the electrolytic cells. The purpose of this testwork is to determine the intricacies of the equipment design and operation, rather than to establish the overall equipment design.

The testwork schedule is given below in Figure 16.



Activity ID	Task Description	Dur. Weeks	Start	Finish
LEACHING				
A1 1N012	Ship sample of core drillings	2	17JUN03	30JUN03
A1 1N024	Leaching tests	8	01JUL03*	25AUG03
A1 1N025	Iron Exchange Testwork	6	01JUL03	11AUG03
A1 1N125	MgO Testwork	5	01JUL03	04AUG03
A1 1N059	Brine production	3	26AUG03	15SEP03
A1 1N067	Filtration testwork	1	26AUG03	01SEP03
A1 1N043	Residue testwork	4	27AUG03	23SEP03
A1 1N060	Ship brine	2	16SEP03	29SEP03
CRYSTALLIZATION - CARNALLITE				
A1 1N039	Carnalite production	8	30SEP03	24NOV03
A1 1N041	Gypsum Crystallization testwork (if required)	5	30SEP03	03NOV03
A1 1N042	Ship raw carnallite sample to STI/VAMI	2	25NOV03	08DEC03
DEHYDRATION - CARNALLITE				
A1 1N049	Dehydration testwork at VAMI	8	09DEC03	16FEB04
A1 1N052	Pneumatic transport testing	4	09DEC03	19JAN04
ELECTROLYSIS				
A1 1N053	Electrolysis test work at UTI	16	17FEB04	07JUN04
A1 1N056	UTI/VAMI milestone Mg ingot production	0		07JUN04

Start Date	23JAN98
Finish Date	06JUN08
Data Date	01APR03
Run Date	02MAY03 14:59

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🟩 Activity
🟦 Progress Bar
🟥 Critical Activity

CM01 Sheet 1 of 1

Cogburn Magnesium Reduction Plant
Leader Mining International Inc.

TESTWORK

HATCH

prepared by P.Théberge

Date	Revision	hecke	pprove

Figure 16. Future testwork schedule

8. SITE & PLANT DESCRIPTION

8.1 Site

Two possible sites have been considered for the Cogburn Magnesium Plant, West Ruby (Upper) Site and the East Ruby (Lower) Site. Site selection has been performed by Merit Consultants International[10]. The West Ruby Site has been selected as the preferred site and the following plant layouts were based on the use of this site

The proposed reduction plant site is located on a plateau approximately 2.1 to 3.2 km northwest of the Fraser River, between Mahood Creek and Ruby Creek. The site is an irregular shaped area of approximately 90 hectares, measuring about 800 to 1200 m, from north to south, and between 600 to 1100 m from east to west. The surface is somewhat undulating, but generally slopes gently from north to south. Elevations range between approximately 200 m in the southwest and about 270 m in the north.

8.2 Plant Layout

8.2.1 Site Constraints

The plan view of the plant layout is given in Figure 17. The isometric view in Figure 18.

The proposed site has constraints that were considered when developing the general plant layout:

- North: The north side of the site is limited by steep upward slope of the mountains.
- East: The Ruby Creek is located on the east side of the site and, separates the proposed plant site location from the proposed haul road to the quarry.
- South: The south side of the site is limited by a steep downward slope.
- West: To the west side, the plant site is limited by the wetlands.

Due to the sloping nature of the site, large amount of cut and fill are required, which became a major determinant in the location of the process buildings. The elevation of the different tiers was adjusted in order to equalize the amount of cut and fill.

Since the site is on a terrace in a mountainous and rocky environment, there is minimal risk for the site preparation costs.

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[10] Merit Consultants International: “Coburn Magnesium Project - Site Selection”, J. Collins, January 2003.

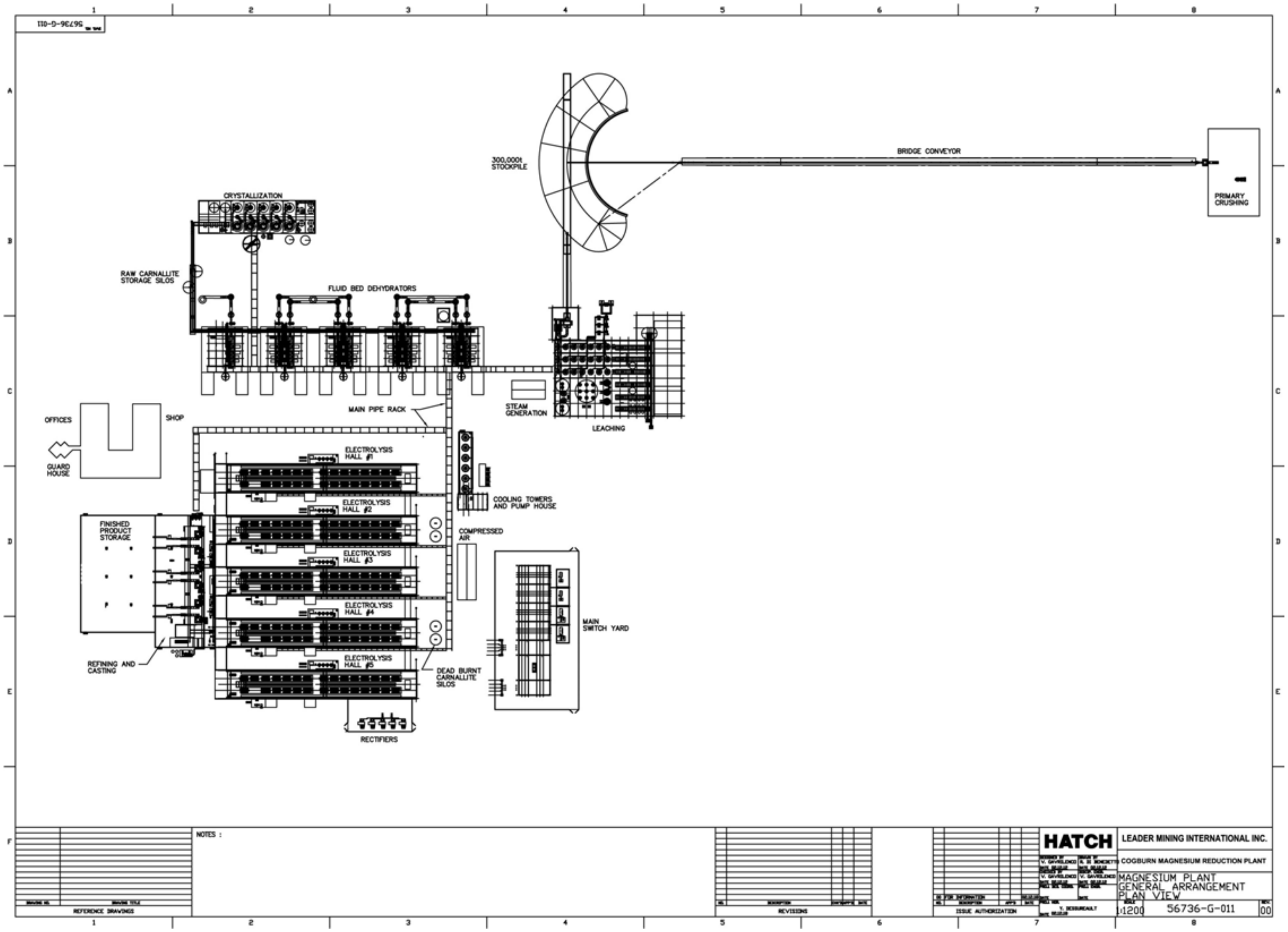

Figure 17. Plant layout – plan view

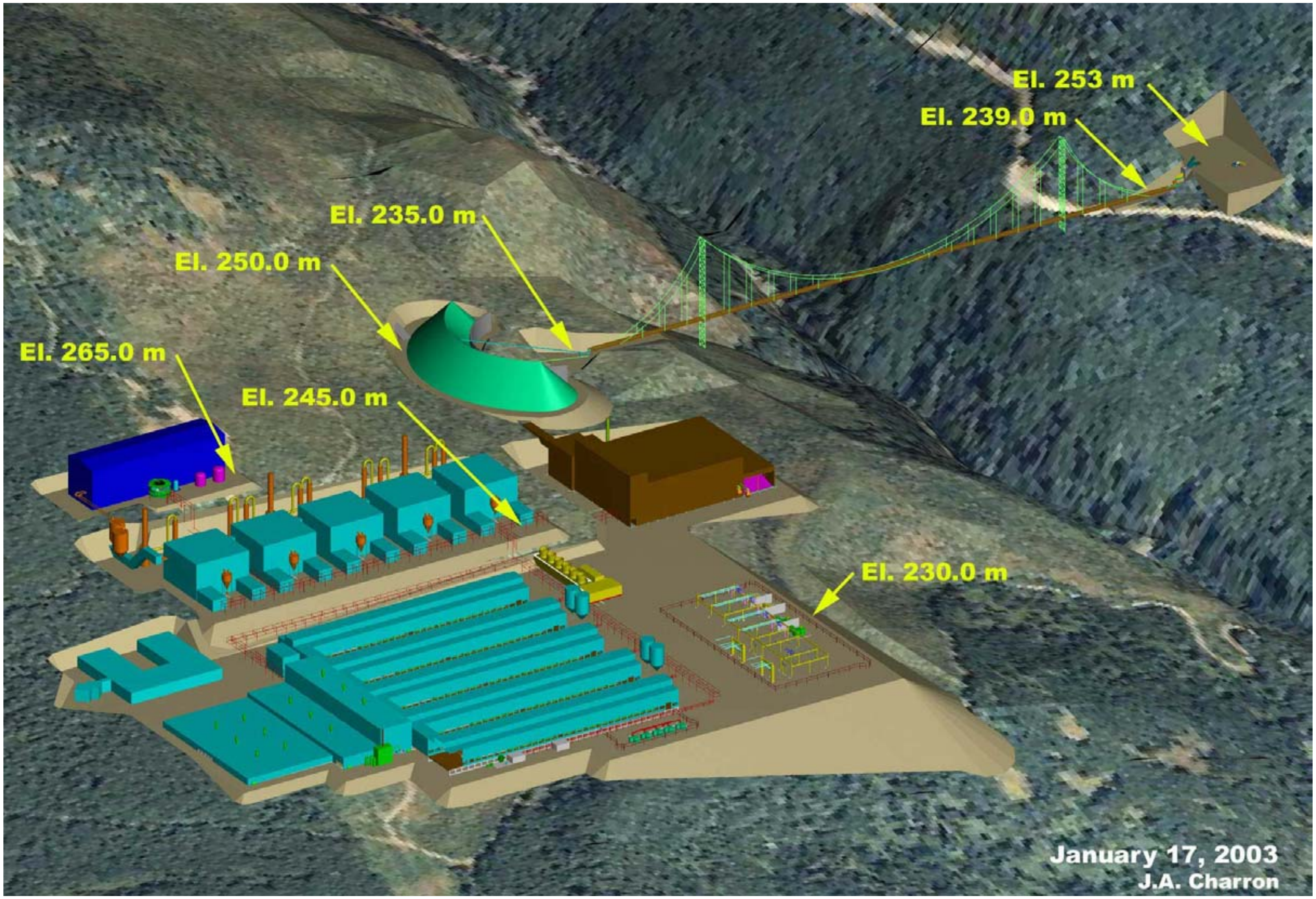

Figure 18. Plant layout – Isometric view with elevations

8.2.2 Process Buildings

The primary crusher is located on the east side of Ruby Creek. Provisions are made for a small ore storage area.

The crushed ore is transferred to the plant site side of the Creek by a belt conveyor, supported by an enclosed suspended conveyor structure. At the end of the conveyor, the ore is stored in a 6 month stockpile.

The SAG mill is fed from the stockpile. It is located between the stockpile and next to the leach building.

In the leach building the ore is leached to produce magnesium rich brine.

The leach brine is pumped to granulation, which is located next to the cell halls. The brine is mixed with spent electrolyte in the granulators and the resulting slurry is pumped to crystallization.

In the crystallization building the slurry is crystallized to form carnallite crystals. The raw carnallite crystals are sent to dehydration via conveyor.

The fluid bed dehydrators remove the water from the carnallite to produce what is called dead-burnt carnallite. The dead-burnt carnallite is stored in silos then pneumatically transported to the cell halls.

There are five cell halls located one next to the other. Space for mobile equipment access and natural ventilation is located between each cell hall.

All cell halls feed a common transport hall, which is located at the west side of the cellhalls and connects the foundry to the cellhalls. The transport hall allows the vacuum ladle trucks to transport the molten magnesium from the cellhalls to the foundry. All five-cell halls and the foundry are located on the same tier.

The warehouse is located at the end of the foundry such that ingots that are produced by the casting machines can be directly transported to the warehouse in preparation for shipping.

8.2.3 Utilities and Miscellaneous

All links between different process buildings are done on pipe racks (with the exception of conveyors).

Residue from leaching is temporarily stored in a hanger at the east end of the leach building. Mobile equipment is then used to transport the residue to a residue management area located in one of the small valleys neighbouring the plant.

The electrolysis and foundry are the two major power consumers; therefore the main switchyard is located near electrolysis buildings.

In order to minimize piping costs, all utility buildings (compressor station, cooling towers, water pump station and steam generation) are located close to the main pipe rack.

The gas and fumes treatment equipment is located as close as possible to the source. Each area requiring gas treatment has its own scrubbers and connected equipment.

Finally plant design and layout is modular, allowing the plant to start-up progressively without interfering with operations.

9. CAPITAL COSTS

9.1 Scope of Estimate

The capital cost estimate (CAPEX) consists of three main parts: direct costs, indirect costs and provisions as described below:

- **Direct costs:** Cost of all equipment and material supply and construction and installation costs for all permanent facilities. The direct costs will include the costs associated with the following:
  - Procurement of all equipment
  - Procurement/fabrication/installation of bulk materials
  - Site preparation works to facilitate new installations
  - Installation labour and supplementary resource requirements for equipment and bulk material installation on site
  - New buildings, structures and associated services
  - Completion of construction of structures and buildings
- **Indirect costs:** Cost of temporary construction facilities and services, construction equipment, freight, insurance and engineering/procurement/construction management services. The Indirect costs are as follows:
  - Construction Facilities: The costs associated with construction facilities are the temporary buildings such as site offices, warehouse, and laydown areas. Included with this cost build-up are the installation costs for the facilities, the outfitting cost for the facilities (furniture, etc), as well as the costs for operations and maintenance (water, power, sewage, cleanup, etc).
  - Construction Support: Includes the costs associated with construction equipment and fuels, small tools and consumables, scaffolding, testing and inspection services.
  - Freight
  - Insurance
  - Vendor’s Representatives
  - Engineering Procurement and Construction Management (EPCM) services
  - Commissioning

- **Provisions**
  - Taxes and Import Duties
  - Contingency: A cost allowance, generally expressed as a percentage on the sum of the direct and indirect costs, to cover necessary work within the defined scope of the project that cannot be identified or itemized at this stage of the project development.

The detailed capital costs are given in binder #4 and the summary is given below. They are based on the nameplate capacity of the plant, i.e. a production of 125,000 tpa of pure Mg and 131,000 tpa of saleable product.

9.2 Primary Summary

The primary summary of the current Capex estimate in terms of Defined and Undefined scope valued is summarized as follows. All Capex are reported in US dollars.

Table 18. Primary summary of the Capex estimate

Defined		**US$m Feb 2003**
	Direct	800
	Indirect	234
	Subtotal	1,034
Undefined	Provisions	202
	Total CAPEX Estimate	**1,237**
Production Capacity Unit Cost		
Based on target output	*(131,000 tpa)*	*9,440 /t*

9.3 Defined Summary by Discipline

The Defined scope of the current Capex estimate in terms of disciplines is summarized as follows:

Table 19. Discipline breakdown of the Capex estimate

		US$'000 Feb 2003
Direct Expenses		
	Multi-Discipline	3,314
	Civil Work	21,881
	Concrete Work	73,932
	Structural Steel Work	67,190
	Architectural	36,806
	Mechanical	357,654
	Piping	47,430
	Electrical	100,531
	Control & Instrumentation	91,511
	Distributable / Pro-Rate	-
	Subtotal	800,248
Indirect Expenses		
	Project Expenses	56,142
	EPCM	94,057
	Contractors Expenses	25,611
	Owners Expenses	58,189
	Subtotal	233,998
	Subtotal Defined	**1,034,247**

9.4 Direct Summary by Area

The Direct part of the current Capex estimate in terms of the different process area is summarized as follows:

Table 20. Breakdown by major process areas of the Capex estimate

		US$'000 Feb 2003
A	MINE	2,841,847
B	FEED PREPARATION	30,685,135
C	LEACHING	68,475,159
D	SPENT ELECTROLYTE GRANULATION (SEG)	8,791,712
E	CARNALLITE CRYSTALLISATION	70,707,150
F	CARNALLITE DEHYDRATION	100,699,424
G	HCL ABSORPTION	27,030,695
H	ELECTROLYSIS - CELLS	313,156,681
J	ELECTROLYSIS - CHLORINE HANDLING	11,693,655
K	REFINING AND CASTING	28,625,589
L	PRODUCTS STORAGE AND HANDLING	5,590,363
M	WASTE MANAGEMENT	3,149,387
S	SITE PREPARATION	5,173,827
T	(NON-PROCESS) FACILITIES	9,797,756
U	PIPING UTILITIES	30,555,836
V	ELECTRICAL & INSTRUMENTATION UTILITIES	96,074,267
	Subtotal	813,048,485
	Includes BC Hydro costs	12,800,000
	Total	**800,248,485**

9.4.1 Labour

The development of the trade or craft labour crew rates used in the capital cost estimate are derived from the data obtained from local construction companies. The basis for the unit rate is open shop and no allowances are included for LOA, etc. in terms of production labour. It was presumed that BC Labour is equivalent to southeast US in terms of productivity.

9.4.2 Battery Limits

The capital estimate includes all the cost related to the physical plant boundaries and for the services and infrastructure required for the plant, such as water, electricity, natural gas, roads, etc.

9.4.3 Contingency

A complete risk analysis was performed based on the precision level of the engineering and costing activities. The contingency was computed based on the risk analysis exercise and is equivalent to 19.6% of the direct and indirect costs.

9.4.4 Capex Accuracy

The accuracy of the capital cost estimate is directly related to the level of detail of the project documents used as the basis of estimate. Accuracy depends on the technological complexity of the project, appropriate quantities and cost and the inclusion of an appropriate contingency determination. The estimate classification applicable to this estimate, based on the deliverables as defined in table 4 classifies this estimate as class 4 (AACE). This represents an accuracy of +25% / -15%.

10. OPERATING COSTS

The cash operating costs were evaluated based on the following inputs:

- Mass balance for consumption of raw materials and reagents
- Vendor Quotes for all the important raw material and reagents costs
- Energy consumption numbers (natural gas and electricity) provided by STI/VAMI, Messo-Chemietechnik Gmbh (Germany) and other equipment vendors
- Preliminary evaluation of overall connected electrical load for remaining electrical requirements.
- Preliminary plant manpower loading for labour requirements
- Average British Columbia mining income for the manpower
- Detailed material requirements for the electrolysis cells and fluid bed dehydrator rebuilt costs
- Allowance for indirect costs and for maintenance supplies (based on other similar metallurgical facilities)

The detailed operating costs are given in binder #4 and the summary is given in Table 21. They are based on the nameplate capacity of the plant, i.e. a production of 125,000 tpa of electrolytic Mg and 131,000 tpa of saleable product consisting of:

- 31,000 mtpa primary Mg
- 50,000 mtpa AZ91D alloy (ASTM standard)
- 50,000 mtpa AM60B (ASTM standard)

The operating costs are assumed to be precise to within 10%.

Table 21. Summary sheet of all operating costs

Description	Unit	Consumption	Unit Price	Annual Cost	Cost per Mg Unit Mass		Comment
		unit/year	US$/unit	US$/year	US$/kg	US$/lb.	
Direct Expenditure							
Plant Operations							
Ore	mt	508,000	$10.55	$5,360,737	$0.041	$0.019	Ore Delivery to Site by EAC
Residue Management	dry mt	380,000	$2.30	$872,500	$0.007	$0.003	On-Site residue management by EAC
CHC Incineration	mt	105	$5,263	$553,263	$0.004	$0.002	Swan Hill Incineration
Reagents	mt	128,213		$24,854,000	$0.190	$0.086	Includes transportation to site
Operating Supplies				$10,959,542	$0.084	$0.038	
Alloying	mt	9,255		$16,392,000	$0.125	$0.057	For alloying elements
Manpower	ManYr	223	$44,659	$9,958,855	$0.076	$0.034	Excludes rebuild
Sub-Total Plant Operations				***$68,950,897***	***$0.53***	***$0.24***	
Utilities							
Electrical Power	kWh	2,180,315,000	$0.0213	$46,404,118	$0.354	$0.161	Price as per Intuit Strategies
Natural Gas	m3	203,101,000	$0.160	$32,496,160	$0.248	$0.113	Price as per Intuit Strategies
Process Water	m3	36,792,000	$0.040	$1,471,680	$0.011	$0.005	Hatch Data
Cooling Water	m3	22,075,200	$0.020	$441,504	$0.003	$0.002	Hatch Data
Make-Up Water	m3	4,380,000	$0.100	$438,000	$0.003	$0.002	Hatch Data
Sub-Total Utilities				***$81,251,462***	***$0.62***	***$0.28***	
Maintenance							
Maintenance Materials & Supplies	of mech. Eqp	5.00%	$250,000,000	$12,500,000	$0.10	$0.04	
Rebuild Material	mt	5,576		$16,605,964	$0.13	$0.06	For cells, furnaces, fluid beds
Manpower	ManYr	206	$55,372	$11,406,730	$0.09	$0.04	Includes rebuild
Sub-Total Maintenance				***$40,512,695***	***$0.31***	***$0.14***	
Sub-Total Direct Expenditure				***$190,715,054***	***$1.46***	***$0.66***	
Indirect Expenditure							
Indirects							
Insurance & Taxes	of capital cost	0.50%	$1,200,000,000	$6,000,000	$0.05	$0.02	
Research & Development	of sales	0.50%	$395,551,880	$1,977,759	$0.02	$0.01	
Manpower (Staff)	ManYr	65	$53,683	$3,489,408	$0.03	$0.01	
General Expenses	of staff	20.0%	$3,489,408	$697,882	$0.01	$0.00	
Sub-Total Indirects				***$12,165,049***	***$0.09***	***$0.04***	
TOTAL				***$202,880,103***	***$1.55***	***$0.703***	

11. ENVIRONMENTAL CONSIDERATIONS

11.1 Environmental Objectives

The global environmental philosophy of the project is to build and operate the facility with the utmost environmental diligence possible, in accordance with the principles of clean plant design and sustainable development.

The preliminary engineering of the plant design was performed with the following objectives:

- to build and operate the plant so as to comply with provincial and national, and where appropriate, international, regulatory standards;
- to treat all gaseous effluents via dust collecting / scrubber systems in order to minimize gaseous emissions;
- have zero liquid effluent, all liquid process effluents are recycled in the plant, all liquids discharged from the residue management area are sent back to the plant, the plant area will have 110% spill protection;
- to minimize the volume of solid wastes, to manage solid wastes in a sound and environmentally responsible manner;
- eliminate as far as possible the discharge of polyaromatic and chlorinated hydrocarbons via installation of CHC removal systems which capture the CHC's for off-site treatment;
- to provide a safe and healthy working environment for the plant personnel.

11.2 Environmental Baseline Conditions

Environmental baseline studies incorporating new and existing data have been performed in support of this project in the vicinity of the proposed quarry, road and plant site facilities by Lorax[11]. Specifically, the report includes assessments of land use, soils, air quality, climate, acid rock drainage and metal leaching, hydrology, water quality and fisheries. Collectively, these data are designed to provide the framework upon which impacts and mitigation strategies can be based.

11.2.1 Drainage Chemistry

The acid rock drainage and metal leaching potential from the Cogburn Emory Zone has been assessed through the evaluation of a number of solid-phase analytical methods. The zone contains ultramafic rocks composed primarily of olivine that has often been altered by either serpentinization and/or carbonitization. This style of alteration typically appears to contribute in excess of 300 kg$CaCO_3$/t to the measured Sobek NP. NPR values calculated from the Sobek NP and TAP range from 5.5 to 697, with a median value of 34.5. Comparing this range of values to the regulatory criteria suggests that there is "no" ARD potential from the Emory Zone materials.

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[11] Lorax: "Cogburn Magnesium Project – Baseline Environmental Conditions" , February 2003.

Drainage chemistry from the Emory Zone is relatively benign, with the exception of minor enrichments in Al, Fe and Ni. The loadings of these metals, however, have an immeasurable impact to water quality in Talc Creek due largely to the dilution capacity offered both by surface water runoff and Talc Creek. Accordingly, the overall impact of the quarry on Talc Creek is predicted to be negligible.

11.2.2 Surface Waters

Because the reduction plant and associated facilities are to be operated on a zero-discharge basis, the sole impact to surface waters will arise in the vicinity of the quarry site.

Baseline surface water quality was measured at several sites in the vicinity of the quarry and at the plant site. Surface drainages in the Cogburn study area are characterized by soft waters, with relatively low-values for conductivity and hardness and moderate to low alkalinity. Total suspended solids are low at all sites even under conditions of high flow, reflecting the relatively small catchments.

Nutrient (ammonium, nitrate and phosphate) levels were generally low, particularly in Talc Creek.

Baseline trace metal concentrations in the Cogburn study area are consistent with trace metal values observed in minimally perturbed areas.

Therefore, the impact on the surface waters is considered to be negligible.

11.2.3 Fisheries

A reconnaissance survey of the fisheries of the Cogburn magnesium project area was conducted during the summer of 2002. The purpose of this study was to identify fish populations and habitat that could be affected by the various components of the project, including road construction, quarrying, trucking, and plant construction and operation. The survey was carried out through a review of existing information and by direct sampling of habitats that would most likely be affected by the project. The streams included in the survey were Talc Creek and tributaries to Talc Creek, Garnet Creek, American Creek (a tributary to Garnet Creek), and a small unnamed tributary to Mahood Creek.

Talc Creek is the receiving stream for runoff from the proposed magnesium quarry. Tributaries to Talc Creek in the upper part of the watershed will be crossed by haul trucks, as will Garnet Creek and its tributaries. The magnesium reduction plant will be located in the Mahood Creek watershed.

A review of existing information revealed the following information:

- ➤ Talc Creek supports dolly varden (*Salvelinus malma)*, rainbow trout, and steelhead populations (*Oncorhynchus mykiss*);
- ➤ fish populations have not been conclusively identified in Garnet Creek, although anecdotal information suggests that this stream may support dolly varden; and

- Mahood Creek supports chum (*Oncorhynchus keta)*, coho (*Oncorhynchus kisutch)*, sockeye (*Oncorhynchus nerka)*, and pink salmon (*Oncorhynchus gorbuscha)*, as well as cutthroat trout (*Oncorhynchus clarki*) and carp (*Cyprinus* sp.).

Field studies were conducted twice in July, 2002. Dolly varden was captured in Talc Creek. Coho salmon fry and rainbow trout were sampled in a small unnamed tributary to Mahood Creek, downstream of the proposed magnesium reduction plant. No fish were caught in American Creek, or in a small upper watershed tributary to Talc Creek. Garnet Creek was not directly sampled due to hazardous sampling conditions.

With the appropriate control actions (erosion control measures including runoff diversion, sediment ponds, appropriate road ditching and the installation of adequately sized culverts and/or bridges along haul roads) the impact will be minimized. Moreover, the plant footprint has been aligned to provide for protection of the stream that is a small tributary to Mahood Creek and that supports coho salmon fry,

11.3 Wildlife Impact

Keystone Wildlife Research was asked to prepare an assessment of the potential impacts of the project upon wildlife and ecosystems present in the area[12]. In order to establish the quantity and quality of wildlife habitats present, Terrestrial Ecosystem Mapping (TEM) was carried out within the project area. The TEM mapping provided a basis for the assessment of wildlife habitat both within the proposed footprint areas as well as adjacent to the footprint areas.

Provincial conservation lists were used to prepare a list of rare plant species, plant communities and wildlife species possibly present in the Cogburn project area. Analysis of the ecosystem mapping was used to assess the likely quality and extent of habitat in the study area for each species under consideration. Species potentially occurring in the study area, and for which specific habitat requirements were known, were chosen for more detailed evaluation (priority species). Preliminary ratings tables (as per RIC 1999) were produced for black-tailed deer, grizzly bear, mountain goat, tailed frog, marten, Northern Goshawk and Northern Spotted Owl. The preliminary ratings tables and ecosystem map data were used to create species themes, which were then overlain to make a resource value map that identifies the quality and quantity of habitat present in the study area for the priority species.

Habitat within the proposed footprint areas was generally rated low to nil suitability for wildlife species on the priority species list. The general wildlife habitat values were highest in the open wetlands in proximity to the selected site. Special attention was taken to put the reduction plant as far as possible from the wetlands in order to protect this habitat.

The Conservation Data Centre was asked for recorded occurrences of rare wildlife and plant species within the study area, but none were on record. The proposed footprint overlaps the Sasquatch Special Resource Management Zone for the Northern Spotted Owl, although the footprint area provides only low suitability owl nesting habitat. Small amounts of moderately high and moderate suitability habitat for the owl are also present within the proposed quarry footprint. Although no high-quality mountain goat habitat was mapped within the proposed footprint areas, known summer and winter ranges for goats are present near the study area,

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[12] Keystone Wildlife Research: “Cogburn Magnesium Project - Wildlife Impact Assessment Report”, February 2003.

and goats undergoing seasonal migrations may move through the study area twice a year during spring and fall.

A simple point count bird survey was completed in June 2002, using point count transects laid out over the two proposed plant site footprints. No red or blue-listed bird species were detected. Bird species abundance and diversity was highest in the wetland habitats.

The proposed Coburn project is not expected to have impacts on wildlife at the provincial or regional scale. Increased traffic on the road from the proposed quarry may affect seasonal migration of local mountain goat herds; however, the number of animals potentially affected is small and disturbance effects will be limited to a short period of several days to a week, twice a year.

11.4 Environmental Aspects of the Process

11.4.1 Process Inputs

11.4.1.1 Water

The operation of the plant will require a steady reliable source of water. Particular care has been taken in order not to require pumping directly from the Fraser River. Water will be drawn from wells located to the south of the plant and near the Fraser River. By this means there will be no interference with fish bearing water and no impact on the waterways.

The plant will be a net consumer of water. Based on preliminary calculations and previous experience with similar projects, the water consumption of the plant will be approximately 500 m^3/h.

The plant has been designed to minimize water consumption. The following philosophy has been applied in order to meet this objective:

- Waste water streams will be recycled;
- Solid residues will have minimal water content;
- Water collected from the plant site and residue disposal area will be sent back to the plant.

11.4.1.2 Ore

The plant's ore consumption will be approximately 510,000 tpa. The ore will be quarried 6 months per year. A 6 month stockpile will assure plant operation during the winter season.

Runoff water from the primary and secondary stockpiles will be captured and returned to the process.

11.4.2 Emission Sources

11.4.2.1 Atmospheric Emissions

The plant was designed so that all process off-gases and vapours from process vessels are ducted to dust handling / scrubbing systems. This allows for the treatment of all off-gases such that environmental standard are met or surpassed.

11.4.2.2 Effluents

The plant will be designed to recirculate wastewater to the greatest degree possible, and thus should have virtually zero liquid effluent. The plant is a net consumer of water and almost all water leaving the plant will be from evaporation.

Solid residues produced from leaching are expected to have approximately 15% moisture. Water collected from the residue management area will be returned to the process.

11.4.2.3 Solid Wastes

The major source of solid wastes will be from the leaching and purification of the magnesium chloride brine. These wastes will consist predominantly of:

- un-leached ore ($2MgO*SiO_2$, $3MgO*2SiO_2*2H_2O$), silica (SiO2) and iron hydroxide $Fe(OH)_{3;}$
- granulation residue;
- dust from vent ducts (cleaned and neutralized);
- water treatment sludge.

These wastes are non-hazardous and can be disposed of according to industry practice. It is expected that these will be sent to the residue management area using scrappers.

The electrolysis and furnace sludges generated at the plant will also be disposed of in the residue management area.

Equipment rebuilt produce several wastes including spent refractory, scrap metals and spent graphite. Metals and graphite can be sold for processing. Spent refractory can be disposed of on site in the residue management area.

In total, the plant is expected to produce 380,000 tpa of solid waste (dry basis).

11.4.2.4 Residue Management Area

The residue management conceptual design has been performed by Knight-Piesold Consulting[13].

The residue management area will be designed as a fully lined facility, isolated from contact with existing surface or ground water. To the greatest extent possible, clean runoff from surrounding catchments will be diverted away from the facility. There will be zero water released from the facility. All water collected in the facility from runoff, rainfall or snowmelt will be directed to a water collection pond and pumped back to the process.

The residue will be hauled to the residue management area, placed in layers and compacted into place by earth-moving machinery. This will maximize the insitu density and thereby keep the volume of the storage facility at a minimum.

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[13] Knight Piesold Ltd, Ref No VA101-00023/1-1: “Cogburn Magnesium Project – Residue Management Area Conceptual Design Plan”, H. Dew, July 24, 2002.

11.4.3 CHC Emissions

Experience from Magnola magnesium plant in Asbestos, Quebec, as well as other magnesium projects around the world, indicates that the production of chlorinated hydrocarbon (CHC's) is among the primary environmental concerns associated with the construction of new magnesium production facilities.

Chlorinated hydrocarbons are a family of organic compounds, which contain chlorine atoms. They include chlorophenols, chlorobenzenes, chlorobiphenyls, polychlorinated biphenyls (PCB's), dioxins and furans. There exist several hundred variations of the above mentioned chlorinated hydrocarbons. Of particular concern are dioxins and furans, which, although they usually only occur at trace levels, are considered harmful to the environment and to human health at extremely low concentrations due to their toxicity, stability and persistence in the food chain.

In the present project, CHC's can potentially be formed during electrolytic reduction process due to the reaction of carbon (present in the anodes) with chlorine. The CHC's leave the electrolysis cell with the chlorine gas. The chlorine gas is burned with natural gas in the fluid bed dehydrator burners. The high temperature found in the burners destroys a large fraction of the CHC's. The fluid bed dehydrator off-gas is then used to produce hydrochloric acid (HCl) in the absorbers. In this last production stage the remaining CHC's are transferred to the HCl acid.

Every effort has been made in order to maximize the removal of CHC's. The Cogburn Magnesium Project has two CHC removal systems, both are based on activated carbon removal of CHC's in liquid effluents. The activated carbon absorbs the CHC's. The activated carbon is then sent off-site for high temperature incineration. Normally CHC treatment would occur at the Swan Hill, Albert, incineration facility.

A preliminary estimate indicated that a total of 105 tonnes of activated carbon per year would be produced and would require incineration.

These environmental measures will allow to virtually eliminating the CHC discharge.

It is expected that the plant will have to conform to similar CHC regulations to those applied to other Canadian magnesium projects, namely Norsk Hydro and Magnola.

It should be noted that due to process differences, namely the absence of chlorinators, it is expected that the STI/VAMI technology will produce less CHC's than produced at Magnola.

11.5 Environmental Approvals and Permitting

Project assessment and permitting details have been support by Marlow Mining Engineering Services[14].

11.5.1 Project Assessment

The environmental assessment process for the Cogburn Magnesium Project is subject to and steered by applicable legislation set out primarily under the British Columbia Environmental

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[14] Marlow Engineering Services: "Cogburn Magnesium Project – Environmental Assessment and Approvals Summary", April 2003.

Assessment Act (S.B.C. 2002, c. 43) (" the BCEAA"). The BCEAA requires that major project proposals obtain an *environmental assessment certificate* before permitting can be finalized and project construction can begin.

The current legislation came into effect on December 30, 2002, replacing the previous Environmental Assessment Act (R.S.B.C. 1996, c. 119), which had been in effect since June 30, 1995. This "streamlining" of the BCEAA stems from recent political initiatives and government policy to revitalize the provincial economy by encouraging more flexible, efficient and timely assessments of project proposals.

The BCEAA ensures that proposed projects undergo a comprehensive, integrated, coordinated and timely assessment. The legislation and accompanying regulations establish the framework for delivering environmental assessments. However, the scope, procedures and methods of each assessment are flexible and tailored specifically to the circumstances of the proposed project. This allows for each assessment to focus on the issues relevant to whether or not that project should proceed.

In recognition and anticipation of entering into the formalized project assessment process, Leader Mining International Inc. has initiated and continues to pursue an information dissemination and consultation process with the public, and has commissioned technical and environmental studies. These initiatives are designed to:

- establish the technical and economic feasibility of the Project;
- establish an environmental baseline for the Project;
- provide expert assessment of perceived and potential environmental impacts;
- investigate issues surrounding key aspects of the assessment process, namely, the community and public interest, and the interests of First Nations, and,
- apprise stakeholders and other interested parties at the local, regional, provincial, national and international levels.

The results of these initiatives have been documented and are included in the Binders of this Production Feasibility Study.

The general framework for a typical environmental assessment is based on eight key steps, as follows:

- Determining if the Environmental Assessment Act applies;
- Determining the review path;
- Determining how the assessment will be conducted (scope and procedures);
- Developing and approving terms of reference for the application for an environmental assessment certificate;
- Preparing and submitting the application;

- Reviewing the application;
- Preparing the assessment report and referring the application to ministers;
- Deciding to issue/not issue an environmental assessment certificate

It is anticipated that Leader will initiate the formal approvals process in mid -2003 with the provincial EAO once surface land tenure issues at the upper plant site has been clarified and acquired, and once key economic determinants, such as long term energy costs and product marketing strategies, are established. Prescribed time limits regulations as they apply to reviewable projects in BC will be in force and will assist in ensuring timely approvals milestones are achieved with a minimum of impact on project feasibility.

The federally regulated approvals process under the Canadian Environmental Assessment Act is initially scoped and coordinated jointly through the provincial EAO. Early approval is in principle quite feasible, since requirements for federal review under the Explosives Act, the Navigable Water Act and the Fisheries Act are not likely to be triggered.

It is anticipated that definition of Terms of Reference will be expedient due to the extensive amount of environmental background and scoping work that has recently been completed. The public consultation and involvement process is continuing, presently focusing on dissemination of information to First Nations and other communities in the Fraser Valley.

11.5.2 Project Permitting

Following EAO certification, Leader will apply for various licenses, permits and other forms of statutory approval necessary to construct and operate the Emory Quarry at Talc Creek, the plant site itself at lower Ruby Creek, and the residue management facility adjacent to the plant.

The provincial permitting and approvals legislation that will apply to the Project will include the:

- Mines Act;
- Forest Act;
- Waste Management Act;
- Water Act, and,
- Land Act.

The permitting of the relatively low tonnage mining operation at the Emory Zone Quarry is expected to be routine under the Mines Act. At this location the permitting process will primarily focus on mitigation of impacts from the upgrade, operation and ultimate closure of the Garnet Creek mine access / hauling road linking the Quarry site to the plant, and on water management planning at the Quarry. Environmental studies to date have not identified significant permitting issues for this project component.

The permitting of the plant site may require more detailed environmental review than those needed for certification, and may take up to several months to prepare. These are expected to focus primarily on demonstrating that point and fugitive atmospheric emissions of plant by-products such as particulates, trace CHC's, NOx, $Cl_{2,}$ H_2, $SO_{2,}$ and HCl, can be mitigated sufficiently in order that consistent air quality standards over the life of the plant with respect to provincial air quality guidelines can be met.

The anticipated changes to baseline noise levels at Project perimeters and local residences will require assessment and permitting. Plant water intake and site water management permitting will be premised on a zero water discharge plan that will be achieved through evaporation of process water.

The permitting of disposal of solid plant waste residue will be premised on ensuring a geotechnically stable residue waste cell design, including geomembrane lining of the base that will prevent discharge of residual pile moisture and precipitation run-off into surrounding surface and ground waters.

Typically, specific permitting applications will commence at least four months prior to expected commencement of construction. For expediency, permitting applications may continue during the initial stages of construction as a critical path item, whereby the construction schedule follows a successful timeline of permit approvals.

12. SOCIO-ECONOMIC IMPACT

12.1 Socio-Economic Assessment

Sveinson Mineral Services Inc. was retained to research and prepare a socio-economic assessment as a supporting document for the overall Cogburn Magnesium Project Production Feasibility Study and as part of the permitting studies for the project[15].

Early indications are that the proposed Cogburn Magnesium Project presents a significant economic opportunity, in particular, for the nearby communities of Hope and Kent-Agassiz. Job creation – direct, indirect, and induced; the associated increase in disposable income associated with employment in the mineral industry; substantial annual operational expenditures; and taxation will provide significant positive economic benefits at all levels – local, regional, and provincial.

Preliminary estimates of the workforce requirements for the proposed 130,000 tpa scenario are approximately 1,100 workers during the magnesium reduction plant construction period, with crews double this number for short periods of time during the construction period and, after plant start-up, a permanent operations workforce of 494 operating and administrative personnel. As well, the quarry, operating from May 1st to October 31st each year, will require 48 personnel.

Job creation estimates (direct, indirect, and induced) for the Cogburn Magnesium Project based on local area employment ratios are summarized in Table 22, while job creation estimates based on provincial employment multipliers are summarized in Table 23.

Table 22. Job Creation Estimates, Based on Local Area Employment Ratios

	Number of Direct Jobs	Potential Jobs Created (Direct, Indirect & Induced No Migration Scenario	Potential Jobs Created (Direct, Indirect & Induced Migration Scenario
Construction Period	1,100	1,412	1,551
Operations – Magnesium Reduction Plant Operating & Administrative Personnel	494	715	782
Operations – Magnesium Reduction Plant Operating & Administrative Personnel and Seasonal Quarry Personnel	542	784	858

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[15] Sveinson Mineral Services Inc: “Socio-Economic Assessment”, April 2003.

Table 23. Job Creation Estimates, Based on Provincial Employment Mining Multipliers

	Number of Direct Jobs	Total Potential Jobs Created Multiplier of 2.0	Total Potential Jobs Created Multiplier of 2.5
Construction Period	1,100	2,200	2,750
Operations – Magnesium Reduction Plant Operating & Administrative Personnel	494	988	1,235
Operations – Magnesium Reduction Plant Operating & Administrative Personnel and Seasonal Quarry Personnel	542	1,084	1,355

PriceWaterhouseCoopers, in its annual independent survey of the mining industry in British Columbia, reported an average salary plus benefits of $81,100 for direct employees in the mining industry in British Columbia for 2001.[16]

The mining industry in Canada typically pays the highest wages of any basic sector of the economy, leading to higher disposable incomes and associated spin-offs. In terms of income multiples, the impact of the potential creation of 542 direct mining industry jobs is significant in comparison to the impacts of job creation in other lower paying sectors of the economy.

Annual expenditures from operations have been estimated to be in the order of US$203 million. Corporate taxes, after recovery of pre-production capital expenditures, have been estimated to be US$ 40 million annually – roughly, federal (50%), provincial (45%) and municipal (5%) and while annual payroll taxes are estimated at C$ 7.3 million.[17]

Local communities proximal to the proposed Cogburn Project site – Hope, Kent, and Harrison Hot Springs – or within easy commuting distance – Chilliwack, Abbotsford, and Mission – offer well-developed community infrastructure, including affordable housing, educational, and health facilities, retail, transportation, social, and recreation services to support the in-migration of additional skilled labour.

12.2 Public Hearing Report

Public and government consultation was organized by JoHarris and Associates[18]. All strategic public, government and private groups have been identified and met with in regard to the Cogburn Magnesium Project.

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[16] PriceWaterhouseCoopers, The Mining Industry in British Columbia – 2001, page 3, May 2, 2002.

[17] Julian Taylor, Personal Communication, February 5, 2003

[18] JoHarris and Associates: “Public and Government Consultation”, April 2003.

The public consultations consisted of open house discussions in the towns of Hope and Agassiz, both located near to the proposed Cogburn project.

Government consultations consisted of:

- meetings with B.C. Minister of Mines;
- meetings with BC Environmental Assessment Office;
- formal presentations to Hope Chamber of Commerce;
- formal presentations to the Mayor and Council of the District of Kent.

In addition, information packages were sent to the B.C. Members of Parliament and Members of the BC Legislative Assembly.

The Project has elicited tremendous support from the public, local government and Chambers of Commerce at Hope and Agassiz, and there is no doubt that the public welcomes it as an ideal opportunity to offset the prevailing stagnant economy in the region.

12.3 First Nations Considerations and Consultations

The impact of the Cogburn Magnesium Project on the first nations was studied by Jo Harris and Associates[19].

The purpose of separate research and consultation with First Nations was to ensure that specific Aboriginal title and rights, as provided by the Canadian Constitution, and outlined in prevailing case law (predominantly *Delgamuukw* and *Sparrow*) are not unduly affected by the proposed project.

Prior to treaty settlement in British Columbia, the role of the federal and provincial governments is to preserve aboriginal resources and such activities as hunting, fishing and gathering. Valued resources include tangibles such as village sites and burial grounds, while intangibles include sacred and spiritual sites.

First Nations' response to the Project can be generally summarized as follows:

- Chehalis, Yale and Cheam have voiced general concerns regarding the protection of Aboriginal title and rights in the pre-treaty environment. Similarly, these First Nations are generally interested in the protection of the environment and wildlife in the quarry area.
- Skawahlook Council has declined to participate in discussions with the company or to assist the company in eliciting feedback from its membership.
- Sto:lo Nation is receiving information on the Project and monitoring progress on behalf of its members. The Nation and individual Stollo members Chawathil, Seabird Island and Shxw'ow'hamel have raised no issues to-date.

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[19] JoHarris and Associates: "Cogburn Magnesium Project - First Nations Considerations and Consultation", February 2003.

Overall, a productive working relationship has been established with First Nations in the vicinity of the proposed Cogburn Magnesium Project traditionally open to participation in the treaty settlement process and other land use matters.

As a result of careful project design and continued productive collaboration with First Nations, it is considered that the Cogburn Magnesium Project will have little to no impact on traditional use or the general environment of any local First Nations. Conversely, those First Nations with whom the Company has established a productive working relationship have advised that the Project constitutes a much-needed opportunity for joint-venturing, contracting, employment and training to offset high unemployment levels and improve the long-term economic base of their communities.

12.4 Archaeological Impact Assessment

The archaeological impact assessment was prepared by Nicole Oakes and Douglas Brown (Archaeologists)[20].

The archaeological impact assessment (AIA) involved the assessment of select portions of approximately 400 hectares of proposed development. The purpose of the archaeological impact assessment was to identify and evaluate archaeological resources within the proposed development areas, assess the scientific and cultural significance of identified heritage remains, and provide recommendations for managing any archaeological resources identified within the proposed development areas.

The AIA resulted in the identification of 1 previously recorded archaeological site, DiRj 8 (Lower Plant Site). The location of DiRj 8 had been only generally described on the original B.C. Archaeological Site Inventory Record, and it is not within the proposed development area. As such, the impact on the project will be minimal.

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[20] Nicole Oakes and Douglas Brown: “Archaeological Impact Assessment of Proposed Developments Related to the Cogburn Magnesium Project, Hope, B.C.”, September 2002.

13. CONCLUSIONS

In February 2002, Leader Mining International awarded Hatch the mandate to complete a Production Feasibility Study on the Cogburn Magnesium Project. The Cogburn Magnesium Deposit is a large ultramafic intrusive body containing consistently high-grade magnesium silicate (+24% magnesium). The discovery is located 120 kilometres east of Vancouver, British Columbia, Canada near the town of Hope. The location has a significant infrastructure advantage in that electric power, natural gas, mainline rail, provincial highways and barge access to nearby deep-sea ports are all adjacent to the property. In addition, the project is located in a mining and forest products extraction region with extensive supporting skilled labour and a broad spectrum of service industries.

The enriched Emory Zone has been subjected to an intensive drilling and sampling program. Under the direction of HATCH, Process Research ORTECH has pilot tested a composite sample, for hydrochloric leach extraction of magnesium. In addition, leach solution was tested at Messo in Germany to define evaporation and crystallization parameters for the preparation of cell feed for the STI/VAMI magnesium electrolysis technology. This metallurgical testwork has proven that this feedstock is of good quality and amenable to traditional metallurgical extraction routes.

In April 2002 Leader signed an option with STI/VAMI for the use of the magnesium electrolysis technology for the Cogburn Project. Successful testing has resulted in preliminary design parameters for development of the Cogburn Project flowsheet. The Cogburn deposit because of its large size, high magnesium grade, low impurity levels, favourable metallurgy, and proximity to infrastructure has the potential to be developed into a world-class, environmentally friendly, long-life magnesium operation. Process information generated during the Study was used to develop capital and operating costs for the project at the selected site location. Following discussions with BC Hydro and Duke Energy, energy costs have been established for the Cogburn Project. In addition the socio-economic, archaeological, first nations and wildlife impacts of the project were studied. This has proved favourable to the development of the project.

The test-work and the engineering completed to-date indicate that the Cogburn Project is technically feasible and economically viable. In order to advance this project further, the following activities must be done in the next phase prior to final project approval.

- Process technology: Some additional discussions with STI/VAMI will be required to negotiate the licensing fees for the next phases.
- Testwork: Some optimization testwork to optimize the leaching flowsheet and improve the operating and capital costs. Different MgO sources will be tested including the potential occurrences of magnesite that can be found in southern British Columbia. Also some testwork by STI/VAMI are required to ensure environmental conformance and to obtain performance guarantees.
- Basic Engineering: The next phase of engineering would be to complete Basic Engineering to advance the level of definition to Bankable Feasibility status.

- Environmental Permitting: The permitting will be supplemented by information obtained during the testwork and the basic engineering.

- Commercial and Financing: Leader must seek partners, financing and off-take contracts. These agreements signed will be subject to the successful completion of optimization process testwork and environmental permitting.

The staged approach helps to protect all investing parties from having to make critical decisions and commitments with incomplete or premature information.

Yves Dessureault & James Anson

JPA:db