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Saskatchewan Ministry of the Economy

Ministry of the Economy
Saskatoon, Saskatchewan, Canada

Potash Mining Supply Chain Requirement Guide

For

Greenfield Mine Lifecycle Costs

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Project Report

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Potash Mining Supply Chain Requirement Guide

DISTRIBUTION

Greenfield Mine Lifecycle Costs

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1. Executive Summary

Tens of billions of dollars are expected to be spent in Saskatchewan in the next 20 years in expansion of the potash sector. This Guide presents the order-of-magnitude costs associated with the main expenditures over the lifecycle of a typical greenfield potash facility.

A model size of 2 million tonnes per year (MTPY) was chosen as the base case for this Guide as it is representative of the scale of new facilities currently under construction or under consideration.

We have defined five lifecycle stages of potash facilities:

- Exploration and Resource Evaluation.
- Regulatory Licences, Permits and Approvals.
- Engineering and Construction.
- Operations and Maintenance.
- Closure, Reclamation and Monitoring.

Exploration and Resource Evaluation considers the previous work done by others, carries out seismic surveys and drilling programs and then evaluates the geological resource potential.

Environmental approval is pivotal to the advancement of a project. Numerous licences, permits and approvals are required for construction and operation to proceed. A mine closure plan is always part of early planning and approval.

Engineering evaluation of the project overlaps with the resource evaluation as the facility must be designed to mine and process the available orebody. The findings of the permits and approvals stage define some of the design parameters that must be complied with in order to proceed. The project is advanced in phases with evaluations done at stage gates to confirm viability to proceed. A successful business case to build will lead to construction where the majority of investment capital is spent.

Considerable rail, roads, natural gas, electrical service and water infrastructure are required for a potash facility. Construction of the shaft and underground facilities for a conventional underground mine takes several years. The surface facility construction overlaps with this so that their availability for initial potash production coincide. The surface processing plant requires hundreds of millions of dollars in equipment purchases and construction contracts to complete. Solution mining underground facilities are less extensive but the surface plant is on the same scale as that of the conventional underground surface facility.

Indirect costs to support the construction activities are considerable and range from site offices to design and construction management services to commissioning of the facility.

Operations and maintenance of the facility requires 300 people or so and annual maintenance costs of $60-70 million for supplies, spares and equipment. Utilities and operating supplies are in addition to this.

At the end of its life, a potash facility must be shut down, the equipment disposed of and the surface returned to a state similar to that which it would have been in if there had never been a mine there. This involves considerable work and expense which is planned for during the operating life of the mine.

2. Introduction

Mining companies are expected to invest tens of billions of dollars in the potash sector over the next 20 years in Saskatchewan. This Guide was written to increase the understanding of the goods and services that will be required to support the development of representative greenfield potash facilities as well as the operating costs of those facilities. The intent is to provide a breakdown of the major cost components and their timing in the lifecycle of a potash facility.

The target audience is goods and service suppliers to the potash sector as well as government so it may be able to provide programming and support for this growth.

Although the major expenditures in the lifecycle of a potash facility are in the construction and the operation stages, there are many other aspects of goods and services crucial to the project implementation that are required. In order to illuminate these and to provide context for this, we have outlined the entire potash facility lifecycle from exploration to closure. More detail is provided on the capital-intensive stages on account of the magnitude of the opportunity.

This Guide is provided as a guideline to order-of-magnitude costs for supply planning purposes only. It is not intended to be used as a forecasting tool for expenditures to be made by mining companies in the sector nor is it to be used for investment purposes. The content of this Guide it not to be used as a design basis for facility design. Similarly, the regulatory processes described within are only to serve as an illustrative guide. The appropriate regulatory authorities must be contacted for planning purposes.

3. Model Study Size

In order to select a representative size of potash production facility for this guide we list below the current Canadian facilities and their approximate production capacities as recently reported. Following this is a list of the Canadian greenfield facilities under construction in 2012 and their reported capacities.

A further section lists the companies that have declared their interest in potash development in Canada. These are taken from publicly-available sources, largely the producers' websites or announcements.

3.1 Current Canadian Potash Facilities and Operational Capacities

- Potash Corporation of Saskatchewan (PCS) (figures for 2012)[1]:
  - Cory – 2.0 MTPY.
  - Allan – 1.6 MTPY.
  - Lanigan – 3.3 MTPY.
  - Rocanville – 2.7 MTPY.
  - Patience Lake – 0.4 MTPY.
  - Sussex, NB – 0.8 MTPY.
- Mosaic Company (Mosaic) (figures for 2011)[2].
  - Esterhazy K1 and K2 – 5.3 MTPY.
  - Colonsay – 1.8 MTPY.
  - Belle Plaine – 2.8 MTPY.
- Agrium (figure for 2011)[3]:
  - Vanscoy – 1.8 MTPY.

3.2 Greenfield Facilities Under Construction in Canada in 2012

- PCS[1]:
  - Scissors Creek – 2.7 MTPY.
  - Picadilly – 1.8 MTPY.
- Mosaic:
  - Esterhazy K3 – 1 MTPY.
- K+S:
  - Legacy[4] – 2 MTPY (ultimate production rate 4 MTPY).

3.3 Potential Entrants Into Potash Mining in Canada in 2012

- BHP Billiton:

[1] Potash Corporation of Saskatchewan http://www.potashcorp.com/about/facilities/potash
[2] The Mosaic Company, Saskatchewan Mining Supply Chain Forum, April 2011
[3] Agrium Board Approves Substantial Potash Expansion, 2012; Mining.com A mine of information http://www.mining.com/2011/12/15/agrium%E2%80%99s-board-approves-substantial-potash-expansion,
[4] K + S Legacy Project, Investor and Analyst Conference Call, 2011

- Jansen[5] – 4 MTPY (ultimate production rate 8 MTPY).

3.4 Companies Conducting Exploration Projects in Saskatchewan But Not Yet Under Construction in 2012

- BHP Billiton.
- Vale.
- Rio Tinto.
- Western Potash Corp.
- Karnalyte Resources Inc.
- Encanto Potash Corp.
- North Atlantic Potash Inc.
- M & J Potash Corp.
- Yancoal Canada Resources Co., Ltd.
- Canada Potash Corporation.

3.5 Recommended Study Size

There are 10 potash-producing mines currently operating in Saskatchewan and all of them have undergone recent expansions or are currently under expansion. These mines range in capacity from 0.4 MTPY (Patience Lake) to 5.3 MTPY (K1 plus K2) and most of them started production in the 1960's. Mosaic's Esterhazy K1 and K2 mines' production are often reported together but the surface production facilities are separate.

Four new potash mines were under construction or advanced development in Saskatchewan in 2012 and most are in the neighbourhood of 2 MTPY in initial capacity. Although the BHP Billiton Jansen project is planned for an ultimate capacity of 8 MTPY, it would be built in 2 MTPY modules by adding process trains in parallel with each other. The Mosaic Esterhazy K3 mine output, however, is planned for 1 MTPY with the ore to be processed at the K2 mill.

We have chosen a study size of 2 MTPY as the basis for our greenfield conventional underground and solution mines as this is relevant to the current greenfield project scales and module increments under construction.

4. Potash Facility Lifecycle Stages

A typical 2 MTPY conventional underground mine potash facility takes 7-9 years to build and ramp up to nameplate production levels and will operate for 40 or more years. Resource evaluation and permitting may extend the front end of this duration somewhat and every mine must have a closure plan that will follow the end of its productive life.

We have divided the potash facility lifecycle into stages and outlined them in the graphical sequence shown in Table 2: Potash Facility Lifecycle Stages. The purpose of this figure is to provide a high level view of the life of a potash mine including approximate costs and

[5] BHP Billiton. *Jansen Project Proposal to Saskatchewan Ministry of Environment.* Saskatchewan: BHP Billiton, 2008.

timelines. It is to be understood that these stages overlap somewhat and that there is considerable integration between the groups involved. In this table, FEL is the abbreviation for Front End Loading which is defined in section Project LifeCycle Process (PLP).

The major potash facility lifecycle stages we have chosen are:

- Exploration and Resource Evaluation.
- Regulatory Licences, Permits and Approvals.
- Engineering and Construction.
- Operations and Maintenance.
- Closure, Reclamation and Monitoring.

Table 1: Overall Lifecycle Costs below is a summary table of the overall potash facility lifecycle costs.

These stages will be further elaborated upon in the following sections with goods and services in the lifecycle supply chain grouped into categories with detail then provided on cost and references to specialty suppliers, where applicable.

Table 1: Overall Lifecycle Costs

	Conventional U/G Mine	Solution Mine
Initial Build		
Exploration, Evaluation	$27,500,000	$27,500,000
Licences, Permits, Approvals	Varied cost	Varied cost
Overall Project Proposal	Varied cost	Varied cost
Environmental Assessment (EA)	$5,000,000	$5,000,000
Research Permits	Included in EA	Included in EA
Exploration Licences	Varied cost	Varied cost
Construction Permits, Licences	Varied cost	Varied cost
Operating Permits, Licences	Varied cost	Varied cost
Mine Closure Approval	Varied cost	Varied cost
Engineering, Construction		
Infrastructure	$218,500,000	$218,500,000
U/G CAPEX	$859,600,000	$360,000,000
Surface CAPEX	$1,954,750,000	$1,921,750,000
Indirects	$920,000,000	$705,000,000
Totals	**$3,985,350,000**	**$3,237,750,000**
Annual Operations, Maintenance	$160,930,000	$234,050,000
Closure, Reclamation, Monitoring	$498,058,000	$234,908,000

Table 2: Potash Facility Lifecycle Stages

Who	Subcontract/Group			FEL1		FEL2		FEL3		FEL4 - Implementation											
Exploration and Resource Evaluation		24 months + - $20-30MM (excl. Land control)																			
Owner		Preliminary evaluation of orebody																			
			Potash Exploration Permits																		
			Surface access agreements																		
			Exploration and definition																		
				Subsurface Mineral Lease																	
				Surface rights for surface operating																	
Regulatory Licences, Permits and Approvals				24-36 months - $ dependent upon site specifics																	
Owner/Consultant	Environmental			Overall Project Proposal																	
				Environmental Assessment																	
					Municipal Development Permit																
					Approval to Conduct Seismic Surveys																
					Drilling Licence																
					Mine Construction and Operation Permits:																
						Pollutant Control Facility Approval															
						Water Licence															
						Groundwater Investigation Permit															
						Permit for Waterworks Intended for Human Consumption															
						Sewage Works Permit															
						Mine Waste/Tailings Permit															
						Minister's Oder - Salt Water Disposal															
						Air Emmissions Permit															
						SaskEnergy Permit to Dig															
						Road Use Agreements															
Engineering and Construction				FEL1 - 6 months - <$2 MM		FEL2 - 9 months - $<20 MM		FEL3 - 12-18 months - <$100 MM			FEL4 - 42-72 months - $3-4,000 MM										
Milestones				Facility options		Option selected		Define selected option		Capital approved			Construction								
Consultant	Project controls				Conceptual estimate		Preliminary estin	Capital estimate plan		Control estimate			Definitive estimate								
					Level 1 schedule		Level 2 schedule		Prelim. Level 3 schedule		Level 3 schedule										
Consultant	Engineering			Site assessment		Options develop	Finalize critical equip.														
							Facility desc.		Advanced facility desc.		Final facility desc.										
					Layout development		Site plot plan	Site investigation	Advanced layout		Install. Specs and dwgs										
				Technology identification		Advanced process design		Advanced PDF	P&IDs	MTOs	Definitive MTOs										
								Critical equip. specs			Equip. Specs										
Consultant	Procurement						Preliminary sourcing strategy		Procurement sourcing strategy												
										Logistics strategy											
									Long Lead POs	Materials pricing	Critical POs	POs	Equip. Delivery								
												Install. Contracts	Installation								
Consultant	Construction							Constructability	Construction execution strategy		Early works plan		Construction management								
Owner/Consultant	Commissioning								Prelim. Commissioning plan		Final commissioning plan			Pre-op. Testing	Commissioning						
Operations and Maintenance																40+ years - $150MM/year					
Owner/Consultant	Environmental - Ops. Compliance															Water treatment					
																Air emissions					
																Waste management					
Owner	Operations															Site G&A					
																Labour					
																Consumables					
																Power					
																Natural gas					
Owner	Maintenance															Maintenance					
Closure, Reclamation and Monitoring																			5-30+ years - $250-500 MM		
Contractor																			Demolition		
																			Waste management		
																			Reclamation		
Consultant																			Monitoring		

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5. Exploration and Resource Evaluation Stage

Companies interested in developing a potash resource must first determine the extent of the geological resource, plan how it will be mined and processed, and gain control of the land and potash resource to do this.

Exploration for potash involves the use of geophysics , drilling and sampling to define the geological properties of the orebody that are then used in the design of the mine and mill processing facilities.

Potash resource evaluation and acquisition in Saskatchewan generally involves the following steps:

- Preliminary Evaluation from existing information on orebody.
- Potash Exploration Permits.
- Surface access agreements.
- Exploration and Definition.
- Subsurface Mineral Lease.
- Surface rights for surface operating.

Brief treatment of the Preliminary Evaluation and Exploration and Definition costs associated with a new mine are provided in the following section Preliminary Evaluation, Exploration and Definition.

Surface access agreements for exploration must be arranged with the individual private landowners or, in the case of Crown lands, a surface lease agreement must be obtained from the agency responsible for managing the specific lands.

Potash Exploration Permits are issued by the Saskatchewan Ministry of the Economy, Mines Branch under The Crown Minerals Act and The Subsurface Mineral Regulations, 1960 for exploration on Crown mineral lands. Crown mineral lands include Crown lands and privately-owned lands. Potash Exploration Permits are issued for five years but can be extended for an additional three years, subject to required exploration expenditures. These permits entitle the holder to the exclusive right to prospect for subsurface minerals in the permit area[6].

Well Licences are required for any drilling or boring for the purpose of exploring for subsurface minerals. These are issued under The Oil and Gas Conservation Act and The Oil and Gas Conservation Regulations, 1985[7]. Permits are also required for seismic work.

[6] Government of Saskatchewan Ministry of Energy and Resources. (1960). *The Subsurface Mineral Regulation*: http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/SR541-67.pdf

[7] Government of Saskatchewan Ministry of Energy and Resources. (2012). *Oil and Gas Conservation Regulations.* http://www.qp.gov.sk.ca/documents/English/Regulations/Repealed/O2R1.pdf

Further discussion of project permitting is provided in the section Summary of Licenses, Permits and Approvals.

5.1 Preliminary Evaluation, Exploration and Definition

Most of the exploration for the existing potash mines in Saskatchewan was done in the 1950s and 1960s. At that time boreholes were drilled to determine core sample properties in order to evaluate the potash resource and plan the mine and processing facilities. Typically, 5-30 boreholes were drilled for this evaluation. Seismic surveys were not used significantly at that time but they have since been used extensively.

Current exploration and definition activities include: evaluating existing drilling and seismic data, 2D and 3D seismic surveys, new drilling and core sampling, well logging and drill stem testing.

The intent of this guide is not to elaborate on these techniques but, rather to identify the major supply categories in this stage of the mine lifecycle and to provide guidance costs for them. These are shown in Table 3: Exploration and Resource Definition.

Table 3: Exploration and Resource Definition

Service/ Product	Supply Type	Price/Unit	# Units	Unit Measure	Total	Cumulative Totals
Exploration						
	Evaluation of Existing Data	$1,000,000	1	lot	$1,000,000	
	2D Seismic Surveys	$1,000,000	1	lot	$1,000,000	
	3D Seismic Surveys	$3,000,000	1	lot	$3,000,000	
	Drilling Program	$1,500,000	15	hole	$22,500,000	
Total						**$27,500,000**

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category.

5.2 Subsurface Mineral Lease and Surface Rights

A successful exploration program may lead the proponent to apply for a Subsurface Mineral Lease in order to develop the resource into production. A Subsurface Mineral Lease is issued by the Saskatchewan Ministry of the Economy, Mines Branch under The Crown Minerals Act and The Subsurface Mineral Regulations, 1960. A Potash Exploration Permit may be converted into a Subsurface Mineral Lease provided that the Permit is in good standing. Leases are issued for 21 years, renewable for successive 21-year terms and subject to expenditure requirements.[8]

[8] Government of Saskatchewan Ministry of Energy and Resources. (1960). *The Subsurface Mineral Regulation.* http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/SR541-67.pdf

Surface rights for the surface operating facility must be negotiated with the landowner if the surface ownership is private. If the surface land is owned by the Crown, a Surface Permit is required which may trigger other evaluations. More discussion on this is held in section Regulatory Licences, Permits and Approvals Stage .

These costs are not covered here as the Subsurface Mineral Lease costs are outlined on the Ministry website and surface rights costs can vary widely.

6. Regulatory Licences, Permits and Approvals Stage

Various licences and permits are required for a potash development project to proceed beyond exploration. These are typically identified during the environmental approval process.

6.1 Saskatchewan Environmental Approval Process

During the exploration stage, proponents should contact the Saskatchewan Ministry of Environment (SMOE) early in the planning stage so that the Ministry has a good understanding of the exploration program and can provide guidance on permitting. As described in the *Mineral Exploration Guideline for Saskatchewan 2012*[9], the SMOE will:

- Determine if there are any site-specific environmental concerns with the program and whether plans to handle those concerns are acceptable.
- Identify interest groups that may be impacted by the program.
- Provide the applicant with any necessary permits and authorizations required for the proposed work.

The proponent may be required to undertake field evaluations for rare and endangered species if historical or habitat information indicates potential occurrence. They must meet all the Best Management Practices as outlined in the guideline above concerning: staking, exploration, work camps, fuel/hazardous materials, fire prevention, access, water crossings, trenching, drilling, core handling, restoration and community engagement.

Various authorizations and permits will be required for exploration activities such as surveys, line cutting, seismic surveys, clearing, work camps, hazardous materials, water crossings, trenching and drilling.

It is also advisable at this stage to conduct an Environmental and Regulatory Risk Review (ERRR) to identify any show-stoppers and triggers for an Environmental Assessment (EA). This is also the stage where baseline study requirements are identified, if applicable.

This section is not intended to provide guidance on the permitting process but rather to illuminate to the reader that many permits are required for early exploration activities. The

[9] Government of Saskatchewan Ministry of Energy and Resources. (1960). *The Subsurface Mineral Regulation:*. http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/SR541-67.pdf

relevant government authorities must be contacted for specific guidance on permitting requirements and processes.

6.2 Overall Project Proposal

In Saskatchewan, the EA process generally begins with the submission of an overall project proposal that outlines the project to provincial and federal authorities so they can determine the scope of review necessary for the project. This process is administered by the Saskatchewan Environmental Assessment Branch (SEAB) of the SMOE under authority of the *Environmental Assessment Act (EAA)* and the *Canadian Environmental Assessment Act (CEAA).*

Any project considered a "development" by the EAA must be reviewed for criteria to determine if a full Environmental Impact Assessment is required. Figure 1: The Saskatchewan Environmental Assessment Process is a high level flow chart of the Saskatchewan EA process. Some relevant abbreviations in this figure include:

- EA – Environmental Assessment
- EAB – Environmental Assessment Board
- SEARP – Saskatchewan Environmental Assessment Review Panel
- EIA – Environmental Impact Assessment
- PSGs – Project-Specific Guidelines
- EIS – Environmental Impact Statement

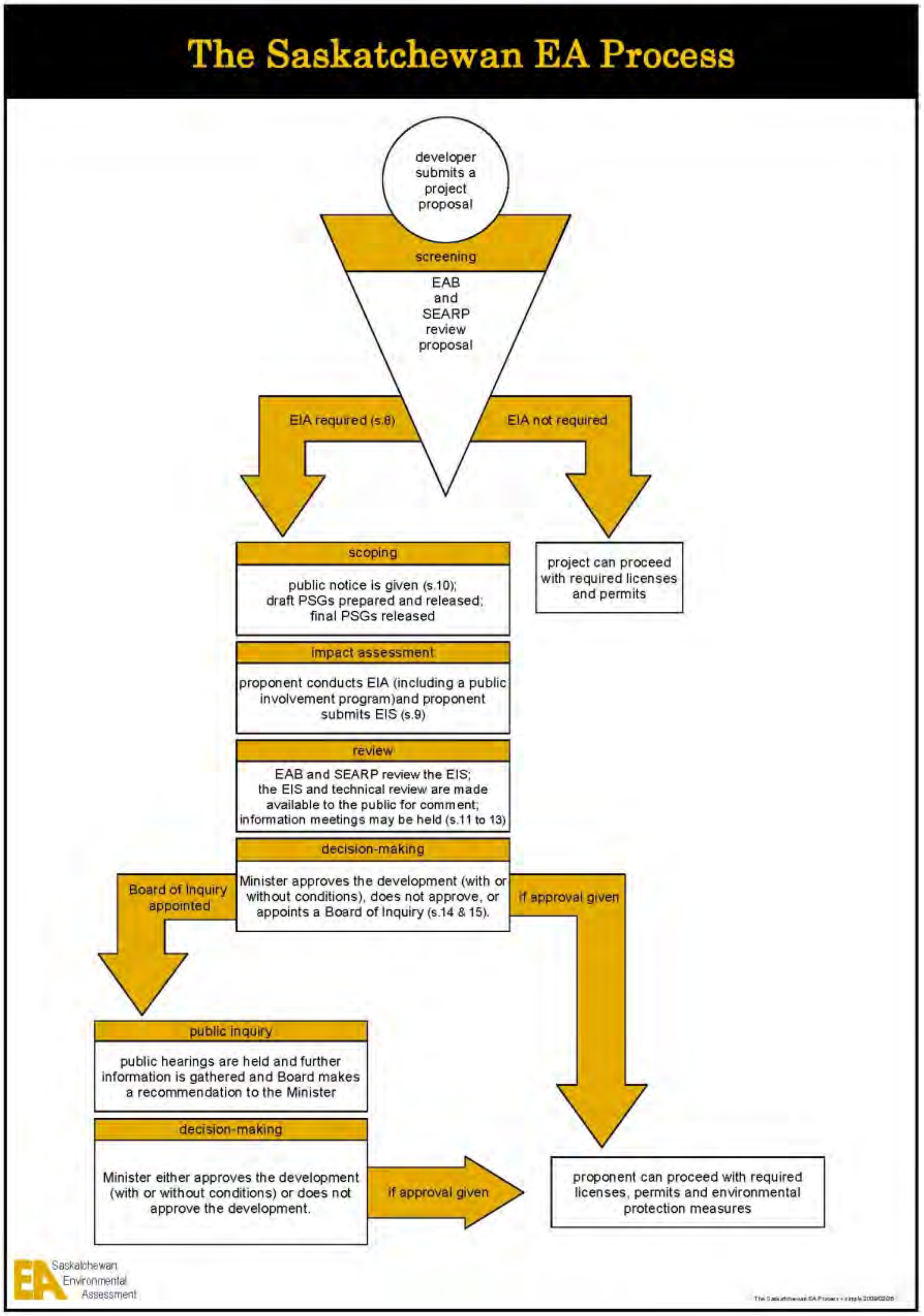

Figure 1: The Saskatchewan Environmental Assessment Process[10]

[10] Saskatchewan Environmental Assessment . (2009, 02 26). *Government of Saskatchewan*. http://www.environment.gov.sk.ca/EAProcessFlowchartSimple

If it is deemed necessary, the EA will evaluate the ecological, socio-economic and cultural aspects of the development. In Saskatchewan, EAs are coordinated for projects with joint federal and provincial jurisdiction under the "Canada-Saskatchewan Agreement on Environmental Assessment" (see *The Environmental Assessment Process in Saskatchewan*[11]. Only once the project has been approved by the SEAB, can the developer continue with the project and apply for other required licenses, permits and authorizations through the various agencies. The EA process can take approximately two years. Services required during this stage typically include:

- Consultants to manage the EA and prepare the submission for the SEAB;
- Consultants, specialists, equipment and laboratories to conduct a description of the existing biophysical, social and economic parameters including the following categories: air, water, geology, soils, vegetation, wildlife and fisheries, heritage resources, land use, and socio-economics.

6.3 Summary of Licenses, Permits and Approvals

A table of Statutory Requirements and Approvals was provided by BHP Billiton in their Jansen Project Proposal submitted to the Saskatchewan Ministry of the Environment, November 2008[12]. Extracts from this document are summarized in the following sections: Overall Project Environmental Approval Requirements, Baseline Environmental Research and Exploration, Mine Construction and Operation and Decommissioning and Reclamation.

6.3.1 Overall Project Environmental Approval Requirements

- Provincial Project Approval – may require an EA.

6.3.2 Baseline Environmental Research and Exploration

- Scientific Research Permit.
- Special Collection Permit.
- Heritage Property Approval.
- Wildlife Habitat Protection Approval.
- Fisheries Research Permit.
- Municipal Development Permit.
- Approval to Conduct Seismic Program.
- Drilling Licence.

[11] Saskatchewan Ministry of Environment. (2011). *The Environmental Assessment Process in Saskatchewan.* http://www.environment.gov.sk.ca/adx/aspx/: Saskatchewan Ministry of Environment.
[12] Rescan Environmental Services . (2008). *Jansen Project Proposal.* Saskatoon, Saskatchewan, Canada.

6.3.3 Mine Construction and Operation

- Pollutant Control Facility Approval.
- Waste Discharge Permit.
- Water Licence.
- Groundwater Investigation Permit.
- Permit for Waterworks Intended for Human Consumption.
- Sewage Works Permit.
- Mine Waste/Tailings Permit.
- Minister's Order – Salt Water Disposal.
- Air Emissions Permit.
- SaskEnergy or TransGas Permit to Dig, Excavate, Blast or Build Structures over Pipelines.
- Road Use Agreements.

6.3.4 Decommissioning and Reclamation

- Mine Closure Approval.
- Approval for Decommissioning and Reclaim of a Pollution Control Facility.

6.3.5 Environmental Assessment Costs

It is difficult to provide realistic costs for the complete list of probable licenses, permits and approvals required for a potash project since they are very specific to the project location and design. However, an EA is almost always required and will identify the environmental, socio-economic and cultural impacts and provide the measures to be taken to mitigate these. Approximate costs for the EA are shown in Table 4: Environmental Assessment Costs below.

Table 4: Environmental Assessment Costs

Service/Product	Supply Type	Price/Unit	# Units	Unit Measure	Total	Cumulative Totals
Environmental Assessment Process						
	Environmental Assessment	$5,000,000	1	lot	$ 5,000,000	
Total						**$5,000,000**

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category. The Saskatchewan Environmental Industry and Managers Association produces the 2012 Membership Directory and Buyers Guide with profiles of regional service-providers.

7. Engineering and Construction Stage

The Engineering and Construction stage of the project lifecycle process is highly capital-intensive and takes place over several years. This chapter describes the steps in this stage from the perspective of the design and management of the project. The following section Details of Typical Potash Facilities, provides a description of the infrastructure, mine and surface facilities required for a greenfield potash facility along with their approximate costs to construct.

7.1 Project LifeCycle Process (PLP)[13]

Significant capital projects, such as development of a potash facility, benefit from a staged structure with tollgates to determine project viability in order to advance to the next stage. Each stage progresses the level of detail in the design and refines the level of accuracy of the capital estimate and schedule. The authors of this guide will refer to the project delivery processes used by Hatch, the Major Project LifeCycle Process. Figure 2: Major Project LifeCycle Process illustrates this framework graphically.

Figure 2: Major Project LifeCycle Process

A brief description of these phases follows. Refer to Figure 2: Major Project LifeCycle Process for further details on the project development, durations and time phasing with other stages of the project.

[13] Project LifeCycle Process (PLP) 2012

7.1.1 *FEL1 – Concept Study*

The purpose of this phase is to develop the technology and plant configuration options. This includes potential technologies identification, early layout development and site assessments. A Level 1 schedule is developed and a conceptual estimate is prepared.

This would typically be completed in six months for a greenfield potash project.

7.1.2 *FEL2 – Pre-Feasibility Study*

This phase determines the optimal project solution and evaluates the importance of project to proceed. Technical options are developed, critical equipment identified and process design is advanced. A preliminary sourcing strategy is developed along with a Level 2 schedule and a preliminary estimate. Environmental and Social Impact Assessments are initiated.

FEL2 duration is typically nine months for a greenfield potash project.

7.1.3 *FEL3 – Feasibility Study*

The work of the FEL3 phase defines the option selected in FEL2 and prepares a comprehensive plan for project execution. Here the layout is advanced, critical equipment is specified and design criteria established. The procurement construction execution strategies are developed. A preliminary Level 3 schedule is prepared and a capital control estimate is prepared for capital approval. The Environmental and Social Impact Assessments are finalized.

7.1.4 *FEL4 – Implementation*

The FEL4 stage executes the plan that was developed in FEL3. Environmental permits are approved. Design is finalized, equipment list, installation specifications and drawings for construction are issued. Purchase orders and contracts are tendered and awarded. Equipment is delivered, construction progresses, equipment and systems are tested, commissioned and ramped up to production. The project is handed over to the owner for operations.

7.2 Environmental Considerations in PLP

Although the environmental approval process and regulatory permitting is discussed in more detail in the section Regulatory Licences, Permits and Approvals Stage above, it is important to understand the interplay of these considerations in the design development and construction of the project.

During the early engineering stages, consultants will begin working on the Environmental Impact Statement (EIS) as per the EA described in section Regulatory Licences, Permits and Approvals Stage above. The EA goes hand-in-hand with engineering development as the project is defined. It is worthy to note that the EIS submittal and approvals will govern engineering and construction activities as will other regulatory requirements. Environment-related activities are identified in the list below in the typical phases of engineering development where they are considered:

- FEL1: stage where it is determined if there are environmental constraints, if there is a requirement for the EA and identification of stakeholders.
- FEL2: EA begins or is ongoing, choosing preferred sustainability options, preparation of permitting strategy and preparation of the conceptual closure plan.
- FEL3: preparation for construction begins. Environmental Management Plans and a draft Closure Plan are prepared.
- FEL4: various construction permits and approvals are acquired in compliance with the Environmental Management Plan and regulations. Environmental monitoring and evaluation of the plans are ongoing.

7.3 Front End Loading Service-Provider Costs

Table 7: Conventional Underground Mine CAPEX is a table of approximate costs for each stage of the Front End Loading process as might be expected for a greenfield potash project. These costs are very approximate and will depend upon the risk tolerance of the owner. A risk-averse owner will favour heavy emphasis on the early stages of evaluation (FEL1 and FEL2) so that resource evaluation, permitting, process design, capital costs and schedule are better understood before the project is advanced. Less risk averse owners may be willing to leave greater certainty in these project elements until later in the development cycle.

Early phase services may be provided by smaller companies but latter phase services are often provided by a company capable of carrying out the full engineering, procurement and construction management (EPCM) suite of services for a project of this size. Section Regulatory Licences, Permits and Approvals Stage costs are not included in the table below but are presented in a table later in that section.

Table 5: Front End Loading Costs

Service/ Product	Supply Type	Description	Price/Unit	# Units	Unit Measure	Total	Cummulative Totals
Front End Loading							
	FEL1		$2,000,000	1	lot	$2,000,000	
	FEL2		$20,000,000	1	lot	$20,000,000	
	FEL3		$100,000,000	1	lot	$100,000,000	
	FEL4	EPCM service costs		1	lot	$500,000,000	
Total							**$622,000,000**

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category.

Consulting Engineers of Saskatchewan website (www.ces.sk.ca) provides a list of members of this association which many EPCM companies subscribe to. All corporations or partnerships engaged in the practice of professional engineering or professional geoscience in Saskatchewan must hold a Certificate of Authorization issued by the Association of Professional Engineers and Geoscientists of Saskatchewan (APEGS). APEGS may be contacted (www.apegs.sk.ca) to determine if a company has a Certificate of Authorization to practice in Saskatchewan.

8. Details of Typical Potash Facilities

This chapter describes the major elements necessary for the construction of a greenfield potash facility including some description of the processes involved so as to give context for the indicative price breakdowns that follow.

8.1 Surface Infrastructure

Considerable infrastructure is required to service a 2 MTPY potash production facility, regardless of whether it is a conventional underground operation or a solution mine operation. These are outlined in the following sections.

8.1.1 Rail

Most potash product is transported from the production facilities by rail, often in specialized railcars designed to maximize the amount of potash per railcar and to facilitate long trains of railcars.

Canpotex is a marketing and logistics company that sells about 10 MTPY of potash from producers in Saskatchewan to markets outside of North America. In 2012 they operated approximately 5,500 railcars, each railcar with a capacity of 100 tonnes of potash. These railcars require wash and maintenance facilities. At present the trains are operated on Canadian Pacific (CPR) and Canadian National Railway Company (CN) rail networks that transport the potash to seaport facilities, largely at Vancouver, British Columbia and Portland, Oregon.

The North American market for potash is approximately 10 MTPY with about 7 MTPY of that supplied by the Saskatchewan producers. This is largely shipped by rail although a small percentage is transported by truck to local markets. The product that is shipped by rail within North America will require the same facilities as the Canpotex-shipped product.

A 2 MTPY potash facility will require 4-5 trains of 170 railcars each making a two-week round trip journey to destination ports or terminals. To facilitate the rail-based transport, rail spurs and onsite infrastructure are required for a new potash production facility. A nominal distance for a rail spur to the facility is considered in the Infrastructure CAPEX section below. Onsite rail infrastructure is included in Conventional Underground Mine Surface Plant CAPEX. Railcar and shipping costs are considered to be included in freight, transportation and distribution costs and are not covered here.

8.1.2 Roads

Roads will be required for access to the site during construction and operation. A nominal distance of four-lane access road from the Saskatchewan highway system is considered in the Infrastructure CAPEX section of this chapter. Onsite roads are included in Conventional Underground Mine Surface Plant CAPEX.

8.1.3 Natural Gas

Potash plants are large users of natural gas for process heating purposes. A gas transmission line installation estimate is included in the Infrastructure CAPEX section for a nominal distance.

8.1.4 Electrical

A high voltage transmission line is required to supply the large electrical energy requirements of a potash facility and is included in the section Infrastructure CAPEX. An allocation for the substation is included in Conventional Underground Mine Surface Plant CAPEX as well as estimates for the distribution within the facility.

8.1.5 Water

Water usage by a potash production facility is large and so this Guide provides for a buried water pipeline and pumping station to be installed with approximate costs provided in the section Infrastructure CAPEX.

8.1.6 Infrastructure CAPEX

Table 6: Conventional Underground Mine Infrastructure CAPEX

Service/Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Offsite Infrastructure							
Electrical Power Supply	230 kV	transmission line	$1,000,000	25	km	$25,000,000	$25,000,000
Rail Access	rail extension		$1,500,000	25	km	$37,500,000	$37,500,000
Road Upgrades	grading and paving	four lane paved	$2,000,000	25	km	$50,000,000	$50,000,000
Water Supply	pumps	4 x 1500 hp installed	$1,500,000	4	each	$6,000,000	
	pipeline	30" jacketed carbon steel	$2,500,000	25	km	$62,500,000	$68,500,000
Natural Gas Pipeline	pipeline	6" jacketed carbon steel	$1,500,000	25	km	$37,500,000	$37,500,000
Total							**$218,500,000**

Crown corporations in Saskatchewan provide the following infrastructure extensions:

- SaskPower – electrical transmission
- SaskWater – water transmission
- TransGas – natural gas transmission

Mainline railways in Saskatchewan are owned by CN and CPR who manage their own extensions in the province. Numerous shortline railways are operated within the province and are listed on the Government of Saskatchewan website at www.highways.gov.sk.ca/shortline-railways . Expansions of the shortline railway network will operate under provincial jurisdiction.

There are many civil contractors in Saskatchewan that provide road upgrades and extensions. These may be sourced by contacting the Saskatchewan Heavy Construction Association through their website at www.saskheavy.ca .

8.2 Conventional Underground Mine

This section provides a description of the underground and surface facilities for a new conventional underground potash facility. Capital costs for construction of these facilities as well as the indirect costs for this construction are provided at the end of each major section.

8.2.1 Underground Facilities

8.2.1.1 Background

There are currently eight conventional underground potash operations in Saskatchewan: Agrium Vanscoy, PCS Cory, PCS Allan, Mosaic Colonsay, PCS Lanigan, Mosaic Esterhazy K1 and K2, and PCS Rocanville Figure 3: Saskatchewan Potash depicts these as well as the solution potash mines in the province. It also outlines the extent of the Prairie Evaporite geological zone that hosts the potash-bearing members at interest.

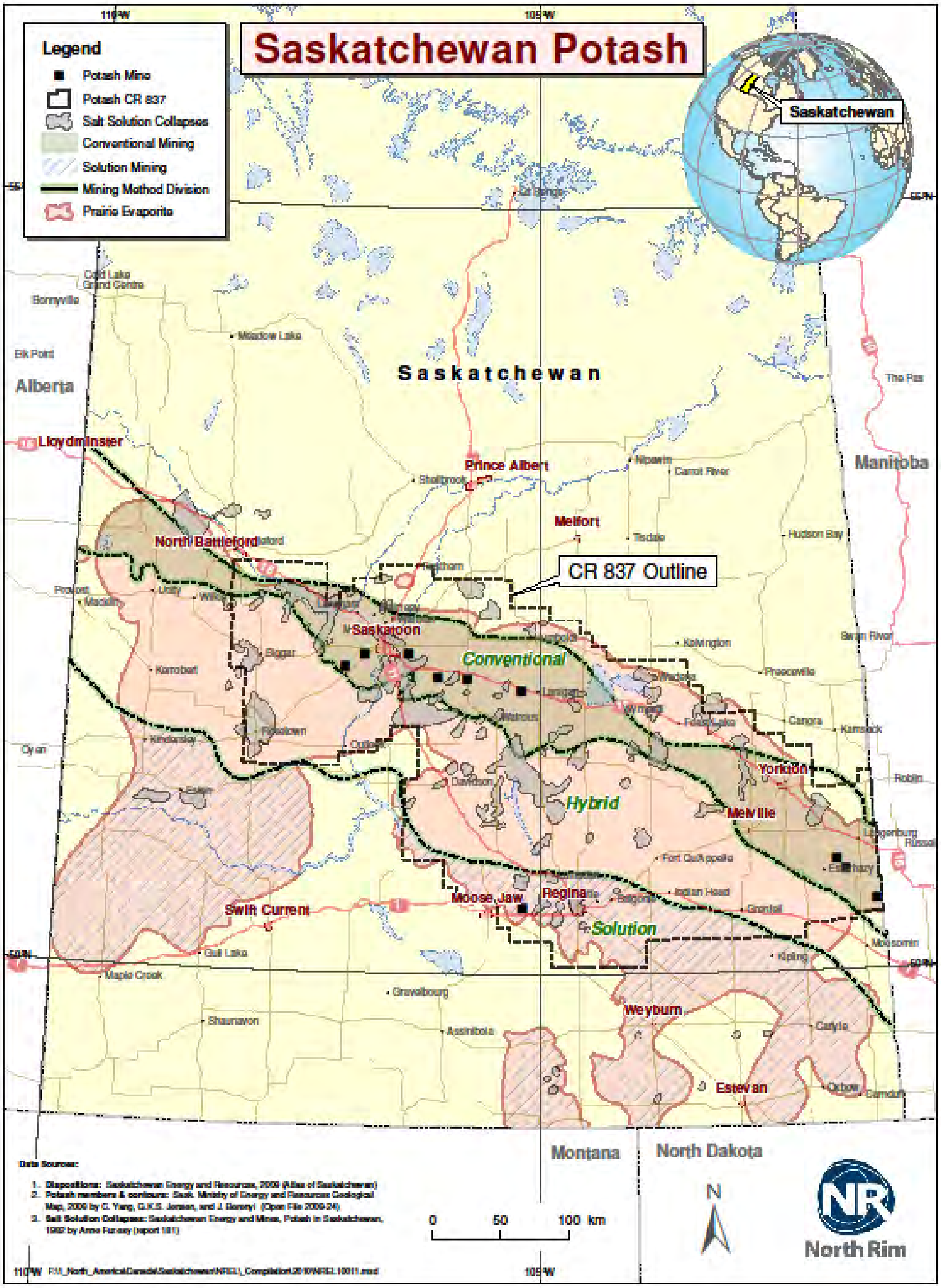

Figure 3: Saskatchewan Potash[14]

The Prairie Evaporite formation, shown in cross section in Figure 4: Potash Members In The Prairie Evaporite, occupies the Elk Point and Williston Basins in Alberta, Saskatchewan, North Dakota and Montana, and hosts the three minable potash horizons being exploited in Saskatchewan at various depths and locations.

[14] North Rim Exploration. (2012, 06 28). *Saskatchewan Potash.* http://www.northrim.sk.ca/pdf/NREL1001.pdf

In Saskatchewan, the Esterhazy Member hosts PCS Rocanville and Mosaic Esterhazy K1 and K2 underground mining operations. This deposit is thinner than the Patience Lake Member, has a slightly lower grade, but has a substantially lower clay content which simplifies the milling process.

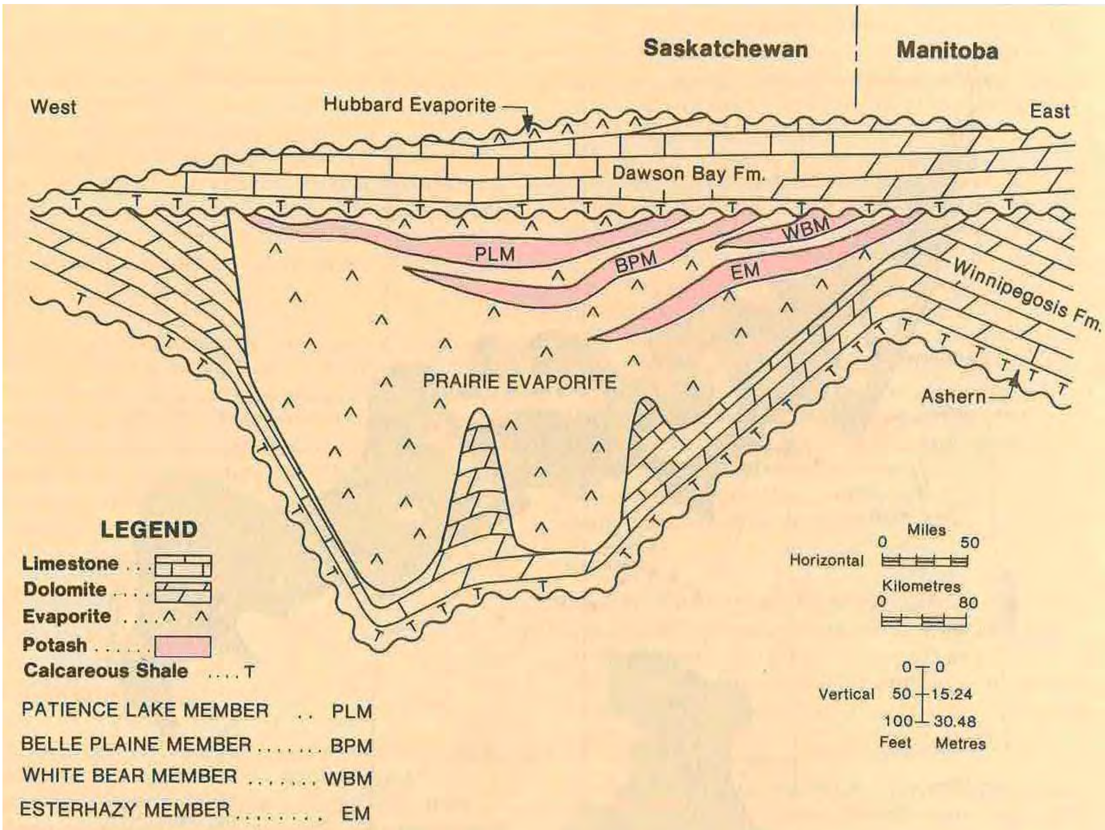

Figure 4: Potash Members In The Prairie Evaporite[15]

The Rocanville mine site is located in the southeast corner of Saskatchewan near the Manitoba border. The ore body is at 1000 m (3200 ft) below the surface with active underground operations covering 145 km^2 (35,800 acres). It has 950 km (570 miles) of tunnels, of which the farthest from the shaft is approximately 11 km (6.6 miles).

The Patience Lake Member hosts the PCS Lanigan, Mosaic Colonsay, PCS Allan, PCS Cory and Agrium Vanscoy conventional underground mining operations.

8.2.1.2 *Mine Access*

Existing underground mines have two shafts to access the orebody. In most cases, one shaft serves as a Service Shaft for manpower and materials access. The other shaft serves as the Production Shaft with hoist and furnishings to bring ore to the surface. One shaft will serve as the downcast shaft for fresh air while the other serves as the upcast or return air shaft. Due to

[15] Fuzesy, A. (1982). *Potash in Saskatchewan.* Saskatchewan: Saskatchewan Energy and Mines Report.

seasonal climatic variation in Saskatchewan, a large mine air heating plant is generally required in conjunction with the downcast air system.

Figure 5: Mine Shaft Detailed View[16]

Figure 5: Mine Shaft Detailed View shows a typical potash mine shaft during sinking. The majority of the existing shafts in Saskatchewan are lined with tubbing through the Blairmore formation, a sand and high pressure water layer, in order to prevent water inflows. It is necessary to maintain the tubbing in a narrow temperature range to prevent excessive shrinkage of the column which could lead to excessive water inflows. The tubbing columns in the upcast shaft are subjected to a more narrow temperature range over the course of the year and do not require the same level of maintenance compared to the downcast shaft lining. It is common practice to caulk leaking joints during the autumn period as the tubbing shrinks with the cooler temperatures as winter approaches.

All mines currently hoist ore from a single loading pocket location designed to use high velocity friction hoisting plants. Figure 6: Schematic Of A Hoisting Shaft and Figure 7: Hoisting Drive show typical shaft hoisting equipment. The shafts operate with rope guides in the majority of cases. This provides a hoisting system which is low maintenance when compared with rigid guide/set systems. Steel installation in most shafts is restricted to

[16] Potash Corp. (2010, 06 22). *Potash Capacity Development Overview*. http://www.potashcorp.com/media/POT_MineTour_2010_Moore_Presentation.pdf

headframe and mining level locations. Many of the guide ropes currently in use have over 10 years of service life with no need for immediate replacement.

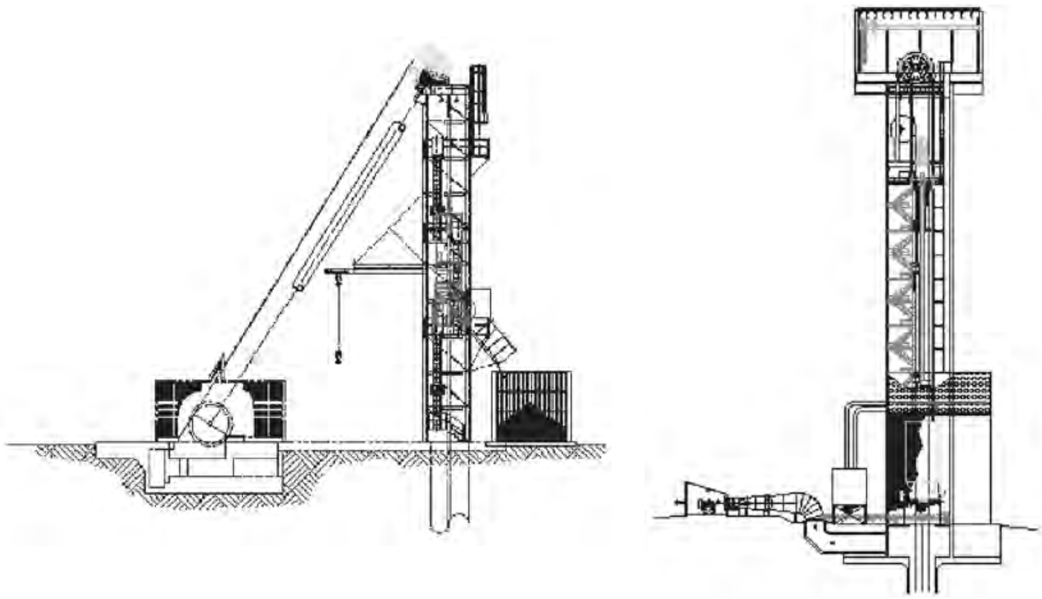

Figure 6: Schematic Of A Hoisting Shaft[17]

Figure 7: Hoisting Drive[18]

[17] Tiley, P. (2011). Hoisting Systems. In *SME Mining Engineering Handbook* (pp. 1295-1323). Society for Mining, Metallurgy, and Exploration, Inc.
[18] *Hepburn Double-Drum Hoist Systems.* (2011). Retrieved July 12, 2012, from Mining-Technology.com: http://www.mining-technology.com/contractors/winding/hepburn/hepburn1.html

8.2.1.3 Conventional Underground Mining – Underground General Layout

Every conventional underground mine in Saskatchewan uses some form of long room-and-pillar mining technology. A typical arrangement of this is shown in Figure 8: Conventional Underground Mining Long Room-And-Pillar.

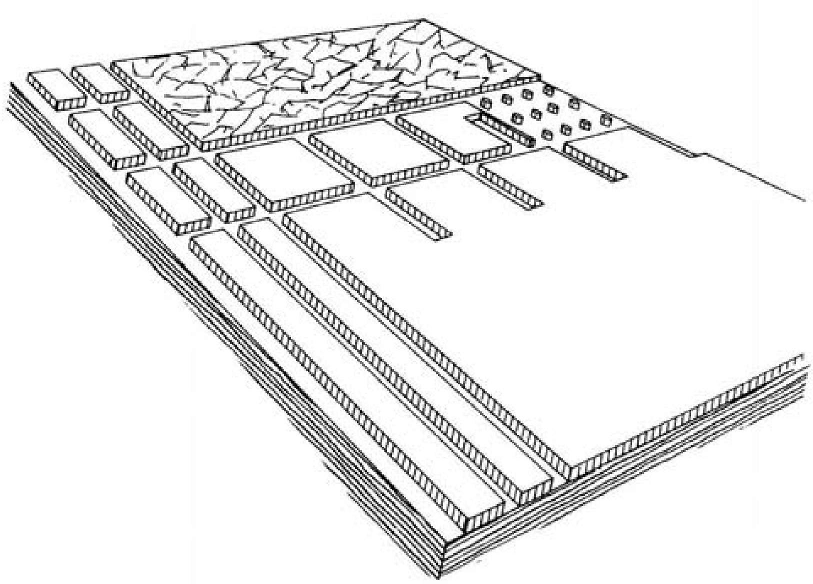

Figure 8: Conventional Underground Mining Long Room-And-Pillar[19]

Ore is mined from compartments called “rooms”. Ore walls are left intact to act as “pillars” to support the roof. Continuous miners mine the potash ore while conveyors and hoists transport it to the surface. It is a simple and efficient technology, however the ore recovery efficiency is only 40-60%, largely because of the amount of material that must be left in place as pillars.

The potash mines consist of an expansive maze of tunnels that span many kilometres. The mine is divided into panels that are then extracted in a planned sequence. An example of a typical mining panel is shown in Figure 9: Plan View Of PCS Rocanville. The lateral extent of the mine workings for each mine varies depending on when the mine went into production, the size of the mine lease and the historic production rate.

[19] Bullock, R. L. (1998). Room and Pillar Method of Open-Stope Mining. In *Techniques in Underground Mining* (pp. 162-170). Littleton: Society for Mining, Metallurgy, and Exploration.

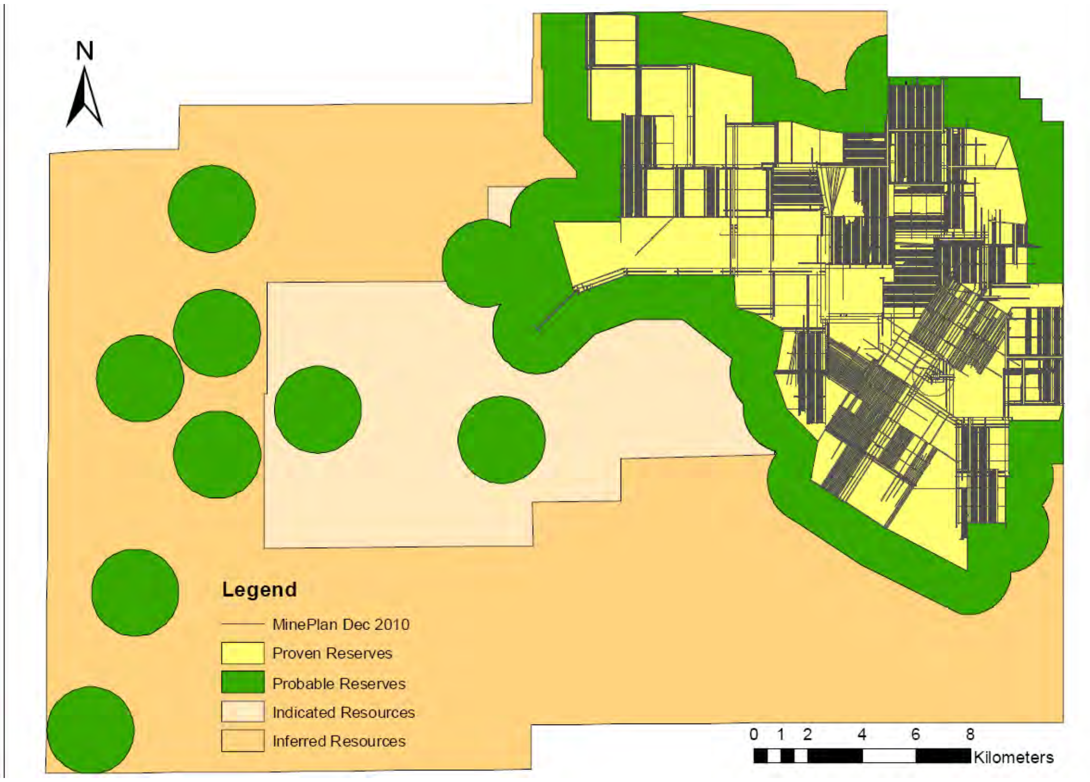

Figure 9: Plan View Of PCS Rocanville[20]

Shaft loadout facilities vary from mine to mine with no two systems being the same. All systems appear to have advantages and disadvantages. One common feature of all the operations is a decline which accesses the shaft bottom. All shaft bottoms can be accessed by wheeled vehicles for maintenance, as well as construction of additional facilities which may become necessary over the mine's life. A typical example is provided in Figure 10: Typical Shaft Pillar Mining Layout.

[20] Potash Corporation of Saskatchewan Inc. (2011). *NI 43-101 Technical Report on Rocanville Potash Deposit (KLSA-002).* Saskatoon: Potash Corporation of Saskatchewan.

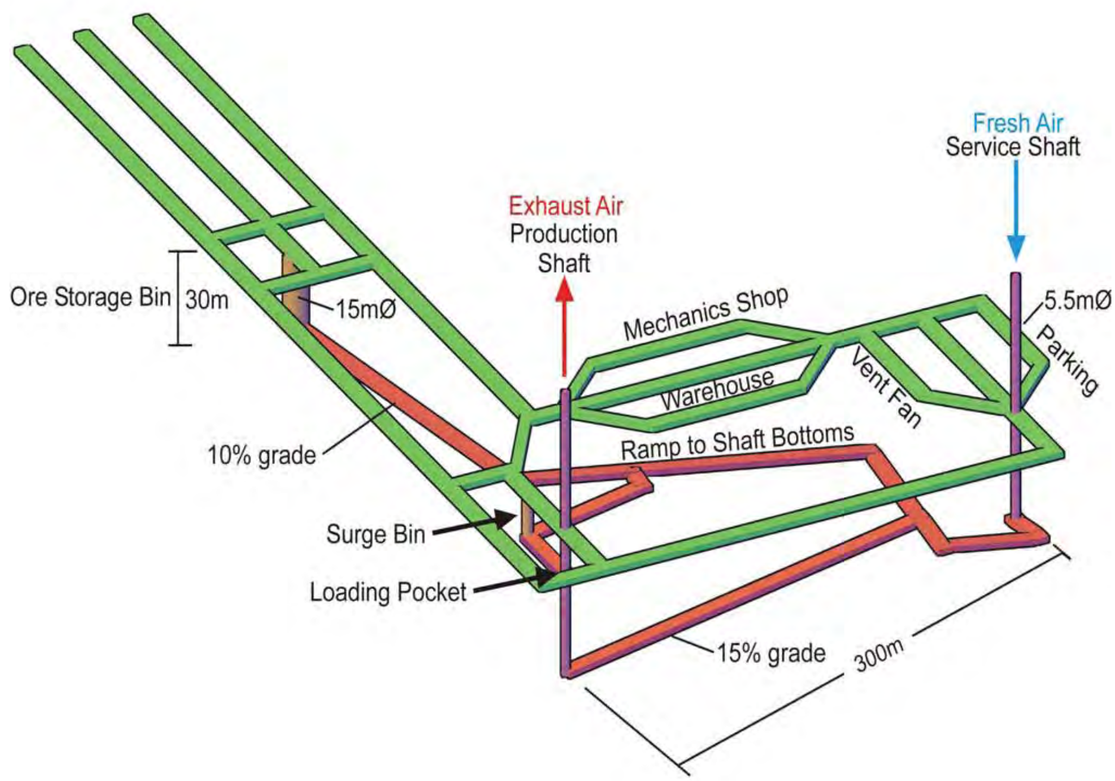

Figure 10: Typical Shaft Pillar Mining Layout[21]

8.2.1.4 Mine Production

The production operations in the area near Saskatoon generally utilize a mine and retreat method wherein the development headings are driven to the furthest extent of the particular mining block from the main haulage belt and then room and pillar operations are used to retreat back to the main line.

Rooms will advance at right angles from the main belt and from both sides of the belt for a distance in excess of 1000 m (3140 ft). A room will be advanced full seam height and generally two continuous miner widths (Figure 11: Continuous Miner First And Second Pass).

[21] BHP Billiton. (2008). Jansen Project Proposal to Saskatchewan Ministry of Envionment. Saskatoon: BHP Billiton

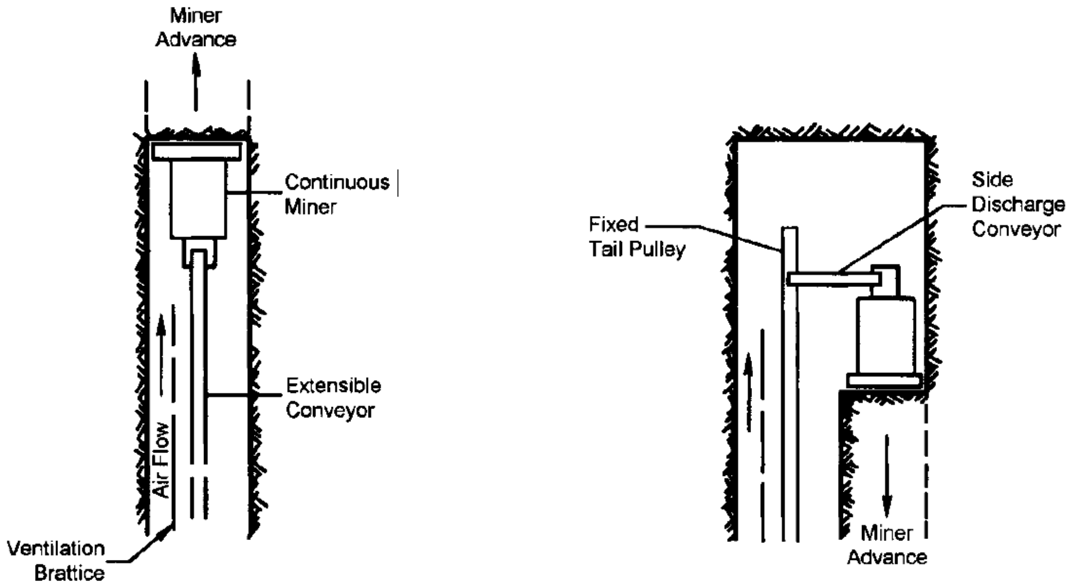

Figure 11: Continuous Miner First And Second Pass[22]

The excavation type depends upon the geological properties of the orebody. Figure 8: Conventional Underground Mining Long Room-And-Pillar shows the long room-and-pillar mining method. A slight variation is called the herringbone type which is shown in Figure 12: Schematic Of Mining Systems. This variation is usually implemented when ground conditions are less stable.

[22] Bullock, R. L. (1998). Room and Pillar Method of Open-Stope Mining. In *Techniques in Underground Mining* (pp. 162-170). Littleton: Society for Mining, Metallurgy, and Exploration.

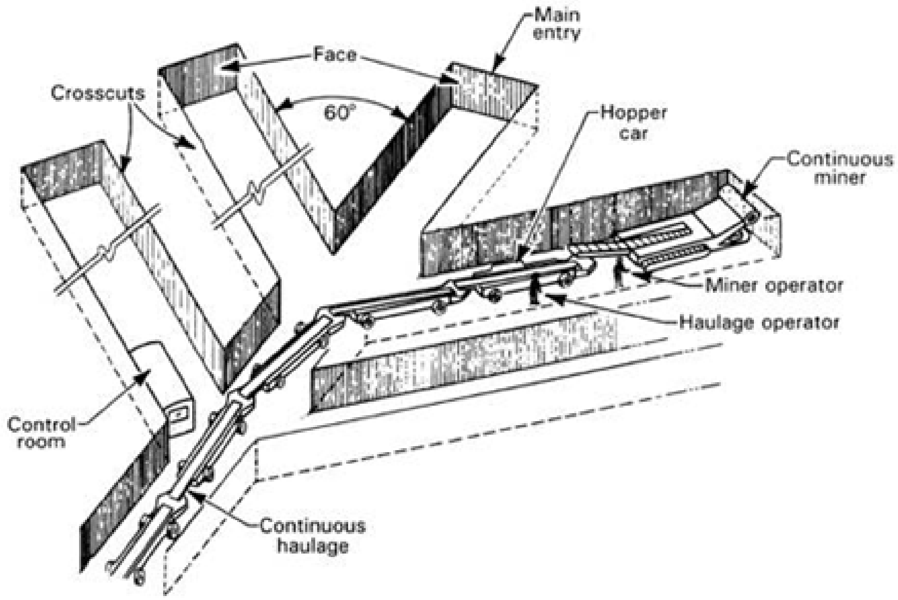

Figure 12: Schematic Of Mining Systems[23]

In the Esterhazy and Rocanville areas, ground conditions are considerably more stable and allow the excavation of very wide rooms. At PCS Rocanville the rooms are excavated three passes wide with four rotor continuous miners (Figure 13: Continuous Miner). The resulting rooms are 26 m (82 ft) wide and can be several kilometres in length. A typical mine face is shown in Figure 14: Continuous Mining Operation Face.

Figure 13: Continuous Miner[24]

[23] Sammarco, J. J. (1998). *Concluding Evaluation of a Continuous Haulage Guidance Sensor.* Pittsburg: US Department of Health and Human Services.

[24] Mills, R. (2010, 09 25). *Three Junior Potash Developers Are Sitting on Big Assets*. Retrieved 06 2012, from Gold Speculator: http://www.gold-speculator.com/ahead-herd/38926-three-junior-potash-developers-sitting-big-assets.html

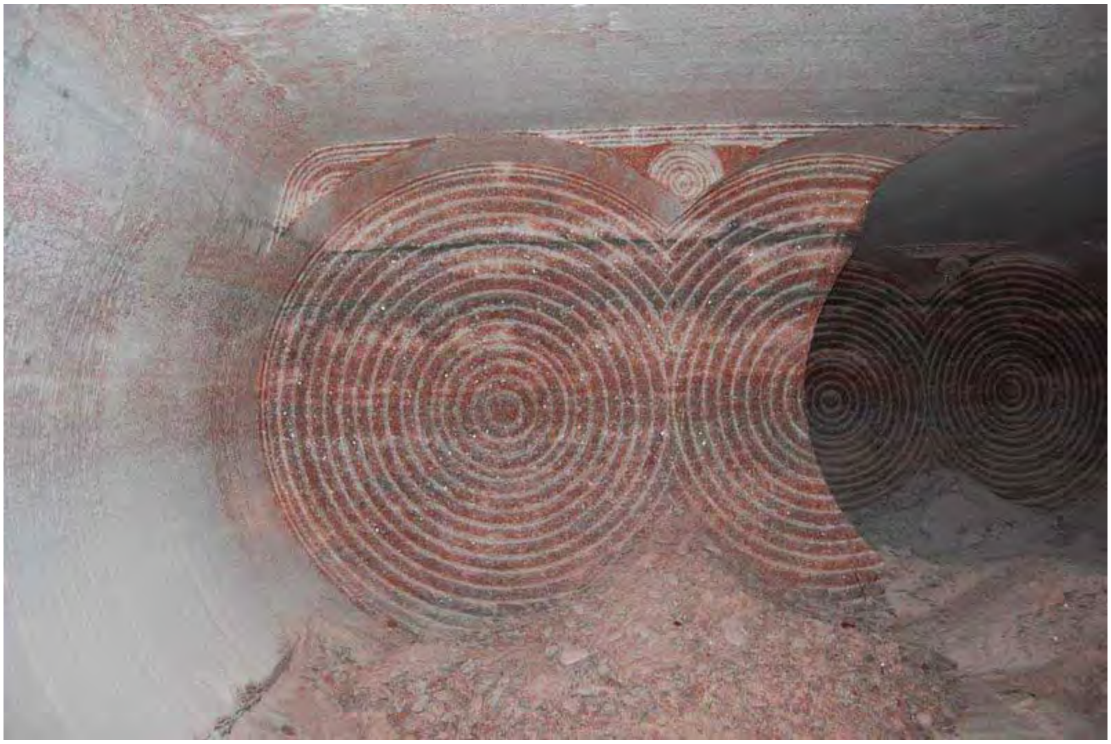

Figure 14: Continuous Mining Operation Face[25]

8.2.1.5 Ore Transport

Mined ore is transported from the continuous miners to the shaft by conveyor belts. Main belts are generally 1.83 m (6 ft) wide and feeder belts from mining blocks are 1.22 m (4 ft) or 1.37 m (4.5 ft) wide; room belts are generally 0.91 m (3 ft) wide. The mined ore is typically stored in a system of bins or bunkers at mine level to allow mining to continue when the shaft is not available for hoisting. During hoisting operations the ore will be withdrawn from the bins, crushed and loaded into skips for hoisting (Figure 15: Schematic Of Room-And-Pillar Mining, Hoisting And Shafts).

[25] *Potash: What is it good for?* (2010, August 17). Retrieved July 12, 2012, from Globe and Mail: http://www.theglobeandmail.com/globe-investor/potash-what-is-it-good-for/article4324906/

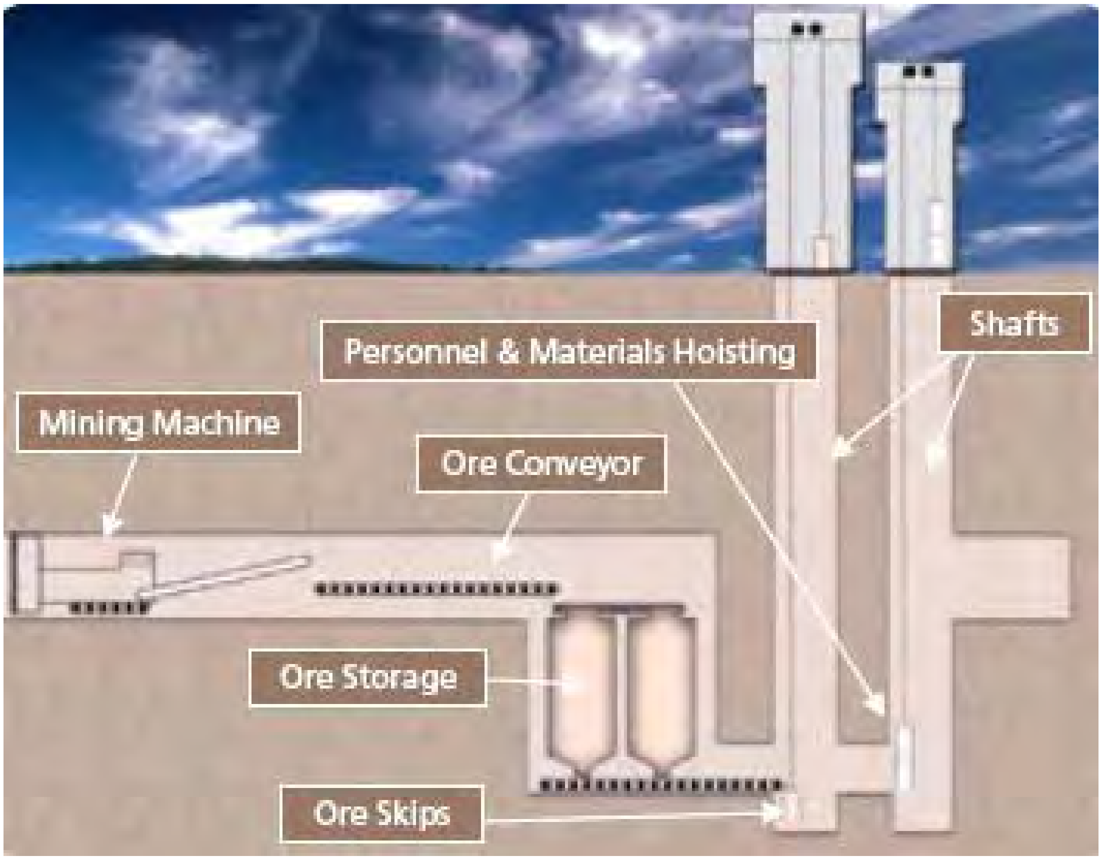

Figure 15: Schematic Of Room-And-Pillar Mining, Hoisting And Shafts

Three types of conveyance systems are typical for potash mines in Saskatchewan:

- Extensible/bridge conveyors (Figure 16: Extensible Conveyor).
- Room conveyors (Figure 17: Room Conveyor).
- Mainline conveyors (Figure 18: Mainline Conveyor).

The size and length will vary considerably depending on the application and desired production rate.

Figure 16: Extensible Conveyor[26]

Figure 17: Room Conveyor[27]

[26] *Coal Mine Used Extensible Belt Conveyor.* (2010). Retrieved July 12, 2012, from Hebei Xinshan Conveyor Machinery Co., Ltd.: http://en.xsconveyor.com/products_detail/&productId=e94c02f0-9bd3-4e4d-af9b-002a6baed1bb.html

[27] CNN Money. (2012). *Mining for Giant Profits*. Retrieved 07 2012, from CNN Fortune & Money: http://money.cnn.com/galleries/2008/fortune/0804/gallery.mosaic.fortune/4.html

Figure 18: Mainline Conveyor[28]

Figure 19: Flexible Conveyor (Flexiveyor)[29]

[28] CNN Money. (2012). *Mining for Giant Profits*. Retrieved 07 2012, from CNN Fortune & Money: http://money.cnn.com/galleries/2008/fortune/0804/gallery.mosaic.fortune/4.html

[29] *Flexiveyor.* (2012). Retrieved July 12, 2012, from Prairie Machine and Parts: http://pmparts.com/wp/products/flexiveyor

At the surface, the skips discharge into mine ore bins which serve as temporary storage to smooth the flow from the mine to the mill. The ore is either conveyed to the mill for processing or stored in a surface ore storage facility if the hoisting capacity exceeds the milling capacity.

8.2.1.6 Mine Services and Facilities

All the main mining equipment is electrically driven. Main power fed to the mine is generally 13.8 kV which is stepped down to 4160 volts to feed the continuous miners and further stepped down to 600 V for the auxiliary equipment and fans. Portable motor control centers are advanced with the face at regular intervals to provide power to the various units. These are generally advanced every 300 to 400 m (940 to 1260 ft) to prevent excessive voltage reduction to the various pieces of equipment.

The area near the shaft pillar houses a majority of the infrastructure required to support mining operations. These typically include:

- Main Electrical Room.
- Equipment maintenance shop.
- Electrical shop.
- Material storage.
- Fuel storage.
- Explosives storage.

There are usually several items of diesel powered equipment within the mine to assist in miscellaneous excavations, construction, etc. This may include diesel load-haul-dump equipment, conventional front end loaders, skid steer loaders, support and maintenance vehicles. Miscellaneous excavations are often completed with a roadheader (Figure 20: Miscellaneous Roadheader) and load-haul-dump combination.

Figure 20: Miscellaneous Roadheader[30]

The mining equipment employed in Saskatchewan mines is mechanically complex and benefits from rigorous preventive maintenance programs. Machines are normally shut down for several hours each day for maintenance and repair. Most production takes place during the night shift. Major rebuilds are scheduled on the mining equipment at regular intervals. Many of the continuous miners in current operation are built on the original frames which may be 40 years old. The mechanical and electrical aspects have been modified several times to reflect updated technology.

Due to rapid rates of advance it is not feasible to advance air and water lines with the continuous miners. Drilling, when required, is done dry (no free silica) with rotary electric/hydraulic equipment or pneumatic percussion drills powered by portable air compressors. Blasting operations are generally restricted to excavations required for belt drive installations, bin excavations or to blast down large areas of loose ground if and as they develop.

8.2.1.7 Conventional Underground Mine CAPEX

The following Table 7: Conventional Underground Mine CAPEX provides a breakdown of the major sections of a shaft sinking and mine development project in Saskatchewan. These sections are further broken down into categories of components and indicative costs are assigned to these categories.

[30] Potash Corp. (2007). *Global Potash Supply and Greenfield Overview.* New York: Potash Corp.

Table 7: Conventional Underground Mine CAPEX

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Mine Service and Production Shafts							
Service Shaft Freezing	Freeze Plant contractor will typically provide:						
		brine	$100,000	1	lot	$100,000	
		circulation tank	$50,000	1	lot	$50,000	
		pumps	$50,000	1	lot	$50,000	
		meters	$50,000	1	lot	$50,000	
		monitoring instrumentation	$100,000	1	lot	$100,000	
		flanges and pipe fittings	$100,000	1	lot	$100,000	
		brine piping	$50,000	1	lot	$50,000	
		ammonia	$100,000	1	lot	$100,000	
		polyethylene down pipes	$100,000	1	lot	$100,000	
		freeze plant	$1,000,000	1	lot	$1,000,000	
		freeze plant labour	$2,500,000	1	lot	$2,500,000	
		engineering lab tests	$100,000	1	lot	$100,000	
		transportation	$100,000	1	lot	$100,000	
		insurance and bonding	$100,000	1	lot	$100,000	
		drilling and casing		1	lot	$40,000,000	
		earthworks	$500,000	1	lot	$500,000	
							$45,000,000
Service Shaft Freezing	Freeze Plant contractor will typically provide:						
		brine	$100,000	1	lot	$100,000	
		circulation tank	$50,000	1	lot	$50,000	
		pumps	$50,000	1	lot	$50,000	
		meters	$50,000	1	lot	$50,000	
		monitoring instrumentation	$100,000	1	lot	$100,000	
		flanges and pipe fittings	$100,000	1	lot	$100,000	
		brine piping	$50,000	1	lot	$50,000	
		ammonia	$100,000	1	lot	$100,000	
		polyethylene down pipes	$100,000	1	lot	$100,000	
		freeze plant	$1,000,000	1	lot	$1,000,000	
		freeze plant labour	$2,500,000	1	lot	$2,500,000	
		engineering lab tests	$100,000	1	lot	$100,000	
		transportation	$100,000	1	lot	$100,000	
		insurance and bonding	$100,000	1	lot	$100,000	
		drilling and casing	$40,000,000	1	lot	$40,000,000	
		earthworks	$500,000	1	lot	$500,000	
							$45,000,000
Service Shaft Sinking	Construction Distributables	will typically include:					
		mobilization	$2,500,000	1	lot	$2,500,000	
		surface setup	$5,000,000	1	lot	$5,000,000	
		sinking setup	$15,000,000	1	lot	$15,000,000	$22,500,000

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	Shaft Sinking	will typically include:					
		permanent works	$35,000,000	1	lot	$35,000,000	
		setup and pre-sink	$10,000,000	1	lot	$10,000,000	
		sinking	$70,000,000	1	lot	$70,000,000	
		change over	$7,500,000	1	lot	$7,500,000	$122,500,000
Production Shaft Sinking	Construction Distributables	will typically include:					
		mobilization	$2,500,000	1	lot	$2,500,000	
		surface setup	$5,000,000	1	lot	$5,000,000	
		sinking setup	$15,000,000	1	lot	$15,000,000	$22,500,000
	Shaft Sinking	will typically include:					
		permanent works	$35,000,000	1	lot	$35,000,000	
		setup and pre-sink	$10,000,000	1	lot	$10,000,000	
		sinking	$70,000,000	1	lot	$70,000,000	
		change over	$7,500,000	1	lot	$7,500,000	$122,500,000
Mine Equipment	Shaft Equipment	will typically include:					
		fans	$5,000,000	1	lot	$5,000,000	
		pumps	$2,000,000	1	lot	$2,000,000	
		production hoist	$35,000,000	1	lot	$35,000,000	
		service hoist	$20,000,000	1	lot	$20,000,000	
		service cages	$5,000,000	1	lot	$5,000,000	
		sheaves	$5,000,000	1	lot	$5,000,000	
		production skips	$5,000,000	1	lot	$5,000,000	
		production headframe	$30,000,000	1	lot	$30,000,000	
		service headframe	$25,000,000	1	lot	$25,000,000	
		production hoist house	$15,000,000	1	lot	$15,000,000	$147,000,000
	Shaft Electrical		$10,000,000	1	lot	$10,000,000	$10,000,000
Mine Infrastructure and Pillar Development							
	Shaft Pillar , Main Line and Branch Drift Development			1	lot	$160,000,000	$160,000,000
	U/G Infrastructure	will typically include:	$15,000,000	1	lot	$15,000,000	
		fans					
		regulators					
		ventillation doors					
		fuel and lube bay					
		electrical sub-station					
		sumps					
		storage area					
		refuge station					
		latrines					
		service garage					$15,000,000
	U/G Mobile Equipment	will typically include:					
		load haul dump loaders	$6,000,000	1	lot	$6,000,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		skid steer loaders	$1,000,000	1	lot	$1,000,000	
		forklifts	$1,000,000	1	lot	$1,000,000	
		road headers	$7,500,000	1	lot	$7,500,000	
		rockbolters	$1,000,000	1	lot	$1,000,000	
		scalers	$500,000	1	lot	$500,000	
		scissor lifts	$1,000,000	1	lot	$1,000,000	
		shuttle cars	$5,000,000	1	lot	$5,000,000	
		supervisor vehicles	$5,000,000	1	lot	$5,000,000	
		personnel carriers	$5,000,000	1	lot	$5,000,000	
		lube vehicles	$2,000,000	1	lot	$2,000,000	
		flatbed trucks	$500,000	1	lot	$500,000	
		deisel compressors	$1,000,000	1	lot	$1,000,000	
		tramming unit	$500,000	1	lot	$500,000	
		trades vehicles	$1,000,000	1	lot	$1,000,000	
		water truck	$500,000	1	lot	$500,000	
		continuous boring machne	$5,000,000	15	each	$75,000,000	$107,500,000
	U/G Ore Handling Equipment	will typically include:					
		conveyors	$25,000,000	1	lot	$25,000,000	
		trippers	$100,000	1	lot	$100,000	
		transfer points	$1,000,000	1	lot	$1,000,000	
		bins	$12,000,000	1	lot	$12,000,000	
		loading pockets	$2,000,000	1	lot	$2,000,000	$40,100,000
Total							**$859,600,000**

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category.

8.3 Conventional Underground Mine Surface Processing

The following section describes the surface processes required for a representative conventional underground mine potash facility. The description provides the context for the capital expenditures required for this plant provided later in this Guide in Table 8: Conventional Underground Mine Surface Plant CAPEX and Conventional Underground Mine Generic Flowsheet.

8.3.1 Conventional Underground Mine Generic Flowsheet

Refer to the generic flowsheet for a conventional underground mine operation presented in Figure 21: Conventional Underground Mine Operation Flowsheet. About 70% of the world total potash and almost 90% of fertilizer grade potassium chloride is produced in plants utilizing conventional Froth Flotation and Compaction which is depicted in this flowsheet. A variation in conventional processing is the Heavy Media Separation used when mining the Esterhazy Member. This is applied due to the unique mineralogy of that ore.

This flowsheet is intended for educational purposes only and should not be used as a basis for design. The subsequent sections describe these operations.

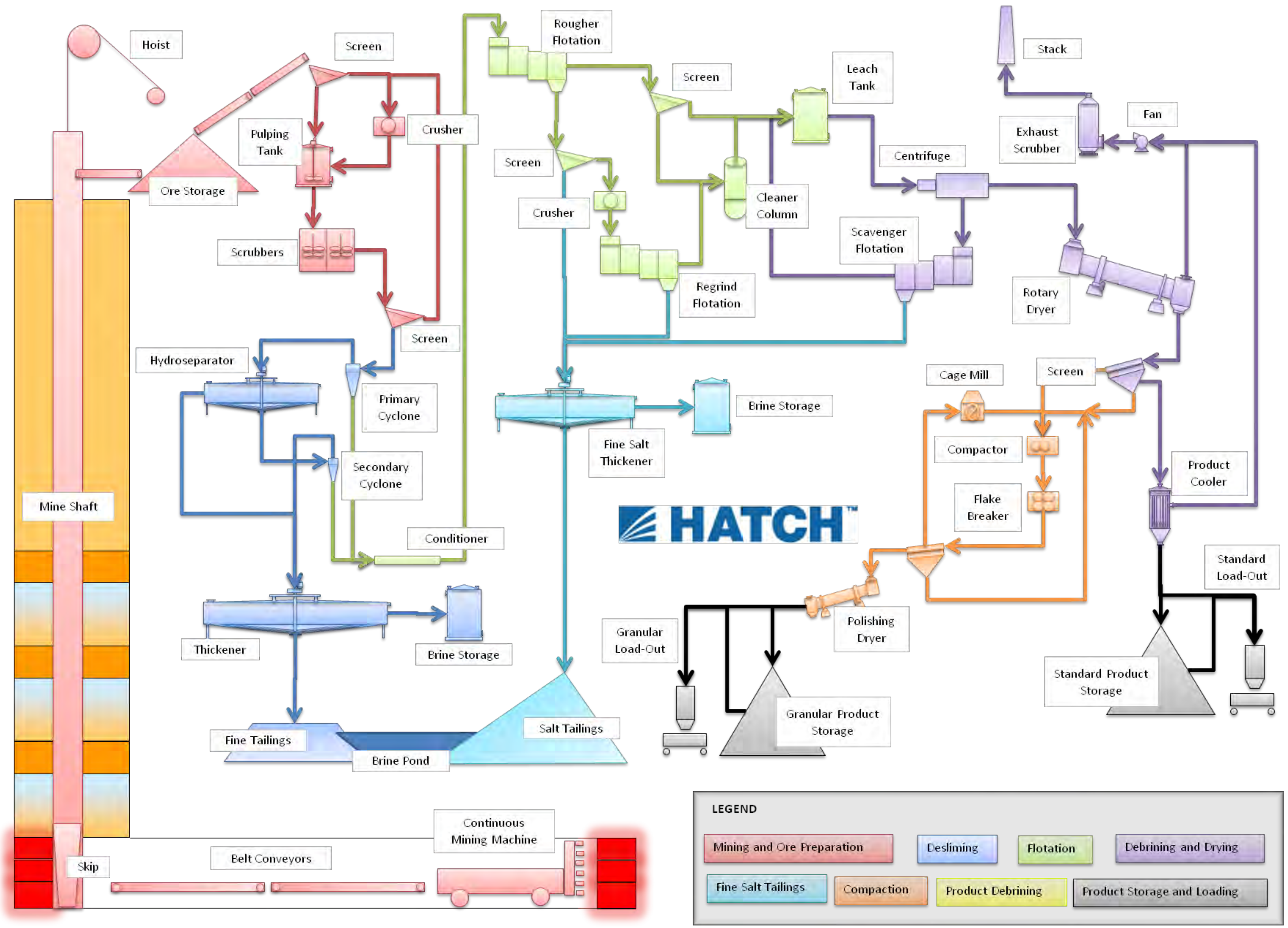

Figure 21: Conventional Underground Mine Operation Flowsheet

8.3.2 Conventional Underground Mine Surface Processes

8.3.2.1 Raw Ore and Storage Handling

The Run-Of-Mine (ROM) ore is produced by continuous miners as described in the previous section Underground Facilities. The ore is usually first processed underground through a jaw crusher that reduces the largest lumps to minimize transportation problems between the mine and the mill. The ore is further reduced in size by roll or impact crushers before it is delivered to the mill.

Ore is stored on surface in bins or a combination of bins and storage buildings known as barns. When ore is needed from the barns, it is pushed to a central drag conveyor using mobile equipment such as bulldozers, backhoes or plows. These barn buffers allow a continuous feed to the mill which reduces fluctuation in the feed rate, which would otherwise cause problems in downstream processing.

8.3.2.2 Front End Crushing and Screening

Potash plants, except for Crystallization plants, (which are discussed in detail in section Solution Mine Surface Processing) start with a comminution section. The objective of this section is to reduce the particle size distribution of the ROM ore to achieve liberation of the potassium chloride (KCl) from the sodium chloride (NaCl) crystals for subsequent downstream steps. Liberation must be complete, as the final product must be greater than 95.5% KCl. Although the ore has been crushed prior to this point, the KCl is not yet completely liberated.

Potash ore is considered a soft rock, with a typical Bond Work Index between 7 and 9. The simplest comminution circuits involve single-stage dry crushing using impactors (Figure 37: Typical Solution Mine Flowsheet, Figure 22: Impact Crusher) in closed circuit with vibrating screens. The size of the screen cloth openings depends on the liberation size of the ore. This will vary from site to site because each ore body has somewhat unique mineralogy.

Crushing plants are operated continuously in wet or dry circuits. Dry circuits have less corrosion of equipment, but wet circuits are cleaner, have earlier slimes wetting and potentially improved liberation. Wet circuits have more efficient screening and therefore lower associated capital costs and easier materials handling.

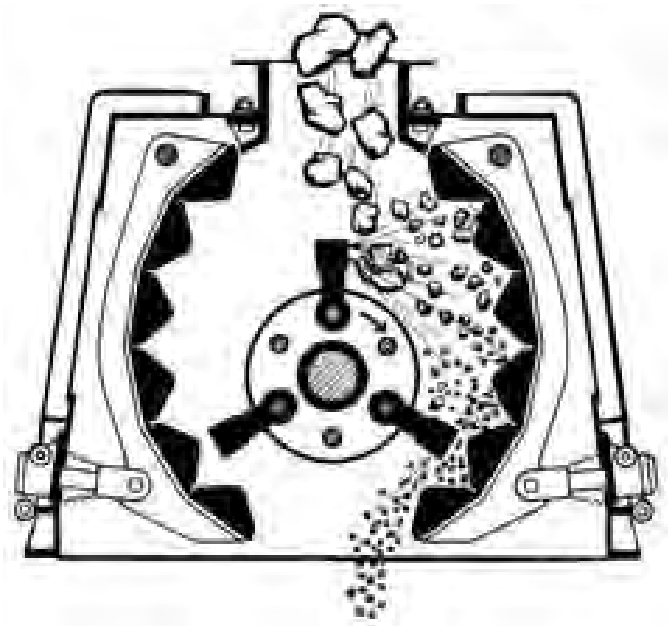

Figure 22: Impact Crusher[31]

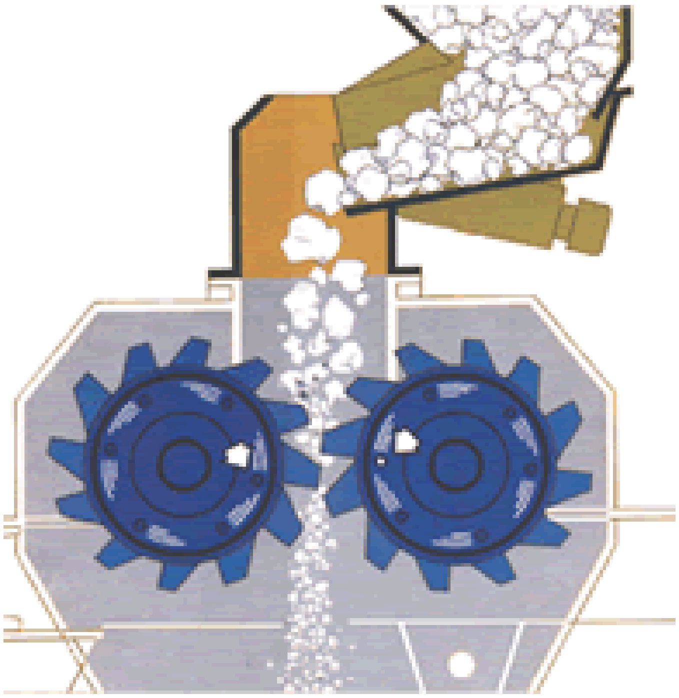

Figure 23: Double Roll Crushers[32]

[31] *More on Size Reduction Technology.* (2012). Retrieved July 11, 2012, from Pennsylvania Crusher: http://www.penncrusher.com/size_reduction/more_on_size_reduction_technology.cfm
[32] *Roller Crusher.* (2011). Retrieved July 11, 2012, from SPB: http://www.crushermaker.com/crusher/roller-crusher.html

Figure 22: Impact Crusher and Figure 23: Double Roll Crushers show different options for crushing the raw ore. Roll crushers have the advantage of lower fines generation, making them ideal for primary crushing. The volume of fines produced by impact crushers is dependent upon rotor speed. However, roll crushers have limited throughput capacity and may be subject to jamming, necessitating the use of a different type of crusher for the finer, secondary crushing.

Other crushing methods are available such as Bradpactors, cage mills, reversible impactors and single roll crushers. Double roll crushers are well suited for potash ore which has low hardness and low abrasiveness.

8.3.2.3 Scrubbing and Desliming Section

In Saskatchewan, insolubles occur as mud seams in the ore beds. They are a mixture of dolomite (MgO), hematite (Fe_2O_3) and minor amounts of clay and anhydrite. The wetting of these fine liberated particles results in dispersion in the brine. Their fine particle size distribution increases their surface area, which leads to increased absorption of the chemical potash collectors and hence negatively impacts flotation.

Scrubbing is designed to liberate the insolubles attached to the potash particles. Slimes are liberated through several stages of high-intensity particle-on-particle attrition scrubbing (Figure 24: Attrition-Scrubbing Cells).

Figure 24: Attrition-Scrubbing Cells[33]

The objective of desliming is to remove the insolubles (slimes) which were liberated by scrubbing. Desliming circuits vary widely due to the slime content in the ore. Two-stage scrubbing is common in mine areas with high insoluble ores.

33 *Attrition Scrubber.* (2008). Retrieved 11 2012, July, from West Pro Machinery.

Hydrocyclones, siphonsizers, cross-flow separators, lamella hydroseparators and thickeners are most commonly used to deslime ores. They all utilize the differences in particle size between the slimes and the larger KCl and NaCl crystals as a principle for separation.

8.3.2.4 Flotation Section

Flotation is the primary means to separate KCl and NaCl particles. The mixture of particles is conditioned to selectively float KCl in a circuit of multiple flotation cells that recover as much KCl as possible.

8.3.2.4.1 Conditioning

Coarse material is conditioned separately from fine material in order to optimize reagent usage and promote coarse particle flotation. Both coarse and fine material are conditioned with a depressant, a potash collector and a frother.

Coarse conditioning is usually done at high slurry densities in either rotating drums or screw conveyors. Fines conditioning is usually done in a series of agitated tanks at a lower slurry density.

8.3.2.4.2 Chemicals

Polyelectrolytes, usually referred to as slime depressants, are applied to reduce the harmful effect of residual clays on sylvite flotation. Natural starches are the most commonly used depressants along with guars and carboxy-methyl-cellulose (CMC).

The collector is used to render the KCl particles hydrophobic while leaving the NaCl hydrophilic. The typical collector used for the KCl flotation is amine. Float oil is a heavy petroleum product that seems to increase the effectiveness of amine in coarse flotation.

The frother is used to stabilize the bubbles so that they do not burst before reaching the top of the flotation cell. Terpene alcohols, alkylpolyglycol ethers, and methyl isobutyl carbinol (MIBC) are the common frothers used in flotation.

8.3.2.4.3 Flotation Process

Flotation is used to separate the KCl from NaCl. As mentioned in 8.3.2.4.2 Chemicals, amine renders KCl hydrophobic while leaving NaCl hydrophilic. When bubbles are introduced in a flotation cell, the hydrophobic KCl particles attach to the bubbles and float to the surface, thus separating the two salts.

Since potash ores contain water-soluble salts, flotation has to be carried out in saturated brine, a highly concentrated electrolyte system. The properties of an aqueous system at such a high electrolyte concentration are very different from dilute aqueous solutions employed in conventional flotation processes. The unique features of potash flotation are the size of floated particles and the rapid kinetics of the flotation.

A typical flotation circuit is found in Figure 21: Conventional Underground Mine Operation Flowsheet and includes Rougher Flotation, Regrind Flotation, Scavenger Flotation and Cleaner Column.

Rougher flotation will float large KCl crystals which are usually of high purity. The tails have a fraction of NaCl, which is disposed of as tails. It also consists of a fraction of liberated KCl particles that did not float due to their slow kinetics and non-liberated KCl. This fraction is sent to the regrind circuit. The regrind circuit crushes the fraction in rod mills or cage mills, screens and floats this fraction to increase KCl recovery. Scavenger flotation recovers very fine KCl lost in the dewatering stage. The floated product from all the flotation cells is sent to cleaner columns to separate any entrained NaCl. Flotation tails are thickened in hydrocyclones and other types of thickeners and pipelined to tailings ponds.

Coarse and fine potash are often floated separately. They can be floated together however they must always be conditioned separately.

Traditional rougher flotation cells are rectangular Denver cells as shown in Figure 25: Classic "Denver" Flotation Cells.

Contact-type flotation cells, shown in Figure 26: Contact-Type Flotation Cells, can be used for scavenger flotation and cleaner columns.

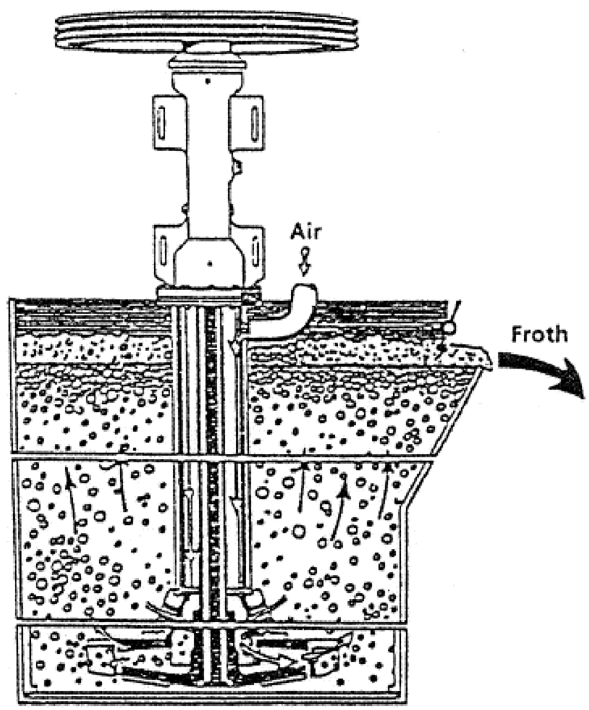

Figure 25: Classic "Denver" Flotation Cells[34]

[34] Kemper, M. (1999). State-of-the-art and new technologies in flotation deinking. *International Journal of Mineral Processing* , 317-333.

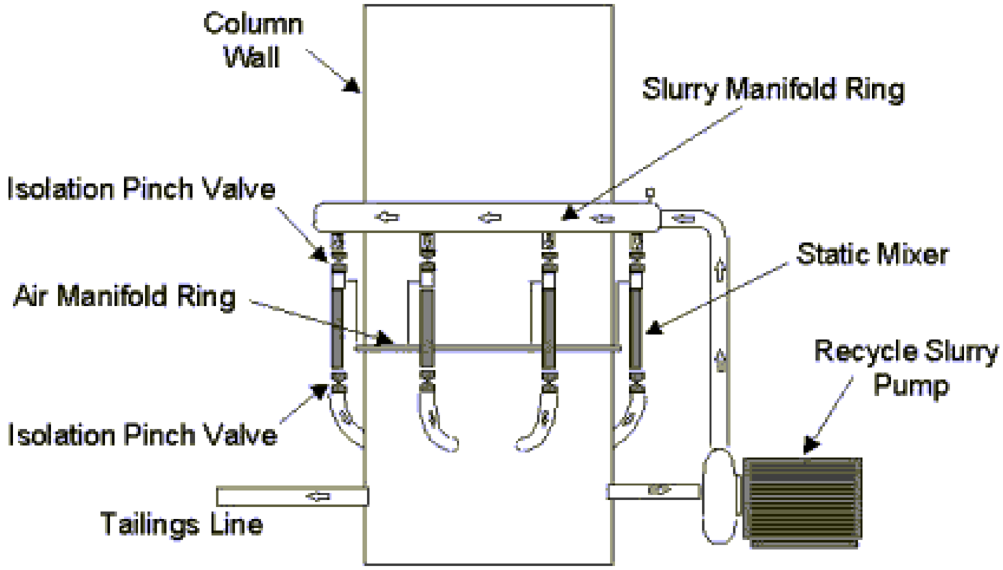

Figure 26: Contact-Type Flotation Cells[35]

8.3.2.5 *Heavy Media Separation*

Heavy media separation using magnetite (Fe_3O_4) and cyclones is used by two operations mining the Esterhazy member in Saskatchewan (not depicted in the flowsheets here). This process produces a separation of the ROM ore at a very coarse size into three streams: tailings, product and middlings. Middlings are subsequently ground and subjected to conventional flotation. This separation process reduces reagent costs, debrining and drying, and compaction may not be required. However, maintenance costs are slightly higher because of the abrasive properties of the magnetite used in the process.

8.3.2.6 *Debrining*

The term "Debrining" is used in the potash industry to describe the removal of brine from the potash product. It is equivalent to the term "Dewatering" used in other industries.

The goals of debrining are to obtain low moisture in the product stream in order to minimize drying costs and to remove adhering brine for increased product purity. In Saskatchewan, screen-bowl centrifuges (Figure 27: Screen-Bowl Centrifuge) are used because they can manage a wide range of feed densities and still effectively reduce moisture.

Screen-bowl centrifuges have a short screen section on the product end of the bowl that gives a greater moisture reduction and the capability of applying a displacement wash to increase KCl purity. Brine removal is important in order to maximize the recovery of process brine.

[35] *Column Flotation.* (2003). Retrieved 12 2012, July, from Metso Minerals Cisa: http://www.svedala-cisa.com/column/columns.htm

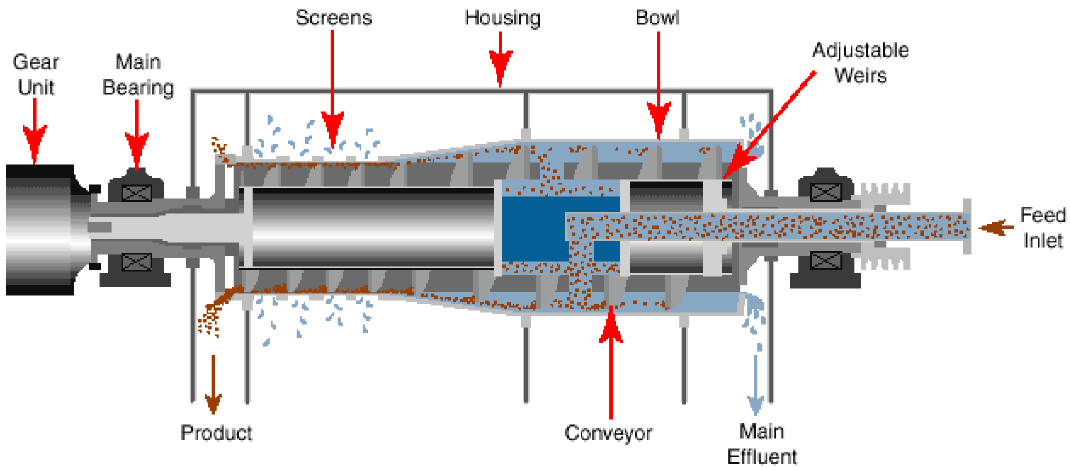

Figure 27: Screen-Bowl Centrifuge[36]

8.3.2.7 Drying

Co-current rotary (Figure 28: Rotary Dryer) and fluidized-bed dryers (Figure 29: Fluid-Bed Dryers for Industrial Minerals) are both used in the industry. Resulting product moistures are less than 0.2% after drying. Dried product is sent to screening, where it can be sorted for saleable product or compaction.

Fines entrained in the gas stream go to cyclones where they are recovered and sent to the Compaction Circuit or a Crystallization Circuit. Dryer exhaust gases are scrubbed to remove any remaining dust in wet scrubbers. Impingement-type scrubbers using brine solutions are the most effective. The scrubber effluent makes a small contribution to plant recovery of potash since this effluent becomes part of the process brine. Alternatively, one producer uses electrostatic precipitation effectively to clean up dryer exhaust gases.

The wet exhaust gases are corrosive and fibreglass reinforced plastics are extensively used for fan ducting and exhaust stacks. All dryers usually run on natural gas, although most are equipped with dual fuel burners for oil usage in periods of natural gas interruption.

[36] *Screen Bowl Decanter Centrifuge.* (2010). Retrieved September 30, 2011, from Andritz: http://www.andritz.com

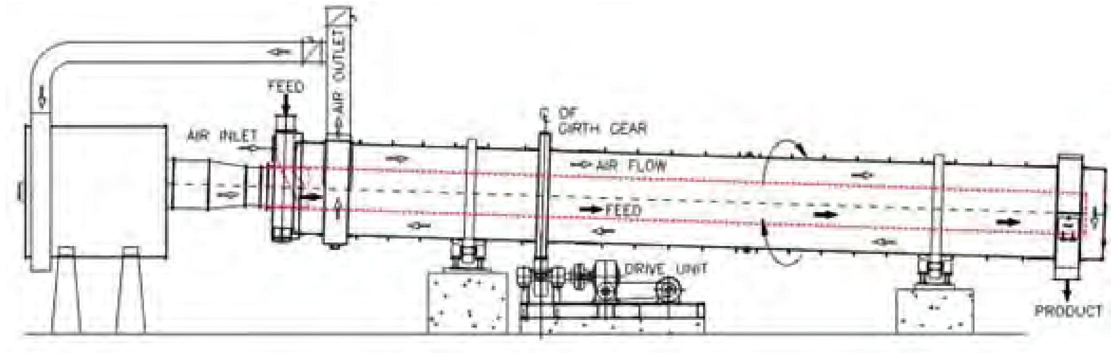

Figure 28: Rotary Dryer[37]

The final product temperature from the dryers is approximately 150 – 200 ºC (302 – 392 °F). This allows for the removal of moisture, the burning of residual organic reagents (especially flotation amine) and provides hot feed to the compactors in the next step.

Figure 29: Fluid-Bed Dryers for Industrial Minerals[38]

[37] *Rotary Dryers.* (2008). Retrieved July 12, 2012, from Mojj Engineering Systems Ltd.: http://www.mojjpune.com/Business%20Divisions/Rotary%20Dryers.html
[38] *Fluid Bed Dryer.* (2012). Retrieved July 12, 2012, from GEA Barr-Rosin: http://www.barr-rosin.com/products/fluid-bed-dryer.asp

8.3.2.8 *Product Screening and Compaction*

Plants produce from three to six products distinguishable by grade and size distribution. Dryer discharge is fed to a product screening circuit where coarse, standard and special standard products are traditionally produced from double-deck screens as shown in Figure 30: Double-Deck Vibratory Screen.

Figure 30: Double-Deck Vibratory Screen[39]

A newer type of screen now being used is the Rotex Mineral Separator as shown in Figure 31: Rotex Mineral Separator (Outside) and Figure 32: Inside View Of A Rotex Mineral Separator.

[39] *Incline Screens.* (2010). Retrieved July 12, 2012, from Elgin Equipment Group: http://www.elginindustries.com/solution/industrial_equipment_products/vibrating_screens/incline_screens.aspx

Figure 31: Rotex Mineral Separator (Outside)[40]

Figure 32: Inside View Of A Rotex Mineral Separator[41]

[40] *Mineral Separator.* (2012). Retrieved July 12, 2012, from Rotex: http://www.rotex.com/products/screeners-separators/rotex-minerals-separator

[41] *Mineral Separator.* (2012). Retrieved July 12, 2012, from Rotex: http://www.rotex.com/products/screeners-separators/rotex-minerals-separator

Screening installations are large due to the fineness of the screens and the materials being handled.

A fourth product, granular, is produced by compaction. In this plant section, standard and special standard material, along with recycle streams, is compressed to a high density in roll-type compaction presses (Figure 33: Koppern Compactor) through the application of pressure.

Most compactors are smooth-rolled and are equipped with force-feed screws that force the feed into the nip of the roll. More recently, grooved rolls that increase roll surface friction combined with gravity feed have come into use.

Figure 33: Koppern Compactor[42]

The resulting compactor flake is crushed and screened to produce granular and coarse product. Circulating loads are high as product yields expressed as a percentage of flake production are typically in the range of 25% to 35%. As market growth is taking place in the granular and coarse products, considerable effort is being put into compaction processes.

Flotation product usually has sufficient reagent on it to avoid caking in storage and handling. Granular product, however, has been reprocessed and if anti-caking reagent is not applied, material handling problems will occur in downstream operations. A combination of amine and oil is applied to the hot granular product in a ribbon mixer prior to the product bins to reduce caking.

[42] *Compaction.* (2012). Retrieved July 12, 2012, from Koppern: http://www.koeppern.com/en_kompakt_set.htm

8.3.2.9 Post Treatment

8.3.2.9.1 Glazing

The final products are mixed with a small amount of water and dried again. The objectives of this step are to obtain a hard outer coating, to fill cracks in the particles, to strengthen the compacted particles and to eliminate sharp corners to reduce dusting problems during shipping and handling.

8.3.2.9.2 Anti-caking

Long chain amines, either alone or dispersed in oil or glycol, are used in the post treatment of potash. Oil is also used to reduce dusting during handling. This is necessary to meet environmental requirements at destination ports. Additives, such as ammonium salts and sodium metasilicate, are also used to strengthen the compacted granules. If the final product is destined to be used for animal feed, no agents are used.

8.3.2.10 Load Out and Storage

The demand for potash is seasonal and the seasonal usage varies with the products, dealer inventories and the agricultural sector economic factors. As a consequence, substantial storage and shipping capacity is required.

Product is put into the storage building through overhead tripper conveyors and reclaimed through grizzly openings to conveyors under the floor of the building. Reclaiming from the piles to the openings is either with loaders, when space is available, or with bulldozers on the pile when space on the floor is not available.

On the coarse and granular side, product is reclaimed over a scalper screen and through a high capacity air classifier. The screen removes tramp oversize material and the classifier brings the product back up to size specification. In handling through storage, some product degradation takes place. On the standard and special standard side, product is screened and dedusted prior to loading. Product is loaded to order and each railcar is weighed and sampled. The logistics of loading a variety of products into a variety of railcars is well developed. All products except white soluble are oiled as a dust suppression measure.

8.3.2.11 General Potash Process Information and Materials Selection

A unique feature of potash milling is that all wet processing takes place in saturated brines. These brines are in chemical equilibrium with the ore at the processing temperature. Excess water added to the circuit results in excess brine. This excess brine will need to be disposed of, which decreases the yield of the circuit. Both soluble and solid losses must be controlled.

Abrasion is not particularly severe, as the minerals being handled are relatively soft. However, with brine slurries the combined effect of corrosion and abrasion can cause rapid failure in some instances where mild steel is used. Weld failures are most common, caused by the galvanic effects of the brines. In brine handling, epoxy paints are usually satisfactory and special paint specifications have been set up for structural steel.

Pumps are usually constructed of Ni-Hard Type IV white cast iron or equivalent, or of high-chrome alloys. These appear to provide the best service on slurries. The flotation reagents both in the flotation circuits and residual in the brines are aggressive to rubber, so rubber is not generally used. A good deal of success has been had with the use of bathroom tile glued and grouted with epoxy resins for tank and launder linings where the combined corrosion-abrasion effects are severe. In less severe service, fibreglass-reinforced epoxy lining is adequate. Screw conveyors handling wet materials are usually fabricated in stainless steels or are faced with alumina tiles bolted and glued to the flights. Piping initially was mild steel, with Victaulic grooved ends welded on. This is being replaced with a combination of flanged polyvinyl chloride (PVC) and polyethylene pipe. Long sweep bends are fabricated in PVC and wrapped with fibreglass reinforced plastic (FRP) for strength. FRP pipe is being used extensively for brine and reagent piping. The preferred material for flotation machine mechanisms is urethane.

8.3.2.12 Conventional Underground Mine Surface Plant CAPEX

The following Table 8: Conventional Underground Mine Surface Plant CAPEX shows the major sections of a potash surface processing facility with further breakdown into supply categories. Indicative costs are provide for each of these categories.

Table 8: Conventional Underground Mine Surface Plant CAPEX

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Ore Transfer and Storage	Mechanical Equipment	will typically include:					
		bins	$2,000,000	1	lot	$2,000,000	
		conveyors	$12,500,000	1	lot	$12,500,000	
		feeders	$1,000,000	1	lot	$1,000,000	
		reclaimers	$1,000,000	1	lot	$1,000,000	
		dust scrubbers	$1,000,000	1	lot	$1,000,000	
		weight scales	$500,000	1	lot	$500,000	
							$18,000,000
	Installation Contracts	will typically include:					
		mechanical	$5,000,000	1	lot	$5,000,000	
		civil and eathworks	$2,000,000	1	lot	$2,000,000	
		concrete	$2,000,000	1	lot	$2,000,000	
		structural	$3,000,000	1	lot	$3,000,000	
		architectural	$1,000,000	1	lot	$1,000,000	
		chutes and ducts	$3,000,000	1	lot	$3,000,000	
		piping	$8,000,000	1	lot	$8,000,000	
		electrical	$3,000,000	1	lot	$3,000,000	
		instrumentation	$3,000,000	1	lot	$3,000,000	
		buildings	$25,000,000	1	lot	$25,000,000	
		construction equipment and freight	$15,000,000	1	lot	$15,000,000	
							$70,000,000
Wet Processing	Mechanical Equipment	will typically include:					
		impactors	$2,500,000	1	lot	$2,500,000	
		hoists	$200,000	1	lot	$200,000	
		cranes	$1,500,000	1	lot	$1,500,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		roll crushers	$3,000,000	1	lot	$3,000,000	
		belt conveyors	$1,000,000	1	lot	$1,000,000	
		drag conveyors	$1,000,000	1	lot	$1,000,000	
		bucket elevators	$3,000,000	1	lot	$3,000,000	
		primary, secondary screens	$21,000,000	1	lot	$21,000,000	
		rougher, regrind screens	$2,000,000	1	lot	$2,000,000	
		dust scrubber	$1,000,000	1	lot	$1,000,000	
		crushed ore bin	$2,000,000	1	lot	$2,000,000	
		cyclones	$4,000,000	1	lot	$4,000,000	
		vibratory feeders	$500,000	1	lot	$500,000	
		launders	$50,000	1	lot	$50,000	
		pumps	$6,000,000	1	lot	$6,000,000	
		scrubbers	$27,000,000	1	lot	$27,000,000	
		hydroseparator	$6,000,000	1	lot	$6,000,000	
		tanks	$250,000	1	lot	$250,000	
		pumpboxs	$100,000	1	lot	$100,000	
		thickener	$3,000,000	1	lot	$3,000,000	
		air blowers	$250,000	1	lot	$250,000	
		regrind cagepaktors	$1,000,000	1	lot	$1,000,000	
		rougher, regrind flotation cells	$4,000,000	1	lot	$4,000,000	
		cleaner, fines flotation cells	$12,000,000	1	lot	$12,000,000	
		leach tanks	$50,000	1	lot	$50,000	
		pump boxes	$500,000	1	lot	$500,000	
		centrifuges	$33,000,000	1	lot	$33,000,000	
		centrate flotation columns	$3,000,000	1	lot	$3,000,000	
							$138,900,000
	Installation Contracts	will typically include:					
		mechanical	$30,000,000	1	lot	$30,000,000	
		civil and earthworks	$10,000,000	1	lot	$10,000,000	
		concrete	$20,000,000	1	lot	$20,000,000	
		structural	$25,000,000	1	lot	$25,000,000	
		architectural	$5,000,000	1	lot	$5,000,000	
		chutes and ducts	$20,000,000	1	lot	$20,000,000	
		piping	$120,000,000	1	lot	$120,000,000	
		electrical	$30,000,000	1	lot	$30,000,000	
		instrumentation	$30,000,000	1	lot	$30,000,000	
		buildings	$75,000,000	1	lot	$75,000,000	
		overall site preparation	$35,000,000	1	lot	$35,000,000	
		construction equipment and freight	$35,000,000	1	lot	$35,000,000	
							$435,000,000
Dry Processing	Mechanical Equipment	will typically include:					
		cranes	$500,000	1	lot	$500,000	
		hoists	$200,000	1	lot	$200,000	
		lump breakers	$300,000	1	lot	$300,000	
		dried product, granular belt conveyors	$3,000,000	1	lot	$3,000,000	
		polishing belt conveyors	$500,000	1	lot	$500,000	
		drag conveyors	$4,000,000	1	lot	$4,000,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		screw conveyor	$3,000,000	1	lot	$3,000,000	
		bucket elevators	$6,000,000	1	lot	$6,000,000	
		screw feeders	$1,500,000	1	lot	$1,500,000	
		scrubbers	$12,000,000	1	lot	$12,000,000	
		product dryers	$6,000,000	1	lot	$6,000,000	
		fluid bed coolers	$2,000,000	1	lot	$2,000,000	
		air filters	$100,000	1	lot	$100,000	
		tramp metal separators	$1,000,000	1	lot	$1,000,000	
		drying mixer	$750,000	1	lot	$750,000	
		dryer, product screen	$2,500,000	1	lot	$2,500,000	
		hoppers	$50,000	1	lot	$50,000	
		compactors	$24,000,000	1	lot	$24,000,000	
		flake breakers	$1,500,000	1	lot	$1,500,000	
		polishing dryer cooler	$3,000,000	1	lot	$3,000,000	
		mixers	$6,000,000	1	lot	$6,000,000	
		screens					
							$77,900,000
	Installation Contracts	will typically include:					
		mechanical	$20,000,000	1	lot	$20,000,000	
		civil and earthworks	$5,000,000	1	lot	$5,000,000	
		concrete	$12,000,000	1	lot	$12,000,000	
		structural	$15,000,000	1	lot	$15,000,000	
		architectural	$5,000,000	1	lot	$5,000,000	
		chutes and ducts	$10,000,000	1	lot	$10,000,000	
		piping	$35,000,000	1	lot	$35,000,000	
		electrical	$15,000,000	1	lot	$15,000,000	
		instrumentation	$15,000,000	1	lot	$15,000,000	
		buildings	$10,000,000	1	lot	$10,000,000	
		overall site preparation	$10,000,000	1	lot	$10,000,000	
		construction equipment and freight	$15,000,000	1	lot	$15,000,000	
							$167,000,000
Product Storage and Loadout	Mechanical Equipment	will typically include:					
		diverters, splitters, trippers	$2,000,000	1	lot	$2,000,000	
		lump breakers	$500,000	1	lot	$500,000	
		belt conveyors	$15,000,000	1	lot	$15,000,000	
		dust scrubber	$1,000,000	1	lot	$1,000,000	
		railcar loading systems	$10,000,000	1	lot	$10,000,000	
		tramp metal separators	$200,000	1	lot	$200,000	
		mixers	$1,000,000	1	lot	$1,000,000	
		scraper reclaimers		1	lot	$6,000,000	
		lump, granular screens	$2,000,000	1	lot	$2,000,000	
							$37,700,000
	Installation Contracts	will typically include:					
		mechanical	$10,000,000	1	lot	$10,000,000	
		civil and earthworks	$5,000,000	1	lot	$5,000,000	
		concrete	$5,000,000	1	lot	$5,000,000	
		structural	$7,000,000	1	lot	$7,000,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		architectural	$2,000,000	1	lot	$2,000,000	
		chutes and ducts	$5,000,000	1	lot	$5,000,000	
		piping	$20,000,000	1	lot	$20,000,000	
		electrical	$10,000,000	1	lot	$10,000,000	
		instrumentation	$10,000,000	1	lot	$10,000,000	
		conveyor galleries	$22,000,000	1	lot	$22,000,000	
		product storage	$125,000,000	1	lot	$125,000,000	
		product loadout	$15,000,000	1	lot	$15,000,000	
		surface mobile equipment	$25,000,000	1	lot	$25,000,000	
		construction equipment and freight	$25,000,000	1	lot	$25,000,000	
							$286,000,000
Tailings Management Area - Stage 1	Salt Pile Area	will typically include:					
		topsoil removal	$3,000,000	1	lot	$3,000,000	
		clearing and grubbing	$2,000,000	1	lot	$2,000,000	
		grading and compaction	$3,500,000	1	lot	$3,500,000	
		corrugated HDPE pipe	$1,000,000	1	lot	$1,000,000	
		granular protection layer	$25,000,000	1	lot	$25,000,000	
							$34,500,000
	Fine Tailings	will typically include:					
		topsoil removal	$2,500,000	1	lot	$2,500,000	
		clearing and grubbing		1	lot	$1,500,000	
		excavation	$3,500,000	1	lot	$3,500,000	
		fill	$5,000,000	1	lot	$5,000,000	
		clay liner	$33,000,000	1	lot	$33,000,000	
		corrugated HDPE pipe	$100,000	1	lot	$100,000	
		granular protection layer	$15,000,000	1	lot	$15,000,000	
		toe drain granular material	$250,000	1	lot	$250,000	
		topsoil for vegetation	$300,000	1	lot	$300,000	
		granular filter media	$200,000	1	lot	$200,000	
		HDPE liner	$30,000,000	1	lot	$30,000,000	
							$91,350,000
	Brine Pond	will typically include:					
		topsoil removal	$1,500,000	1	lot	$1,500,000	
		clearing and grubbing	$750,000	1	lot	$750,000	
		excavation	$9,000,000	1	lot	$9,000,000	
		clay liner	$22,000,000	1	lot	$22,000,000	
		granular protection layer	$7,000,000	1	lot	$7,000,000	
		HDPE liner	$21,000,000	1	lot	$21,000,000	
							$61,250,000
	Containment Dyke	will typically include:					
		fill	$6,000,000	1	lot	$6,000,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		toe drain granular material	$1,000,000	1	lot	$1,000,000	
		road base granular	$100,000	1	lot	$100,000	
		topsoil for vegetation	$350,000	1	lot	$350,000	
		handrails	$3,000,000	1	lot	$3,000,000	
							$10,450,000
	Perimeter Ditch	will typically include:					
		topsoil removal	$1,000,000	1	lot	$1,000,000	
		clearing and grubbing	$500,000	1	lot	$500,000	
		excavation	$7,000,000	1	lot	$7,000,000	
							$8,500,000
	Reclaim Brine Pipeline	will typically include:					
		cut	$500,000	1	lot	$500,000	
		bedding sand	$100,000	1	lot	$100,000	
		fill	$750,000	1	lot	$750,000	
		HDPE pipe	$200,000	1	lot	$200,000	
			$5,000,000	1	lot	$5,000,000	$6,550,000
	Brine Disposal System						
	will typically include:						
	Deep Injection Wells		$5,000,000	5	each	$25,000,000	
	Pumphouse Building		$200,000	1	lot	$200,000	
	Mechanical Equipment	will typically include:					
		cyclone	$200,000	1	lot	$200,000	
		belt filter	$5,000,000	1	lot	$5,000,000	
		small pumps	$1,000,000	1	lot	$1,000,000	
		large pumps	$3,000,000	1	lot	$3,000,000	
		small tanks	$50,000	1	lot	$50,000	
		large tanks	$200,000	1	lot	$200,000	
		pumpboxes	$50,000	1	lot	$50,000	
		lamella thickener	$2,000,000	1	lot	$2,000,000	
		30" HDPE pipe	$5,000,000	1	lot	$5,000,000	
		16"HDPE pipe	$3,500,000	1	lot	$3,500,000	
	Electrical & Instrumentation for TMA		$1,000,000	1	lot	$1,000,000	
	34.5kV T-Line (TMA Power Supply)		$1,500,000	1	lot	$1,500,000	
							$47,700,000
	Brine Disposal Installation Contracts	will typically include:					
		multi-discipline labour	$40,000,000	1	lot	$40,000,000	
		construction equipment and freight	$20,000,000	1	lot	$20,000,000	
							$60,000,000
Utilities	Powerhouse	emergency generators	$2,500,000	2		$5,000,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	Main Sub-Station and Power Distribution						
	will typically include:						
	Major Equipment & HV Cable System		$20,000,000	1	lot	$20,000,000	
	Protection, Control, and Communications		$1,000,000	1	lot	$1,000,000	
	AC & DC Auxiliary Systems		$500,000	1	lot	$500,000	
	Grounding System		$250,000	1	lot	$250,000	
	LV Cabling		$200,000	1	lot	$200,000	
	Mechanical Systems and Building Services		$500,000	1	lot	$500,000	
	Civil / Structural Work		$10,000,000	1	lot	$10,000,000	
	Cabling from Sub-station to Buildings		$5,000,000	1	lot	$5,000,000	
		construction equipment and freight	$3,000,000	1	lot	$3,000,000	
							$40,450,000
	Water storage and distribution						
	will typically include:						
	Water Treatment Building Equipment		$10,000,000	1	lot	$10,000,000	
	Water Treatment Building		$5,000,000	1	lot	$5,000,000	
	Water Distribution Piping		$15,000,000	1	lot	$15,000,000	
	Sewage Treatment Plant Buildings		$20,000,000	1	lot	$20,000,000	
	Sewage Treatment Plant		$2,000,000	1	lot	$2,000,000	
	Ponds		$3,000,000	1	lot	$3,000,000	
		construction equipment and freight	$1,000,000	1	lot	$1,000,000	
							$56,000,000
	Reagents						
	will typically include:						
	Reagents Storage Building		$4,000,000	1	lot	$4,000,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	Reagents Process Systems		$8,000,000	1	lot	$8,000,000	
		construction equipment and freight	$1,000,000	1	lot	$1,000,000	
							$13,000,000
	Fuel and Natural Gas Storage and Distribution						
	will typically include:						
	Fuel and Natural Gas Facility		$8,000,000	1	lot	$8,000,000	
	Fuel and Natural Gas Distribution Equipment		$5,000,000	1	lot	$5,000,000	
							$13,000,000
	Compressed air						
	will typically include:						
	Plant Wide Service Piping		$10,000,000	1	lot	$10,000,000	
	Compressed Air Building		$20,000,000	1	lot	$20,000,000	
	Compressed Air System		$10,000,000	1	lot	$10,000,000	
							$40,000,000
Non-Process Infrastructure	Non-Process Buildings						
	will typically include:						
	Warehouse		$15,000,000	1	lot	$15,000,000	
	Electrical/Mechanical Maintenance Building		$10,000,000	1	lot	$10,000,000	
	Administration Building		$30,000,000	1	lot	$30,000,000	
	First Aid		$5,000,000	1	lot	$5,000,000	
	Fire Station and Fire Station Offices		$12,000,000	1	lot	$12,000,000	
	Fuel Storage and Fuelling Station		$2,000,000	1	lot	$2,000,000	
	Rail & Locomotive Maintenance Facility		$5,000,000	1	lot	$5,000,000	
	Laboratory		$6,000,000	1	lot	$6,000,000	
		construction equipment and freight	$10,000,000	1	lot	$10,000,000	
							$95,000,000
	Yards, roads and parking						
	will typically include:						

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	On-site Rail Yard		$15,000,000	1	lot	$15,000,000	
	On-site Road Network		$15,000,000	1	lot	$15,000,000	
	Parking Lot		$3,000,000	1	lot	$3,000,000	
	Pipe Rack		$30,000,000	1	lot	$30,000,000	
		construction equipment and freight	$4,000,000	1	lot	$4,000,000	
							$67,000,000
	Below grade services and drainage						
	will typically include:						
	Raw Sewage Piping	PVC	$7,000,000	1	lot	$7,000,000	
	Firewater System	PVC	$4,000,000	1	lot	$4,000,000	
		construction equipment and freight	$1,000,000	1	lot	$1,000,000	
							$12,000,000
	Process Systems						
	Instrumentation		$1,000,000	1	lot	$1,000,000	
							$1,000,000
	Operational Systems						
	Instrumentation	typically for:					
		Surface Infrastructure	$10,000,000	1	lot	$10,000,000	
		TMA Infrastructure	$2,000,000	1	lot	$2,000,000	
		U/G Infrastructure	$45,000,000	1	lot	$45,000,000	
		Visualization and Business Systems	$1,000,000	1	lot	$1,000,000	
		Integration Systems	$1,000,000	1	lot	$1,000,000	
		Production Systems	$1,500,000	1	lot	$1,500,000	
		Recurring Costs	$6,000,000	1	lot	$6,000,000	
							$66,500,000
Total							**$1,954,750,000**

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category.

8.3.2.13 Conventional Underground Mine Indirects for CAPEX

The following table Table 9: Conventional Underground Mine Indirect Costs shows the major indirect cost elements for the construction of a typical conventional underground potash facility along with indicative costs for these elements. It should be noted that the EPCM costs have been included here as well.

Table 9: Conventional Underground Mine Indirect Costs

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Indirects	Construction Temp. Facilities, Costs	camp, power, offices, services		1	lot	$215,000,000	
	Third Party Consultants		$10,000,000	1	lot	$10,000,000	
	Vendor Representatives		$10,000,000	1	lot	$10,000,000	
	First Fills		$5,000,000	1	lot	$5,000,000	
	Critical Spares		$30,000,000	1	lot	$30,000,000	
	EPCM including Studies and Execution		$600,000,000	1	lot	$600,000,000	
	Commissioning		$50,000,000	1	lot	$50,000,000	$920,000,000
Total							**$920,000,000**

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8.4 Solution Mine

The following section describes the subsurface and surface processing facilities required for a typical solution mine in Saskatchewan. Each major section is followed by a capital cost breakdown.

8.4.1 Solution Mine Subsurface Facilities

Solution mining operations, as shown in Figure 34: Sump Development, Figure 35: Cavern, Connection and Roof Developmentand Figure 36: Primary Solution Mining, are used where conventional underground mining is impractical due to formation depth, temperature, or presence of a hazardous gas. Heated brine is pumped underground to dissolve the KCl salts and is then transported back to the surface for KCl crystallization.

Potash solution mining in Saskatchewan originates from a technology developed in the late 1960's. Two producing operations recover potash through a solution mining process in Saskatchewan: PCS Patience Lake and Mosaic Belle Plaine.

The mine is initiated by drilling two wells, through the potash source. Once the wells are completed, sump development starts by injecting fresh water to create a sump area in the NaCl zone below the KCl-bearing zone. The sump allows insoluble material to settle within the cavern thus avoiding the need to remove it in downstream surface processes.

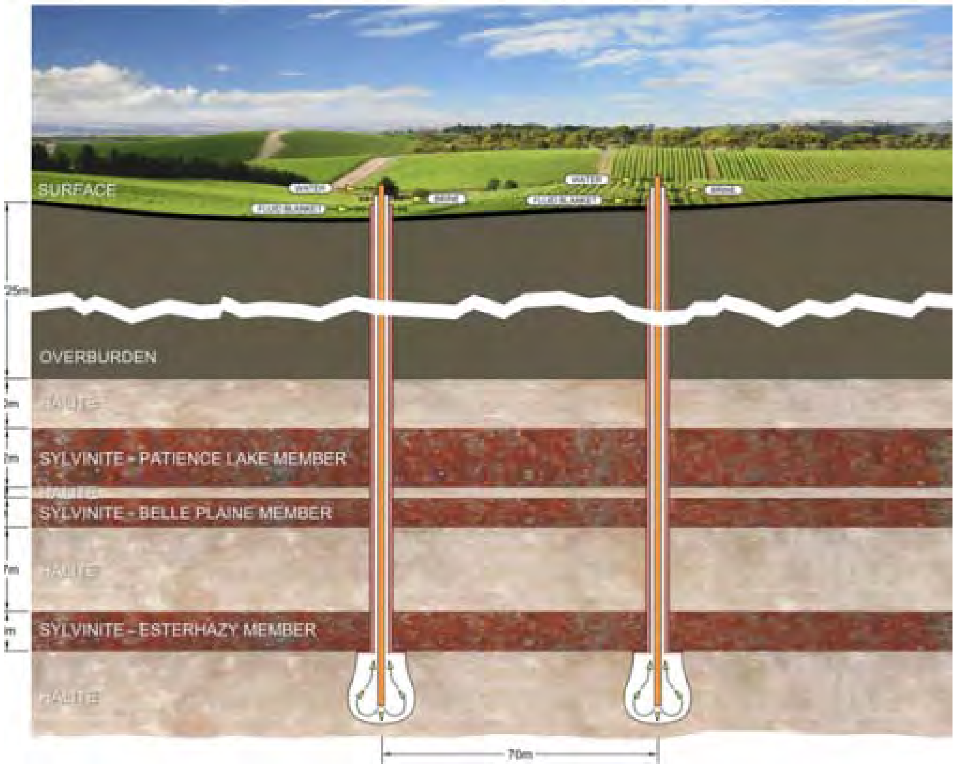

Figure 34: Sump Development[43]

Once the sumps are created, fresh water injection continues in order to expand the sumps into caverns and then to join these two areas. A diesel blanket is used to prevent advancement of the cavern into the KCl-bearing zone until primary mining is to begin.

[43] *Solution Mining.* (2012). Retrieved July 12, 2012, from Western Potash: http://www.westernpotash.com/about-potash/solution-mining

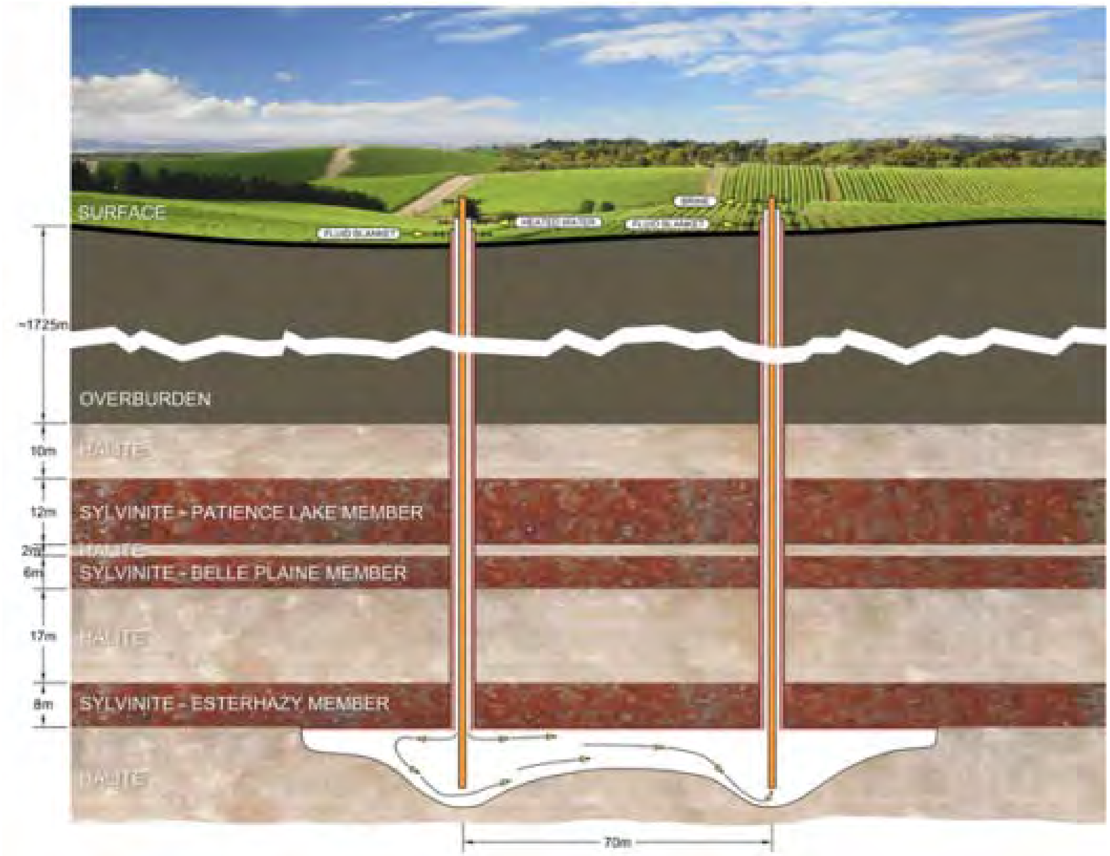

Figure 35: Cavern, Connection and Roof Development[44]

Primary mining is initiated by allowing the diesel blanket to retreat into the KCl-bearing zone so that the injected, heated fresh water can dissolve both the halite (NaCl) and sylvite (KCl) in the zone.

[44] *Solution Mining.* (2012). Retrieved July 12, 2012, from Western Potash: http://www.westernpotash.com/about-potash/solution-mining

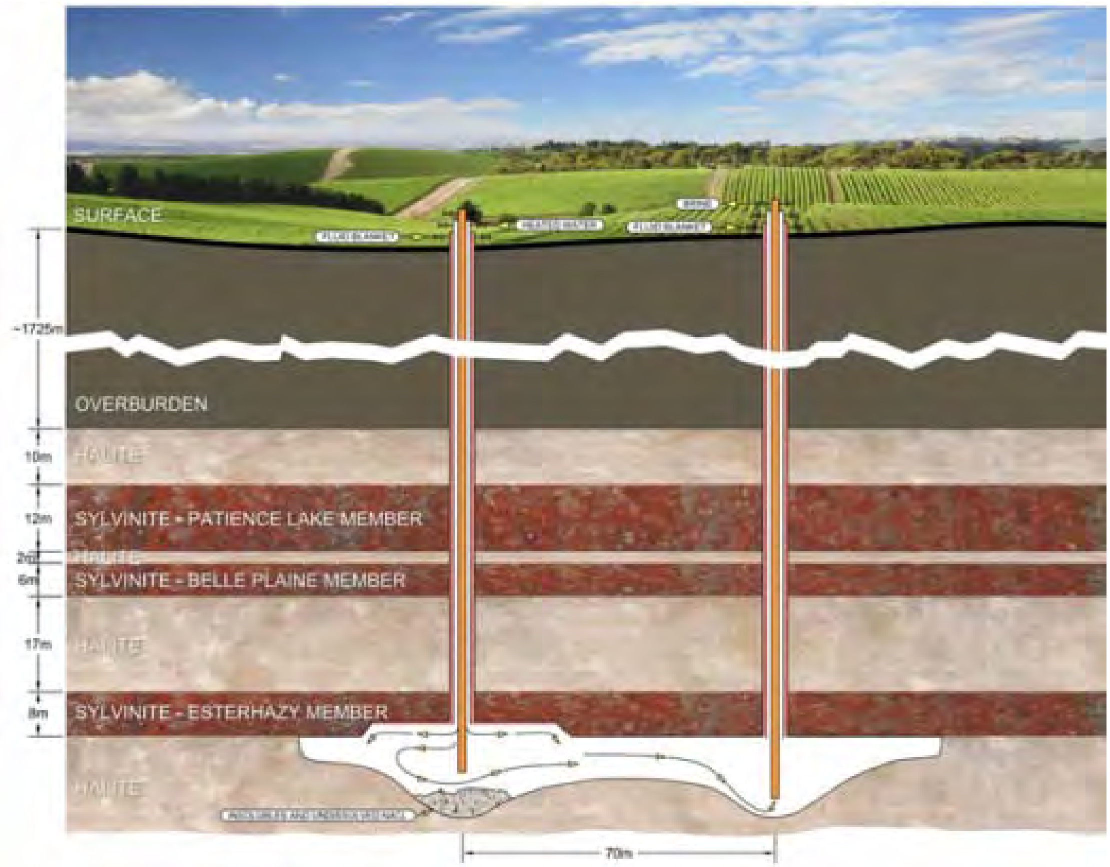

Figure 36: Primary Solution Mining[45]

As the potash mining progresses towards the top of the potash zone, secondary mining can be initiated. Instead of fresh water, heated and saturated NaCl brine is injected. Because of the saturation properties of KCl and NaCl in water, only the KCl will dissolve into solution and a small amount of NaCl will be precipitated out of solution. The overall cavern production rate in secondary mining will decrease since KCl dissolution in hot NaCl brine is slower than in fresh water. However, recovery rate from the formation is increased and so it is worthwhile to do, up to a point.

8.4.1.1 *Solution Minefield CAPEX*

Following in Table 10: Solution Minefield CAPEX is a table of indicative prices for the development of a solution minefield in Saskatchewan.

[45] *Solution Mining.* (2012). Retrieved July 12, 2012, from Western Potash: http://www.westernpotash.com/about-potash/solution-mining

Table 10: Solution Minefield CAPEX

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Minefield							
Minefield	Production Wells		$4,000,000	80	wells	$320,000,000	$320,000,000
	Minefield Piping	will typically include:	$40,000,000	1	lot	$40,000,000	
		24" insulated					
		16" insulated					
		3" insulated and traced					$40,000,000
Total							$360,000,000

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category.

8.4.2 *Solution Mine Surface Processing*

Processing KCl from a solution mine is different in the initial stages from processing KCl from a conventional underground mine. The feed from the solution mine is a liquid rather than a solid. Therefore, KCl has to be precipitated by crystallization rather than separated by flotation.

It should be noted that some conventional underground mines dissolve fine KCl into a brine and crystallize it into a white product similar to what is done in solution mining. The crystallization description below applies to both solution mining and conventional underground mine applications where crystallization is used.

A capital cost breakdown is provided in Table 11: Solution Mine Surface Plant CAPEX.

8.4.2.1 *Solution Mine Generic Flowsheet*

A typical flowsheet for a solution mine operation is shown in Figure 37: Typical Solution Mine Flowsheet Debrining, drying, compaction and screening are similar in both conventional underground and solution mine processing, and have been covered previously in Conventional Underground Mine Surface Processes, so will not be repeated here. Evaporation, Crystallization and Cooling Ponds, which are distinct from most conventional underground processing operating, are described in the following section Solution Mine Surface Processes.

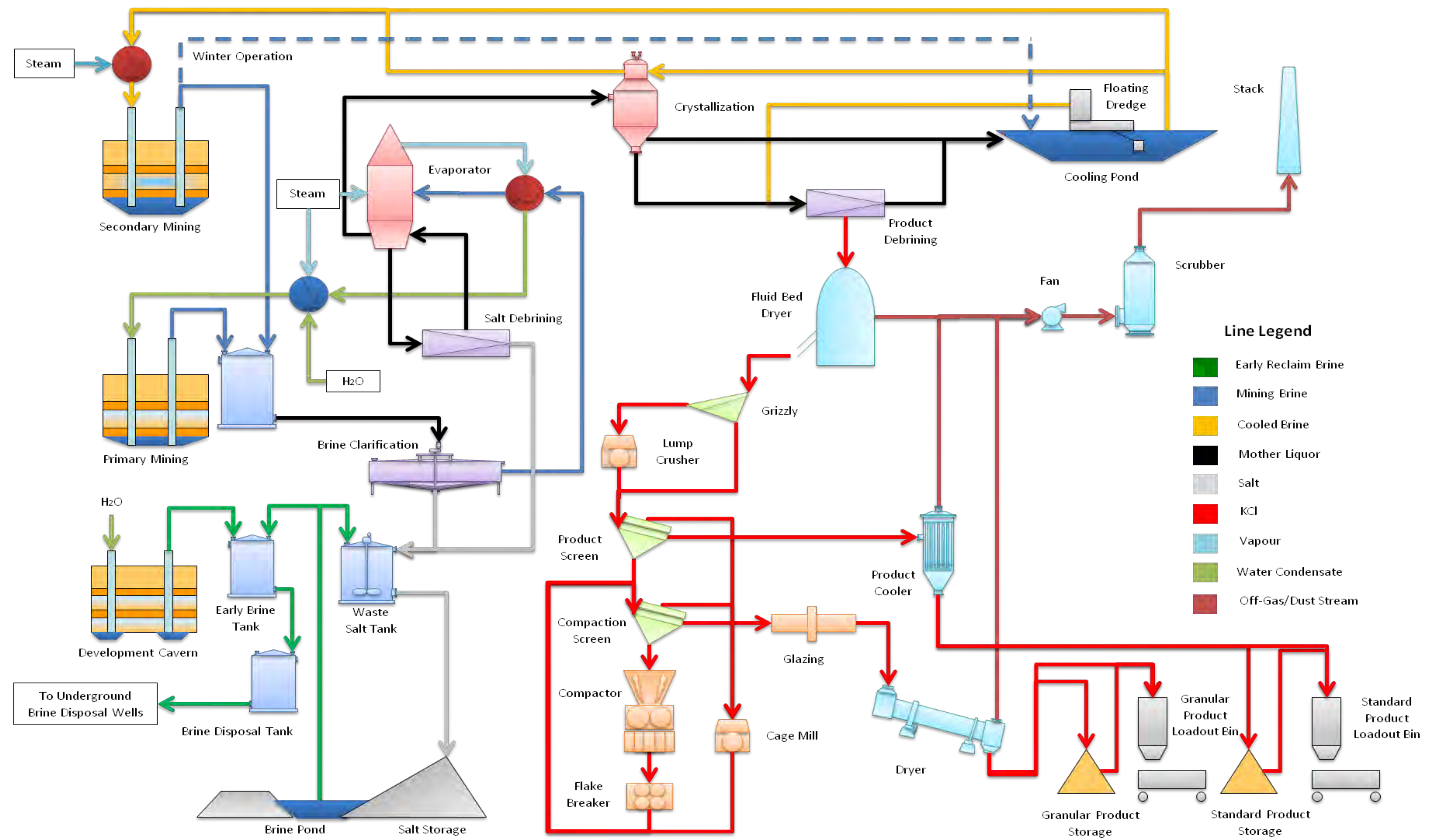

Figure 37: Typical Solution Mine Flowsheet

8.4.2.2 Solution Mine Surface Processes

8.4.2.2.1 Evaporation

The brine from the solution minefield returns to the surface processing plant at around 45 °C and is saturated with KCl and NaCl at this temperature. This brine is then heated to approximately 100 °C, which raises the KCl solubility and decreases the NaCl solubility (Figure 38: Solubility Of Saturated KCl And NaCl Solutions At Various Temperatures), making the brine undersaturated in KCl and supersaturated in NaCl. This causes NaCl to begin to precipitate from solution. For successful crystallization, a brine saturated in KCl is required. Water is then evaporated from the brine in a series of evaporators to raise the concentration of KCl to saturation. As NaCl was already saturated prior to evaporation, more NaCl will precipitate during evaporation in order to maintain saturation as the water evaporates. The resulting slurry is clarified to remove the precipitated NaCl prior to crystallization. After NaCl removal, the brine is pumped to the crystallization circuit.

8.4.2.2.2 Crystallization

The crystallization process is required in solution mining but it can also be a way for processing fines in a conventional underground mining operation and an opportunity to increase the process recovery. For very specific applications that require a final white product (food, pharmaceutical) from either a solution or conventional underground operation, crystallization is essential.

The basic principle behind potash crystallization is quite simple: KCl is more soluble in water at higher temperatures, so the product is dissolved at high temperature and precipitated at low temperature. This is illustrated in the graph in Figure 38: Solubility Of Saturated KCl And NaCl Solutions At Various Temperatures.

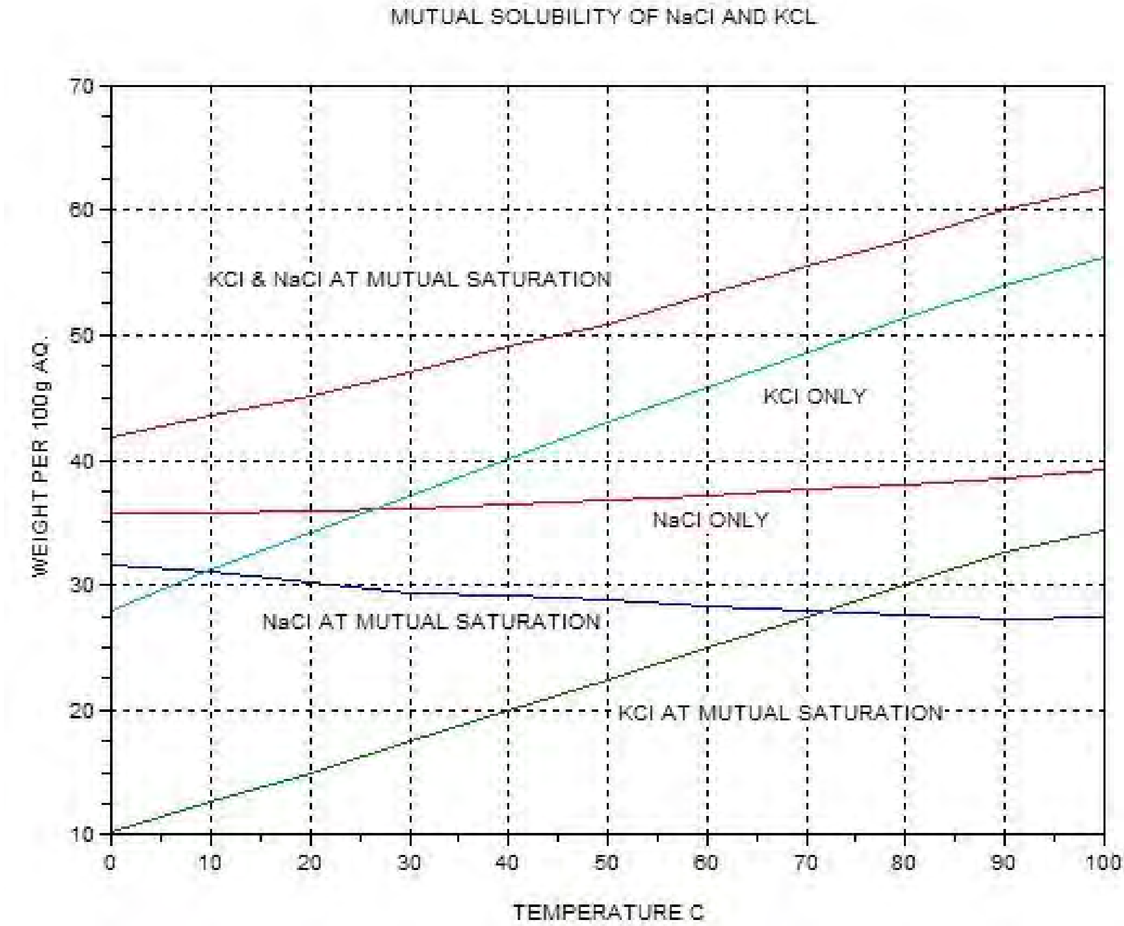

Figure 38: Solubility Of Saturated KCl And NaCl Solutions At Various Temperatures[46]

Fortunately, the solubility of NaCl has the opposite trend over this temperature range, increasing in solubility as temperature decreases, and so tends to stay in solution as the temperature drops. As the temperature drops, the KCl precipitates out and the result is a crystallised potash product of high purity, usually over 99% KCl.

The most common crystallizers used for potash are draft tube crystallizers (Figure 39: Draft Tube Crystallizer). They produce a larger crystal than other types, which is beneficial for grade. They are operated in a series of from four to eight units. This increases efficiency and production. Each sequential crystallizer in series operates at a lower temperature and pressure to precipitate the KCl progressively.

46 *Separation of Salts*. (2001, 5 14). Retrieved 07 2012, from Science Madness: http://www.sciencemadness.org/talk/viewthread.php?tid=20352

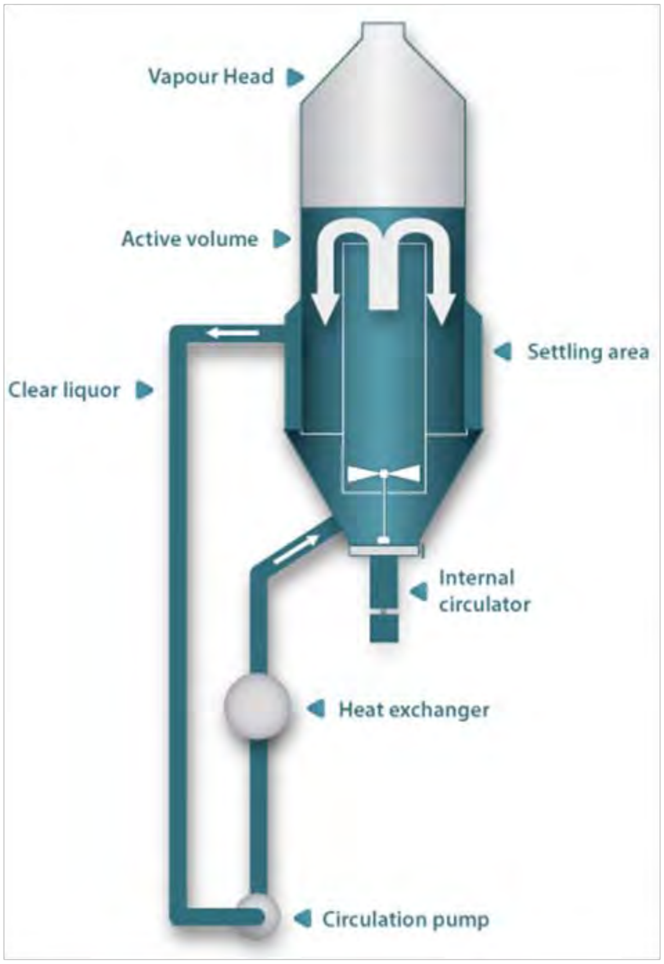

Figure 39: Draft Tube Crystallizer[47]

Corrosion problems are severe in crystallizer plants where hot chloride slurries and brines are being handled. Pumps make use of high-chrome and stainless steel alloys, vessels are either rubber or fibreglass-lined and extensive use is made of FRP pipe. Dissolver heat exchanger tubing is usually a 90% copper, 10% nickel alloy, although titanium has also been used. Monel or Monel-cladding has also been used in dissolver and crystallizer applications with good success.

8.4.2.2.3 Cooling Ponds

In Saskatchewan, cooling ponds offer an alternative to evaporation – crystallization circuits. Two natural-environment processes aid in crystallizing KCl in ponds: temperature and evaporation. NaCl poor and KCl rich hot brine is pumped into the ponds. As the brine cools, the solubility of KCl is reduced and it crystallizes out of solution. Also, aided by the surface area of the ponds, water evaporates which means less KCl is soluble so more KCl crystallizes out from this natural process. Meanwhile, the NaCl concentration stays

[47] *Draft Tube Baffle Type.* (2010). Retrieved July 12, 2012, from Chemical Process Systems: http://www.chemprosys.com/draft%20tube%20baffle%20type.htm

undersaturated and so does not crystallize out. The precipitated KCl is dredged from the bottom of the cooling ponds and processed into potash product.

8.4.2.2.4 Tailings Management

Another feature of solution mining is that the NaCl surface tailings quantity is considerably smaller when compared to that of conventional underground operations. This is because primary solution mining tailings can be disposed of back into the cavern and secondary solution mining preferentially dissolves the KCl leaving the NaCl underground. Similarly, a large portion of the slimes in solution mining is left underground and therefore there is less surface processing or storage of slimes required.

Conventional underground mining, on the other hand, hoists all the KCl-NaCl ore to the surface for processing. Since the ore is only 35% or so KCl, a large tailings pile results from the NaCl. Slimes are also brought to the surface and are disposed of after processing in a fine tailings storage area on the surface.

8.4.2.3 Solution Mine Surface Plant CAPEX

The following Table 11: Solution Mine Surface Plant CAPEX shows the capital expenditures required for a complete solution mine surface operation. It is broken into sections and further into categories.

Table 11: Solution Mine Surface Plant CAPEX

Service Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Raw Brine Collection	Mechanical Equipment	will typically include:					
		large pumps	$8,000,000	1	lot	$8,000,000	
		small pumps	$250,000	1	lot	$250,000	
		small tanks	$3,500,000	1	lot	$3,500,000	
		large tanks	$8,000,000	1	lot	$8,000,000	
		oil tanks	$100,000	1	lot	$100,000	
		cranes	$100,000	1	lot	$100,000	
							$19,950,000
	Installation Contracts	will typically include:					
		mechanical					
		civil and earthworks	$2,000,000	1	lot	$2,000,000	
		concrete	$5,000,000	1	lot	$5,000,000	
		structural	$5,000,000	1	lot	$5,000,000	
		architectural	$4,000,000	1	lot	$4,000,000	
		chutes and ducts	$2,000,000	1	lot	$2,000,000	
		piping	$5,000,000	1	lot	$5,000,000	
		electrical	$5,000,000	1	lot	$5,000,000	
		instrumentation	$4,000,000	1	lot	$4,000,000	
		buildings					
		overall site preparation	$5,000,000	1	lot	$5,000,000	
		construction equipment and freight	$5,000,000	1	lot	$5,000,000	
							$42,000,000
Cooling Pond	Cooling Pond	will typically include:					
		topsoil removal	$1,500,000	1	lot	$1,500,000	
		clearing and grubbing	$750,000	1	lot	$750,000	

Service Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		excavation	$9,000,000	1	lot	$9,000,000	
		clay liner	$22,000,000	1	lot	$22,000,000	
		granular protection layer	$7,000,000	1	lot	$7,000,000	
		HDPE liner	$21,000,000	1	lot	$21,000,000	
							$61,250,000
	Containment Dyke	will typically include:					
		fill	$6,000,000	1	lot	$6,000,000	
		toe drain granular material	$1,000,000	1	lot	$1,000,000	
		road base granular	$100,000	1	lot	$100,000	
		topsoil for vegetation	$350,000	1	lot	$350,000	
		handrails	$3,000,000	1	lot	$3,000,000	
							$10,450,000
	Perimeter Ditch	will typically include:					
		topsoil removal	$1,000,000	1	lot	$1,000,000	
		clearing and grubbing	$500,000	1	lot	$500,000	
		excavation	$7,000,000	1	lot	$7,000,000	
							$8,500,000
	Cooling Pond Pipeline	will typically include:					
		cut	$500,000	1	lot	$500,000	
		bedding sand	$100,000	1	lot	$100,000	
		fill	$1,000,000	1	lot	$1,000,000	
		HDPE pipe	$5,000,000	1	lot	$5,000,000	
							$6,600,000
Evaporation Facility	Mechanical Equipment	will typically include:					
		clarifiers	$8,000,000	1	lot	$8,000,000	
		large tanks	$1,000,000	1	lot	$1,000,000	
		medium tanks	$500,000	1	lot	$500,000	
		small tanks	$1,500,000	1	lot	$1,500,000	
		hydrocyclones	$1,000,000	1	lot	$1,000,000	
		evaporators	$100,000,000	1	lot	$100,000,000	
		troughs	$250,000	1	lot	$250,000	
		centrifuge	$15,000,000	1	lot	$15,000,000	
		vacuum system	$4,000,000	1	lot	$4,000,000	
		small pumps	$1,500,000	1	lot	$1,500,000	
		medium pumps	$6,000,000	1	lot	$6,000,000	
		large pumps	$750,000	1	lot	$750,000	
		small cranes	$50,000	1	lot	$50,000	
		large cranes	$750,000	1	lot	$750,000	
							$140,300,000
	Installation Contracts	will typically include:					
		mechanical					
		civil and earthworks	$15,000,000	1	lot	$15,000,000	
		concrete	$30,000,000	1	lot	$30,000,000	
		structural	$25,000,000	1	lot	$25,000,000	
		architectural	$20,000,000	1	lot	$20,000,000	
		chutes and ducts	$15,000,000	1	lot	$15,000,000	
		piping	$30,000,000	1	lot	$30,000,000	
		electrical	$30,000,000	1	lot	$30,000,000	
		instrumentation	$25,000,000	1	lot	$25,000,000	
		buildings					
		overall site preparation	$30,000,000	1	lot	$30,000,000	
		construction equipment and freight	$35,000,000	1	lot	$35,000,000	
							$255,000,000

Service Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Crystallization Facility	Mechanical Equipment	will typically include:					
		hotwells	$350,000	1	lot	$350,000	
		vacuum crystallizer	$56,000,000	1	lot	$56,000,000	
		small pumps	$1,000,000	1	lot	$1,000,000	
		medium pumps	$3,500,000	1	lot	$3,500,000	
		heat exchangers	$500,000	1	lot	$500,000	
		cranes	$500,000	1	lot	$500,000	
							$61,850,000
	Installation Contracts	will typically include:					
		mechanical					
		civil and earthworks	$7,500,000	1	lot	$7,500,000	
		concrete	$15,000,000	1	lot	$15,000,000	
		structural	$15,000,000	1	lot	$15,000,000	
		architectural	$12,000,000	1	lot	$12,000,000	
		chutes and ducts	$7,500,000	1	lot	$7,500,000	
		piping	$15,000,000	1	lot	$15,000,000	
		electrical	$15,000,000	1	lot	$15,000,000	
		instrumentation	$10,000,000	1	lot	$10,000,000	
		buildings					
		overall site preparation	$15,000,000	1	lot	$15,000,000	
		construction equipment and freight	$20,000,000	1	lot	$20,000,000	
							$132,000,000
Debrining and Drying	Mechanical Equipment	will typically include:					
		hydrocyclones	$1,000,000	1	lot	$1,000,000	
		small tanks	$50,000	1	lot	$50,000	
		large tanks	$250,000	1	lot	$250,000	
		thickener	$500,000	1	lot	$500,000	
		centrifuges	$12,000,000	1	lot	$12,000,000	
		pumps	$750,000	1	lot	$750,000	
		cranes	$250,000	1	lot	$250,000	
		screw feeder	$500,000	1	lot	$500,000	
		dryer	$5,000,000	1	lot	$5,000,000	
		pneumatic conveyor	$500,000	1	lot	$500,000	
		scrubber	$5,000,000	1	lot	$5,000,000	
		scrubber stack	$2,000,000	1	lot	$2,000,000	
							$27,800,000
	Installation Contracts	will typically include:					
		mechanical					
		civil and earthworks	$4,000,000	1	lot	$4,000,000	
		concrete	$6,000,000	1	lot	$6,000,000	
		structural	$6,000,000	1	lot	$6,000,000	
		architectural	$4,000,000	1	lot	$4,000,000	
		chutes and ducts	$4,000,000	1	lot	$4,000,000	
		piping	$6,000,000	1	lot	$6,000,000	
		electrical	$6,000,000	1	lot	$6,000,000	
		instrumentation	$4,000,000	1	lot	$4,000,000	
		buildings					
		overall site preparation	$6,000,000	1	lot	$6,000,000	
		construction equipment and freight	$8,000,000	1	lot	$8,000,000	
							$54,000,000
Compaction Plant	Mechanical Equipment	will typically include:					
		bucket elevators	$8,000,000	1	lot	$8,000,000	
		screen	$6,000,000	1	lot	$6,000,000	
		lump breakers	$1,000,000	1	lot	$1,000,000	
		drag conveyors	$7,000,000	1	lot	$7,000,000	

Service Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		baghouse	$1,500,000	1	lot	$1,500,000	
		stacks	$4,000,000	1	lot	$4,000,000	
		surge bins	$750,000	1	lot	$750,000	
		vibratory feeders	$50,000	1	lot	$50,000	
		compactors	$21,000,000	1	lot	$21,000,000	
		flake breaker	$1,500,000	1	lot	$1,500,000	
		crushers	$2,000,000	1	lot	$2,000,000	
		belt conveyors	$250,000	1	lot	$250,000	
		polishing mixer	$1,000,000	1	lot	$1,000,000	
		polishing dryer	$2,000,000	1	lot	$2,000,000	
		cranes	$500,000	1	lot	$500,000	
		polishing dryer baghouse	$2,000,000	1	lot	$2,000,000	
							$58,550,000
	Installation Contracts	will typically include:					
		mechanical					
		civil and earthworks	$6,000,000	1	lot	$6,000,000	
		concrete	$12,000,000	1	lot	$12,000,000	
		structural	$12,000,000	1	lot	$12,000,000	
		architectural	$10,000,000	1	lot	$10,000,000	
		chutes and ducts	$8,000,000	1	lot	$8,000,000	
		piping	$12,000,000	1	lot	$12,000,000	
		electrical	$12,000,000	1	lot	$12,000,000	
		instrumentation	$10,000,000	1	lot	$10,000,000	
		buildings					
		overall site preparation	$12,000,000	1	lot	$12,000,000	
		construction equipment and freight	$15,000,000	1	lot	$15,000,000	
							$109,000,000
tProduct Storage and Loadout	Mechanical Equipment	will typically include:					
		trippers	$1,000,000	1	lot	$1,000,000	
		flake crushers	$1,000,000	1	lot	$1,000,000	
		belt conveyors	$12,000,000	1	lot	$12,000,000	
		baghouse	$1,000,000	1	lot	$1,000,000	
		stacks	$2,000,000	1	lot	$2,000,000	
		bucket elevators	$2,000,000	1	lot	$2,000,000	
		railcar loading systems	$10,000,000	1	lot	$10,000,000	
		surge bins	$3,000,000	1	lot	$3,000,000	
		mixers	$1,000,000	1	lot	$1,000,000	
		scraper reclaimers	$6,000,000	1	lot	$6,000,000	
		screens	$2,000,000	1	lot	$2,000,000	
							$41,000,000
	Installation Contracts	will typically include:					
		mechanical	$8,000,000	1	lot	$8,000,000	
		civil and earthworks	$4,000,000	1	lot	$4,000,000	
		concrete	$8,000,000	1	lot	$8,000,000	
		structural	$8,000,000	1	lot	$8,000,000	
		architectural	$7,000,000	1	lot	$7,000,000	
		chutes and ducts	$3,000,000	1	lot	$3,000,000	
		piping	$8,000,000	1	lot	$8,000,000	
		electrical	$8,000,000	1	lot	$8,000,000	
		instrumentation	$6,000,000	1	lot	$6,000,000	
		conveyor galleries	$22,000,000	1	lot	$22,000,000	
		product storage	$125,000,000	1	lot	$125,000,000	
		product loadout	$15,000,000	1	lot	$15,000,000	
		overall site preparation	$8,000,000	1	lot	$8,000,000	
		surface mobile equipment	$25,000,000	1	lot	$25,000,000	

Service Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		construction equipment and freight	$30,000,000	1	lot	$30,000,000	
							$285,000,000
Tailings Management Area - Stage 1	Salt Pile Area	will typically include:					
		topsoil removal	$750,000	1	lot	$750,000	
		clearing and grubbing	$500,000	1	lot	$500,000	
		grading and compaction	$750,000	1	lot	$750,000	
		corrugated HDPE pipe	$500,000	1	lot	$500,000	
		granular protection layer	$5,000,000	1	lot	$5,000,000	
							$7,500,000
	Fine Tailings	will typically include:					
		topsoil removal	$500,000	1	lot	$500,000	
		clearing and grubbing	$250,000	1	lot	$250,000	
		excavation	$750,000	1	lot	$750,000	
		fill	$1,500,000	1	lot	$1,500,000	
		clay liner	$9,000,000	1	lot	$9,000,000	
		corrugated HDPE pipe	$50,000	1	lot	$50,000	
		granular protection layer	$3,000,000	1	lot	$3,000,000	
		toe drain granular material	$50,000	1	lot	$50,000	
		topsoil for vegetation	$100,000	1	lot	$100,000	
		granular filter media	$50,000	1	lot	$50,000	
		HDPE liner	$6,000,000	1	lot	$6,000,000	
							$21,250,000
	Reclaim Brine Pond	will typically include:					
		topsoil removal	$1,500,000	1	lot	$1,500,000	
		clearing and grubbing	$1,000,000	1	lot	$1,000,000	
		excavation	$9,000,000	1	lot	$9,000,000	
		clay liner	$22,000,000	1	lot	$22,000,000	
		granular protection layer	$7,000,000	1	lot	$7,000,000	
		HDPE liner	$21,000,000	1	lot	$21,000,000	
							$61,500,000
	Containment Dyke	will typically include:					
		fill	$6,000,000	1	lot	$6,000,000	
		toe drain granular material	$1,000,000	1	lot	$1,000,000	
		road base granular	$100,000	1	lot	$100,000	
		topsoil for vegetation	$500,000	1	lot	$500,000	
		handrails	$3,000,000	1	lot	$3,000,000	
							$10,600,000
	Perimeter Ditch	will typically include:					
		topsoil removal	$1,000,000	1	lot	$1,000,000	
		clearing and grubbing	$500,000	1	lot	$500,000	
		excavation	$7,000,000	1	lot	$7,000,000	
							$8,500,000
	Reclaim Brine Pipeline	will typically include:					
		cut	$500,000	1	lot	$500,000	
		bedding sand	$100,000	1	lot	$100,000	
		fill	$750,000	1	lot	$750,000	
		HDPE pipe	$250,000	1	lot	$250,000	
			$5,000,000	1	lot	$5,000,000	
							$6,600,000
	Brine and Tailings Disposal System						
	will typically include:						
	Deep Injection Wells		$5,000,000	5	each	$25,000,000	

Service Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	Pumphouse Buildings		$200,000	1	lot	$200,000	
	Mechanical Equipment	will typically include:					
		cyclone	$250,000	1	lot	$250,000	
		belt filter	$5,000,000	1	lot	$5,000,000	
		small pumps	$1,000,000	1	lot	$1,000,000	
		large pumps	$3,000,000	1	lot	$3,000,000	
		small tanks	$50,000	1	lot	$50,000	
		large tanks	$250,000	1	lot	$250,000	
		Pump boxes	$50,000	1	lot	$50,000	
		lamella thickener	$2,000,000	1	lot	$2,000,000	
		30" HDPE pipe	$5,000,000	1	lot	$5,000,000	
		16"HDPE pipe	$3,500,000	1	lot	$3,500,000	
	Electrical & Instrumentation for TMA		$1,000,000	1	lot	$1,000,000	
	34.5kV T-Line (TMA Power Supply)		$1,500,000	1	lot	$1,500,000	
							$47,800,000
	Brine Disposal Installation Contracts	will typically include:					
		multi-discipline labour	$40,000,000	1	lot	$40,000,000	
		construction equipment and freight	$10,000,000	1	lot	$10,000,000	
							$50,000,000
Utilities	Powerhouse	will typically include:					
		emergency generators	$2,500,000	2	each	$5,000,000	
		gas-fired boilers	$6,000,000	5	each	$30,000,000	
		deaerators	$500,000	1	lot	$500,000	
		feed pumps	$750,000	1	lot	$750,000	
		temperature and pressure reducers	$500,000	1	lot	$500,000	
		temperature reducers	$1,000,000	1	lot	$1,000,000	
							$37,750,000
	Main Sub-Station and Power Distribution						
	will typically include:						
	Major Equipment & HV Cable System		$20,000,000	1	lot	$20,000,000	
	Protection, Control, and Communications		$1,000,000	1	lot	$1,000,000	
	AC & DC Auxiliary Systems		$500,000	1	lot	$500,000	
	Grounding System		$250,000	1	lot	$250,000	
	LV Cabling		$250,000	1	lot	$250,000	
	Mechanical Systems and Building Services		$500,000	1	lot	$500,000	
	Civil / Structural Work		$10,000,000	1	lot	$10,000,000	
	Cabling from Sub-station to Buildings		$5,000,000	1	lot	$5,000,000	
		construction equipment and freight	$10,000,000	1	lot	$10,000,000	
							$47,500,000
	Water storage and distribution						
	will typically include:						

Service Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	Water Treatment Building Equipment		$10,000,000	1	lot	$10,000,000	
	Water Treatment Building		$5,000,000	1	lot	$5,000,000	
	Water Distribution Piping		$15,000,000	1	lot	$15,000,000	
	Sewage Treatment Plant Buildings		$20,000,000	1	lot	$20,000,000	
	Sewage Treatment Plant		$2,000,000	1	lot	$2,000,000	
	Ponds		$3,000,000	1	lot	$3,000,000	
		construction equipment and freight	$1,000,000	1	lot	$1,000,000	
							$56,000,000
	Reagents						
	will typically include:						
	Reagents Storage Building		$4,000,000	1	lot	$4,000,000	
	Reagents Process Systems		$8,000,000	1	lot	$8,000,000	
		construction equipment and freight	$1,000,000	1	lot	$1,000,000	
							$13,000,000
	Fuel and Natural Gas Storage and Distribution						
	will typically include:						
	Fuel and Natural Gas Facility		$8,000,000	1	lot	$8,000,000	
	Fuel and Natural Gas Distribution Equipment		$5,000,000	1	lot	$5,000,000	
							$13,000,000
	Compressed air						
	will typically include:						
	Plant Wide Service Piping		$10,000,000	1	lot	$10,000,000	
	Compressed Air Building		$20,000,000	1	lot	$20,000,000	
	Compressed Air System		$10,000,000	1	lot	$10,000,000	
							$40,000,000
Non-Process Infrastructure	Non-Process Buildings						
	will typically include:						
	Warehouse		$15,000,000	1	lot	$15,000,000	
	Electrical/Mechanical Maintenance Building		$10,000,000	1	lot	$10,000,000	
	Administration Building		$30,000,000	1	lot	$30,000,000	
	First Aid		$5,000,000	1	lot	$5,000,000	
	Fire Station and Fire Station Offices		$12,000,000	1	lot	$12,000,000	
	Fuel Storage and Fuelling Station		$2,000,000	1	lot	$2,000,000	
	Rail & Locomotive Maintenance Facility		$5,000,000	1	lot	$5,000,000	
	Laboratory		$6,000,000	1	lot	$6,000,000	
		construction equipment and freight	$10,000,000	1	lot	$10,000,000	
							$95,000,000

Service Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	Yards, roads and parking						
	will typically include:						
	On-site Rail Yard		$15,000,000	1	lot	$15,000,000	
	On-site Road Network		$15,000,000	1	lot	$15,000,000	
	Parking Lot		$3,000,000	1	lot	$3,000,000	
	Pipe Rack		$20,000,000	1	lot	$20,000,000	
		construction equipment and freight	$5,000,000	1	lot	$5,000,000	
							$58,000,000
	Below grade services and drainage						
	will typically include:						
	Raw Sewage Piping	PVC	$7,000,000	1	lot	$7,000,000	
	Firewater System	PVC	$4,000,000	1	lot	$4,000,000	
		construction equipment and freight	$1,000,000	1	lot	$1,000,000	
							$12,000,000
	Process Systems						
	Instrumentation		$1,000,000	1	lot	$1,000,000	
							$1,000,000
	Operational Systems						
	Instrumentation	will typically include:					
		Surface Infrastructure	$10,000,000	1	lot	$10,000,000	
		TMA Infrastructure	$2,000,000	1	lot	$2,000,000	
		Visualization and Business Systems	$1,000,000	1	lot	$1,000,000	
		Integration Systems	$1,000,000	1	lot	$1,000,000	
		Production Systems	$1,500,000	1	lot	$1,500,000	
		Recurring Costs	$6,000,000	1	lot	$6,000,000	
							$21,500,000
Total							$1,921,750,000

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category.

8.5 Solution Mine Indirects for CAPEX

The following Table 12: Solution Mine Indirect Costs shows the major indirect cost elements for the construction of a typical solution mine potash facility along with indicative costs for the elements. It should be noted that the EPCM costs have been included here as well.

Table 12: Solution Mine Indirect Costs

Service/ Product	Supply Type	Description	Price/ Unit	#Units	Unit Measure	Total	Cumulative Totals
Indirects	Construction Temp. Facilities, Costs	camp, power, offices, services	$165,000,000	1	lot	$165,000,000	
	Third Party Consultants		$10,000,000	1	lot	$10,000,000	
	Vendor Representatives		$10,000,000	1	lot	$10,000,000	

Service/ Product	Supply Type	Description	Price/ Unit	#Units	Unit Measure	Total	Cumulative Totals
	First Fills		$5,000,000	1	lot	$5,000,000	
	Critical Spares		$20,000,000	1	lot	$20,000,000	
	EPCM including Studies and Execution		$450,000,000	1	lot	$450,000,000	
	Commissioning		$45,000,000	1	lot	$45,000,000	
							$705,000,000
Total							$705,000,000

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category.

9. Operations and Maintenance Stage

Most new potash facilities are designed to operate for 40 years or more. There are significant Maintenance, Repair and Operations (MRO) costs incurred annually for these operating years. These are tabulated below in Table 13: Conventional Underground Mine MRO Costs and Table 14: Solution Mine MRO Costs for the nameplate operating capacities of the facilities. These costs are further broken down into categories. The MRO costs will increase over time but the costs indicated are representative of a relatively new operation.

Most equipment follows a failure rate versus time curve that is the shape of a bathtub (Figure 40: Component Failure vs Time[48]). The Infant Mortality phase is a run-in period that is followed by a Useful Life Period where failure rate is relatively constant subject to regular maintenance. The final Wearout Period shows increasing failure rate as equipment wears out and will ultimately require replacement.

[48] U.S. Department of Energy. (2010, 08 19). *Deferral Energy Management Program*. Retrieved 2012, from Energy Efficiency & Renewable Energy: http://www1.eere.energy.gov/femp/program/om_bestpractices.html

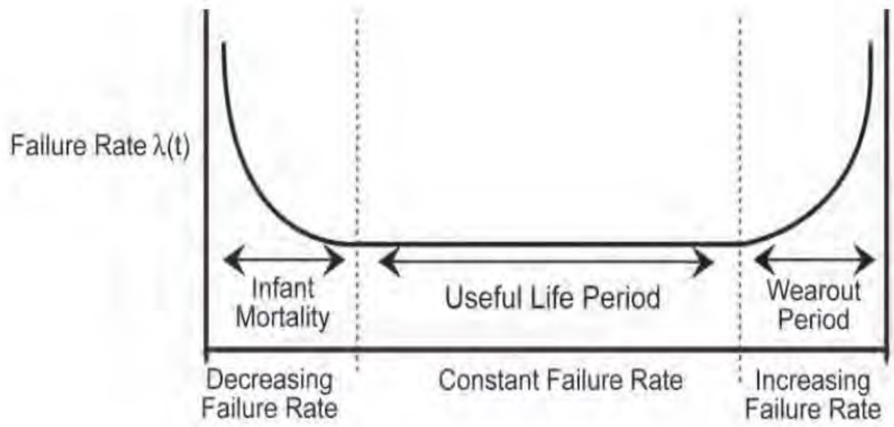

Figure 40: Component Failure vs Time

The maintenance program chosen for use throughout the Useful Life Period can extend or shorten the life of equipment with respect to its intended design life. Reactive Maintenance[49], where equipment is repaired when it fails, will shorten the Useful Life Period considerably and result in higher overall costs than if another maintenance regime was used. Overall maintenance costs include those related to shorter equipment life, labour overtime costs, higher spares inventory and secondary equipment failure costs.

Preventive Maintenance programs perform maintenance on a regular time-based or machine-time based schedule[50]. The O&M Best Practices Guide, Release 3.0 cites Preventive Maintenance being able to reduce overall maintenance costs by 12-18% over Reactive Maintenance programs.

Predictive Maintenance is based on detecting the onset of equipment degradation and can be used to reduce overall costs by 8-12% over Preventive Maintenance programs.

Reliability-Centered Maintenance programs combine all the features of Preventive and Predictive Maintenance techniques but also add root cause analysis of failures that is then used to minimize the likelihood of these problems recurring.

Therefore, the maintenance program adopted has a major impact on MRO costs throughout the life of a potash facility. It is beyond the scope of this Guide to associate the above analysis with the cost tables provided in Table 13: Conventional Underground Mine MRO Costs and Table 14: Solution Mine MRO Costs. However, a reasonable estimate for overall maintenance cost increase is 2-3% per year after an initial few years of steady-state maintenance costs.

[49] U.S. Department of Energy. (2010, 08 19). *Deferral Energy Management Program*. Retrieved 2012, from Energy Efficiency & Renewable Energy: http://www1.eere.energy.gov/femp/program/om_bestpractices.html

[50] U.S. Department of Energy. (2010, 08 19). *Deferral Energy Management Program*. Retrieved 2012, from Energy Efficiency & Renewable Energy: http://www1.eere.energy.gov/femp/program/om_bestpractices.html

Most of the existing potash production facilities in Saskatchewan have been in production for 30-40 years and have a planned annual shutdown of 3-4 weeks for major maintenance work and tie-in of new equipment. Other shorter regular shutdown days are planned as well. The longer shutdowns generally require considerable outside contractor input to complete the work as there is a lot of work condensed into a short period of time.

Refer to Table 13: Conventional Underground Mine MRO Costs and Table 14: Solution Mine MRO Costs for the following elaboration on MRO Costs line items:

- Technical Services/Maintenance – these are staff positions for the following trades and services:
    - Millwright
    - Electrician
    - Pipefitting
    - Instrumentation and control
    - Water management
    - Predictive maintenance testing – thermography, oil analysis, vibration
- Maintenance Supplies – for all areas, these include:
    - Shop tools and consumables – oils, grease, grinding disks, welding rod, fasteners, belts, paint
    - Replacement parts for operating equipment – motors, bearings, heat exchanger coils, pump seals, impellers, valves, filters
- Contracted Services – outside services are required to provide maintenance and specialty support during scheduled shutdowns including:
    - Air quality testing
    - Shutdown trades – scaffolding, millwright, electrician,
    - PLC and other control equipment programming
    - Engineering services for upgrades or technical inspections
- Mine and Shaft Operation – Equipment Operating Supplies including:
    - Electric motors

  - Conveyor belts
  - Idlers
  - Gear boxes
  - Tires
  - Filters
  - Hydraulic pumps, motors and hoses
- Surface Plant Operation – Maintenance Supplies including:
  - Replacement screens
  - Crusher components
  - Flotation drives and belts
  - Gearboxes

9.1 Conventional Underground Mine MRO Costs

Table 13: Conventional Underground Mine MRO Costs

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Mine and Shaft Operation							
Fixed Cost							
	Labour	Operation	$12,500,000	1	annual	$12,500,000	
		Technical Services/Maintenance	$6,000,000	1	annual	$6,000,000	
							$18,500,000
Variable Cost	Permanent Materials		$2,000,000	1	annual	$2,000,000	
							$2,000,000
	Consumables	will typically include:	$1,000,000	1	annual	$1,000,000	
		miner bits					
		vent bag, curtain wall					
		cables, plugs					
		supplies - operating miner	$150,000	5	miners	$750,000	
		spare parts and MRO inventory	$2,000,000	1	annual	$2,000,000	
							$3,750,000
	Equipment Operating Supplies	will typically include:					
		continuous miner	$7,500,000	1	annual	$7,500,000	
		bridge conveyor	$1,000,000	1	annual	$1,000,000	
		roadheader	$300,000	1	annual	$300,000	
		roofbolter	$300,000	1	annual	$300,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		load haul dump loaders	$500,000	1	annual	$500,000	
		scaler	$500,000	1	annual	$500,000	
		service vehicles	$100,000	1	annual	$100,000	
		mancarriers	$200,000	1	annual	$200,000	
		boss buggies	$300,000	1	annual	$300,000	
		forklift	$100,000	1	annual	$100,000	
		skid steer loader	$1,000,000	1	annual	$1,000,000	
		portable compressor	$100,000	1	annual	$100,000	
		feeder breaker	$300,000	1	annual	$300,000	
		development miners	$3,500,000	1	annual	$3,500,000	
		ore haulers	$500,000	1	annual	$500,000	
		train movers	$750,000	1	annual	$750,000	
		scissor trucks	$300,000	1	annual	$300,000	
		water trucks	$300,000	1	annual	$300,000	
		lube trucks	$350,000	1	annual	$350,000	
		surface trucks	$30,000	1	annual	$30,000	
		mobile cranes	$300,000	1	annual	$300,000	
							$18,230,000
		conveyor system	$1,500,000	1	annual	$1,500,000	
							$1,500,000
	Electrical Power		$5,700,000	1	annual	$5,700,000	
	Natural Gas		$1,200,000	1	annual	$1,200,000	
							$6,900,000
Mine and Shaft Operation Subtotal							
Surface Plant Operation							
Fixed Cost							
	Labour	Operation	$13,000,000	1	annual	$13,000,000	
		Technical Services/Maintenance	$9,500,000	1	annual	$9,500,000	
							$22,500,000
Variable Cost	Operating Supplies	will typically include:					
		flotation amine	$2,500,000	1	annual	$2,500,000	
		flotation oil	$1,500,000	1	annual	$1,500,000	
		frother	$2,500,000	1	annual	$2,500,000	
		hydrochloric acid	$50,000	1	annual	$50,000	
		depressant	$2,500,000	1	annual	$2,500,000	
		flocculent	$1,500,000	1	annual	$1,500,000	
		industrial oil	$3,500,000	1	annual	$3,500,000	
		anti-caking amine	$2,000,000	1	annual	$2,000,000	
		sodium hydroxide	$500,000	1	annual	$500,000	
							$16,550,000
	Water		$1,000,000	1	annual	$1,000,000	
	Electrical Power		$11,000,000	1	annual	$11,000,000	
	Natural Gas		$15,000,000	1	annual	$15,000,000	
	Propane		$100,000	1	annual	$100,000	
	Diesel, Gasoline		$1,500,000	1	annual	$1,500,000	
							$28,600,000
	Maintenance Supplies**	Ore Transfer and Storage	$3,000,000	1	annual	$3,000,000	
		Wet Processing	$5,000,000	1	annual	$5,000,000	
		Dry Processing	$7,000,000	1	annual	$7,000,000	
		Product Storage and Loadout	$3,500,000	1	annual	$3,500,000	
		Reagents	$500,000	1	annual	$500,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
		Surface Tailings and Brine Mgmt	$1,000,000	1	annual	$1,000,000	
		Water Storage and Distribution	$500,000	1	annual	$500,000	
							$20,500,000
Surface Plant Operations Subtotal							
General and Administration							
Fixed Cost							
	Labour	G&A	$4,000,000	1	annual	$4,000,000	
							$4,000,000
Infrastructure							
Fixed Cost	Road Maintenance		$500,000	1	annual	$500,000	
	Rail Maintenance		$1,000,000	1	annual	$1,000,000	
	Powerlines General Maintenance		$100,000	1	annual	$100,000	
	Powerlines Preventive Maintenance		$200,000	1	annual	$200,000	
							$1,800,000
Miscellaneous Supplies	Contracted Services	Surface Maintenance	$3,500,000	1	annual	$3,500,000	
		Miscellaneous Surface	$1,000,000	1	annual	$1,000,000	
		Underground	$2,500,000	1	annual	$2,500,000	
							$7,000,000
	Administrative Supplies		$500,000	1	annual	$500,000	
	Laboratory Supplies		$500,000	1	annual	$500,000	
	Medical, Janitorial Supplies		$100,000	1	annual	$100,000	
	Training, Orientation Supplies		$500,000	1	annual	$500,000	
	PPE, Safety Supplies		$500,000	1	annual	$500,000	
	IT, Communications Supplies		$7,000,000	1	annual	$7,000,000	
							$9,100,000
Sundry Overhead Costs	Insurance			1	annual	Not Included	
	Legal Services			1	annual	Not Included	
	Travel Expenses			1	annual	Not Included	
	Employee Transport			1	annual	Not Included	
	Marketing			1	annual	Not Included	
G&A Subtotal							
Total							**$160,930,000**
	** As percent of Capital						

9.2 Solution Mine MRO Costs

Table 14: Solution Mine MRO Costs

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Minefield Operation							
Fixed Cost							
	Labour	Operation	$1,000,000	1	annual	$1,000,000	
Variable Cost	Minefield Development	wells	$3,000,000	10	each	$30,000,000	
							$31,000,000
Surface Plant Operation							
Fixed Cost							
	Labour	Operation	$18,000,000	1	annual	$18,000,000	
		Technical Services/ Maintenance	$12,000,000	1	annual	$12,000,000	
							$30,000,000
Variable Cost	Operating Supplies						
		flocculent	$50,000	1	annual	$50,000	
		anti-caking agent	$10,000,000	1	annual	$10,000,000	
		anti-dusting agent	$1,500,000	1	annual	$1,500,000	
		diesel oil (for mine blanket)	$10,000,000	1	annual	$10,000,000	
							$21,550,000
	Water		$5,000,000	1	annual	$5,000,000	
	Electrical Power		$10,000,000	1	annual	$10,000,000	
	Natural Gas		$100,000,000	1	annual	$100,000,000	
	Propane		$100,000	1	annual	$100,000	
							$115,100,000
	Maintenance Supplies**	Brine Collection	$1,000,000	1	annual	$1,000,000	
		Cooling Pond	$500,000	1	annual	$500,000	
		Evaporation	$4,000,000	1	annual	$4,000,000	
		Crystallizer	$2,000,000	1	annual	$2,000,000	
		Debrining and Drying	$1,000,000	1	annual	$1,000,000	
		Compaction	$1,500,000	1	annual	$1,500,000	
		Product Storage and Loadout	$3,500,000	1	annual	$3,500,000	
		Reagents	$500,000	1	annual	$500,000	
		Surface Tailings and Brine Mgmt	$1,000,000	1	annual	$1,000,000	
		Water Storage and Distribution	$500,000	1	annual	$500,000	
							$15,500,000
General and Administration							
Fixed Cost							
	Labour	G&A	$10,000,000	1	annual	$10,000,000	
							$10,000,000
Infrastructure							
Fixed Cost	Road Maintenance		$500,000	1	annual	$500,000	
	Rail Maintenance		$1,000,000	1	annual	$1,000,000	
	Power lines General Maintenance		$100,000	1	annual	$100,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	Power lines Preventive Maintenance		$200,000	1	annual	$200,000	
							$1,800,000
Miscellaneous Supplies	Contracted Services	Surface Maintenance	$3,500,000	1	annual	$3,500,000	
	Administrative Supplies		$500,000	1	annual	$500,000	
	Laboratory Supplies		$500,000	1	annual	$500,000	
	Medical, Janitorial Supplies		$100,000	1	annual	$100,000	
	Training, Orientation Supplies		$500,000	1	annual	$500,000	
	PPE, Safety Supplies		$500,000	1	annual	$500,000	
	IT, Communications Supplies		$7,000,000	1	annual	$7,000,000	
							$9,100,000
Sundry Overhead Costs	Insurance			1	annual	Not Included	
	Legal Services			1	annual	Not Included	
	Travel Expenses			1	annual	Not Included	
	Employee Transport			1	annual	Not Included	
	Marketing			1	annual	Not Included	
Total							**$234,050,000**

** As percent of capital cost

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category.

9.3 Environmental Monitoring During Operations

During operations, environmental work involves mostly adherence to compliance requirements, seeking approvals for new projects or amending approvals as required, stakeholder relations, and ongoing progressive closure and reclamation plan reviews.

Operations and maintenance and monitoring of the major environmental components of the project include:

- Water Treatment: water treatment plant and ponds.
- Air Emissions Controls: operations and maintenance and monitoring of air emissions control equipment such as scrubbers.
- Waste Management: waste management program, waste rock management, tailings management facility.

There is ongoing monitoring concerning the groundwater, soil and vegetation amendments and wildlife management.

The programs above require various experts and equipment throughout the life of the mine.

10. Closure and Reclamation Stage

Planning for mine closure is a requirement of overall mine lifecycle planning. An initial conceptual plan for decommissioning and reclamation is submitted with the original EA and updated over the course of the mine lifecycle. Once the project is approved to proceed through the EA process, the permits required to construct and operate the facility will include approval of a plan for decommissioning and reclamation. This plan will typically need to be updated every five years.

The closure plan will describe the primary decommissioning and reclamation objective of restoring the mine site to a condition similar to that which existed prior to the mining activity. There are many steps taken during the planning, design and operation of the facility to ensure that the decommissioning and reclamation are planned for and that there are funds available from the owner to carry out the work at closure. This section will only provide guidance on typical decommissioning and reclamation activities at closure and following, but not the process throughout the prior operating life of the mine.

Closure and reclamation planning, however, is progressive during the operations of the mine so that the financial impact is reduced at closure.

Once mining and processing is complete, the closure process begins. This involves, in general:

- Decommissioning and demolition of mine, mining equipment, dewatering, equipment, chemicals, fuels, waste, cables, ventilation, power plants, process plant, pipelines, vessels, camp.
- Waste management of contaminated soil, equipment, steel, buildings, hazardous waste.
- Reclamation in the form of landform design, surface water control, groundwater control, stability and erosion control, land use plan, revegetation, other infrastructure plans.
- Monitoring and maintenance of the tailings management facility and water treatment plants if required.

Below are tables Table 15: Conventional Underground Mine Closure and Reclamation Costs and Table 16: Solution Mine Closure and Reclamation Costs that provide guidance on typical closure and reclamation costs for these two types of potash mine operations. It is important to note that there has not been a potash mine closure in Saskatchewan to date and so the following tables on cost guidance are highly speculative estimates.

10.1 Closure and Reclamation Costs – Conventional Underground Mine

Table 15: Conventional Underground Mine Closure and Reclamation Costs

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Decommissioning and Reclamation (D&R)							
Underground Mineworks and Surface Infrastructure							
	remove hazardous materials from UG mine		$10,000,000	1	lot	$10,000,000	
	remove headframe		$1,000,000	2	each	$2,000,000	
	cap shaft		$500,000	2	each	$1,000,000	
							$13,000,000
Surface Buildings and Plant							
	ore transfer and storage	demolition and removal	$1,780,000	1	lot	$1,780,000	
	wet processing	demolition and removal	$11,400,000	1	lot	$11,400,000	
	dry processing	demolition and removal	$4,900,000	1	lot	$4,900,000	
	product storage and loadout	demolition and removal	$6,400,000	1	lot	$6,400,000	
	utilities	demolition and removal	$3,300,000	1	lot	$3,300,000	
	non-process infrastructure	demolition and removal	$4,800,000	1	lot	$4,800,000	
	hazardous waste removal and disposal		$5,000,000	1	lot	$5,000,000	
	contaminated soil removal and disposal		$5,000,000	1	lot	$5,000,000	
	reclamation	break up concrete and cover with soil	$5,000,000	1	lot	$5,000,000	
		revegetate	$3,000	200	ha	$600,000	
							$48,180,000
Tailings Management Area							
	reshape tailings pile for drainage		$3,000,000	30	year	$90,000,000	
	brine collection and injection	operation	$2,500,000	30	year	$75,000,000	
	brine collection and injection	maintenance	$1,000,000	30	year	$30,000,000	
	removal and disposal of clay liner		$55	1,000,000	m^3	$55,000,000	
	removal and disposal of pond liner		$30	2,000,000	m^2	$60,000,000	
	drilling injection wells		$5,000,000	10	each	$50,000,000	
	grouting of injection wells		$100,000	10	each	$1,000,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	topsoil over site	replacement of original stockpiled	$10	1,000,000	m^3	$10,000,000	
	revegetate		$3,000	200	ha	$600,000	
							$371,600,000
Post-Closure Monitoring	Environmental Monitoring	during D&R	$10,000,000	1	lot	$10,000,000	
		post-closure	$1,000,000	10	years	$10,000,000	
							$20,000,000
Indirects	management and supervision	10%	$45,278,000	1	lot	$45,278,000	
							$45,278,000
Total							$498,058,000

The InfoMine website provides an excellent database for mining-related suppliers, consultants and equipment at www.infomine.com which can be sorted by region and category.

10.2 Closure and Reclamation Costs – Solution Mine

Table 16: Solution Mine Closure and Reclamation Costs

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
Decommissioning and Reclamation (D&R)							
Solution Minefield							
	raw brine collection	demolition and removal	$1,240,000	1	lot	$1,240,000	
	most recent solution mining area	remediation	$500,000	1	lot	$500,000	
		revegetate	$3,000	100	ha	$300,000	
							$2,040,000
Surface Buildings and Plant							
	evaporation facility	demolition and removal	$7,100,000	1	lot	$7,100,000	
	crystallization facility	demolition and removal	$3,500,000	1	lot	$3,500,000	
	debrining and drying	demolition and removal	$1,500,000	2	lot	$3,000,000	
	compaction	demolition and removal	$3,000,000	3	lot	$9,000,000	
	product storage and loadout	demolition and removal	$6,400,000	1	lot	$6,400,000	
	utilities	demolition and removal	$3,300,000	1	lot	$3,300,000	
	non-process infrastructure	demolition and removal	$4,800,000	1	lot	$4,800,000	
	hazardous waste removal and disposal		$5,000,000	1	lot	$5,000,000	
	contaminated soil removal and disposal		$5,000,000	1	lot	$5,000,000	

Service/ Product	Supply Type	Description	Price/ Unit	# Units	Unit Measure	Total	Cumulative Totals
	reclamation	break up concrete and cover with soil	$5,000,000	1	lot	$5,000,000	
		revegetate	$3,000	200	ha	$600,000	
							$52,700,000
Cooling Pond							
	removal and disposal of clay liner		$55	400,000	m^3	$22,000,000	
	removal and disposal of pond liner		$30	700,000	m^2	$21,000,000	
	topsoil over site	replacement of original stockpiled	$10	400,000	m^3	$4,000,000	
	revegetate		$3,000	100	ha	$300,000	
							$47,300,000
Tailings Manageme nt Area							
	reshape tailings pile for drainage		$1,000,000	5	year	$5,000,000	
	brine collection and injection	operation	$500,000	5	year	$2,500,000	
	brine collection and injection	maintenance	$250,000	5	year	$1,250,000	
	removal and disposal of clay liner		$55	400,000	m^3	$22,000,000	
	removal and disposal of pond liner		$30	700,000	m^2	$21,000,000	
	grouting of injection wells		$100,000	10	each	$1,000,000	
	topsoil over site	replacement of original stockpiled	$10	400,000	m^3	$4,000,000	
	revegetate		$3,000	100	ha	$300,000	
							$94,959,000
Post-Closure Monitoring	Environmental Monitoring	during D&R	$10,000,00 0	1	lot	$10,000,000	
		post-closure	$1,000,000	10	years	$10,000,000	
							$20,000,000
Indirects	management and supervision	10%	$17,909,00 0	1	lot	$17,909,000	
							$17,909,000
Total							**$234,908,000**

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