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PREFEASIBILITY ECONOMICS OF SOLUTION MINING COLORADO NAHCOLITE

by

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ABSTRACT

The worlds largest known deposit of nahcolite, a natural occurring sodium bicarbonate, exists in the Piceance Creek Basin of Colorado. Total in-place reserves have been estiamted at 32 billion short tons. The purpose of this thesis is to analyze the economics of producing recrystallized nahcolite, unrefined soda ash, or refined soda ash from the Piceance Creek Basin resource using solution mining methods.

Recrystallized nahcolite was chosen as a potential product because of new and extensive interests that have been expressed by the power and utility companies in using nahcolite as a flue gas desulfurization (FGD) reagent. Recent tests conducted by several indepenent companies have shown that the dry injection of nahcolite is the most effective process for removing sulfur dioxide from the stack gases of power plants burning low-sulfur coal.

Economic analyses of producing unrefined and refined soda ash from the nahcolite resource were also included based on the market potential for a unique and inexpensive low-grade source of sodium carbonate, and an alternate

source of refined soda ash, respectively.

The results of the economic analyses showed that in order to maintain an 18 percent nominal internal rate of return the recrystallized nahcolite, unrefined soda ash, and refined soda ash would have to be sold at $42.75, $59.22, and $72.94 per ton f.o.b. Rifle, Colorado, repectively. The marketing analysis has shown that the potential demand for nahcolite as a FGD reagent will reach 12 million annual short tons by the mid-1990's, and that the delivered price and purity of the nahcolite will be the only limiting constraints for this market demand. Market surveys have also shown that there is an immediate interest in 750,000 to 935,000 short tons of unrefined soda ash, and 1,400,000 to 1,650,000 short tons of refined soda ash.

Based on the results of this thesis it was concluded that a large enough market potential exists for solution mined nahcolite to support a large industry. Prefeasibility cost estimates have also shown that several products can be profitably produced from the nahcolite resource.

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ACKNOWLEDGEMENTS

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Finally, I would like to express my appreciation and gratitude to the many people who have assisted me during the course of this study. I regret that I cannot list each person individually.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND FACTORS

Nahcolite ($NaHCO_3$) is a natural occurring soduim bicarbonate. It is a water soluble mineral which can serve as a raw material for the manufacture of basic industrial chemicals and has received most recent attention as a reagent for removing sulfur dioxide from industrial stack gases. The only significant resource of nahcolite known in the world is located in the Green River Formation in the Piceance Creek Basin of northwestern Colorado. This deposit contains a massive concentration of nahcolite and dawsonite (a sodium aluminum carbonate) intermixed with oil shale covering an area of approximately 150,000 acres and measuring 1,300 feet thick at the center (Dyni, 1974).

The Piceance Creek Basin is a large structural and topographic basin that contains vast reserves of oil shale, nahcolite, and dawsonite. All of these resources are found within the Green River Formation, which is a sedimentary unit deposited in a large lake system some 50 million years ago. The nahcolite and dawsonite reserves are found in a limited geographic area in the depositional center of the Piceance Creek Basin, in association with the thickest deposits of oil shale. Here, the sodium-rich oil shale has a maximum thickness of 1,300 feet with the top of the formation ranging in depth from about 1,400 to 2,000 feet below the surface. Estimated in-place reserves for nahcolite and dawsonite are 32 billion and 29 billion short tons, respectively (Dyni, 1981). Estimated in-place reserves of shale oil for the entire Piceance Creek Basin resource is 1.2 trillion barrels of oil-equivalent (National Petroleum Council, 1973).

1.2 POTENTIAL USES

The primary markets for nahcolite lie in its use as a reagent in the emerging flue gas scrubbing market and as a raw material for producing industrial chemical derivatives such as soda ash (Na_2CO_3), caustic soda (NaOH), and commercial grade sodium bicarbonate ($NaHCO_3$).

1.2.1 FLUE GAS DESULFURIZATION

The flue gas desulfurization (FGD) market encompasses virtually every industry requiring sulfur removal from stack gases. Nahcolite used as a dry additive to stack gases reacts to absorb sulfur dioxide (SO_2) according to the following reactions:

$$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$$
$$Na_2CO_3 + SO_2 + 1/2\ O_2 \rightarrow Na_2SO_4 + CO_2$$

In 1981, a large scale joint field test by Electric Power Research Institute (EPRI), Public Service Company of Colorado, and Charter's Multi-Mineral Corporation at the Public Service Company's Cameo plant clearly demonstrated that a nahcolite-baghouse system can absorb a high percentage of sulfur dioxide and will remove significantly more particulates at a lower cost than the "wet scrubbing" and "spray drying" methods currently being used in power plants and industrial operations (Muzio, 1983).

No commercial supply of nahcolite is available at the present time. Consequently, more expensive lime and limestone spray dryers have accounted for over 75 percent of megawatt scrubbing capacity of recently installed power plants and 53 percent of retrofit installations. If nahcolite were available, it could gain a significant share of the FGD market in dry injection sytems due to its lower cost and greater reliability over the alternative spray drying processes.

1.2.2 SODA ASH

Nahcolite can be processed into crude or refined soda ash. Refined soda ash is an industrial chemical used primarily in glass manufacture, chemicals, pulp and paper, and waste water treatment. In 1982, domestic demand for refined soda ash was 7.8 million short tons, while domestic capacity exceeded 10.8 million short tons. Although the soda ash market is presently over-supplied, nahcolite-based soda ash could compete as an alternate source of soda ash on another rail system. At the present time, most of the domestic soda ash is produced and shipped from Green River, Wyoming. Several large consumers of soda ash have expressed an interest in purchasing a portion of their soda ash from an alternate source to eliminate their dependency on one railroad.

The only commercially available soda ash is the high density, high purity grade (approximately 99.4% pure). Many users of soda ash in the bottling, chemical, waste water treatment, and enhanced oil recovery industries require only a crude grade soda ash but are forced to purchase the only available, more expensive high-grade soda ash. If a source of crude soda ash were developed, it could gain a significant share of the soda ash market by supplying an inexpensive source of crude sodium carbonate.

1.2.3 OTHER USES

Other potential uses for nahcolite are in the caustic soda and commercial-grade sodium bicarbonate markets. Currently, caustic soda is produced as a co-product with chlorine, from the electrolysis of brine. Consequently, if there is not a balance between the demand for caustic soda and chlorine, one will be in short supply. Since 1979, chlorine demand has been weak, causing a shortage of caustic soda. If a low-cost source of sodium carbonate could be developed to produce caustic soda, it could gain a significant market share.

Two potential markets for large quantities of sodium bicarbonate are in animal feed and waste water treatment. The use of sodium bicarbonate (bicarb) in animal feed is the fastest growing market for bicarb, and could overshadow the others within a few years. The several benefits claimed for using sodium bicarbonate to control alkalinity in waste water treatment plants include increased methane production and reduction of sulfide odors, corrosion relief, increased solids settling, and toxic pollutant removal. With the great number of water treatment facilities in the United States, the market potential could prove to be very large.

1.3 STATEMENT OF PROBLEM

Since the discovery of the oil shale resources in northwestern Colorado, the oil industry has acquired large blocks of oil shale lands around the southern and western perimeter of the Piceance Creek Basin where the canyons have exposed the bed of oil shale known as the Mahogany Ledge. Inadvertently, the attention of the oil shale industry has been focused on the thinnest oil shale deposits, instead of the incredibly thick deposits that are co-deposited with nahcolite in the depositional center of the basin.

Events in the oil shale industry over the past few years have clearly illustrated that selective extraction of only oil shale from the perimeter of the basin is not profitable by any proven process without significant government subsidies (Pace Engineering, 1982). Consequently, there has been an expressed interest in concurrently recovering the nahcolite and oil shale for the mutual economic benefit of both operations, or even recovering the nahcolite and leaving the oil shale for future recovery when oil prices can support such an operation. In either case, markets for large quantities of nahcolite must be developed.

1.4 OBJECTIVES OF STUDY

This thesis, on a preliminary research level, will serve to determine the economic feasibility of extracting, upgrading, and marketing solution mined nahcolite. The objective of this study is to evaluate prefeasibility data supplied by Nielsen Resources Corporation to determine whether or not the economics justify further work in the solution mining of nahcolite. Since nahcolite can be processed into several sodium oxide derivatives, this study will be limited to refined soda ash, unrefined soda ash, and nahcolite as potential marketable products. Although the revenue from the sale of nahcolite could significantly effect the overall economic feasibiity of an oil shale operation, this effect will not be discussed in this thesis but should be the basis of further research.

In order to analyze the market potential of nahcolite and it's derivatives, it is necessary to: (1) Determine the economics of solution mining and upgrading the minerals, and (2) to estimate the potential market for these products at a market price that is based on the prices of competitive products. For this, the following tasks were conducted:

Task 1- Determine the costs of solution mining raw nahcolite and the processing of recrystallized nahcolite, unrefined soda ash, and refined soda ash. The first task, described in chapter 2, was to establish the full costs of solution mining the nahcolite and processing it into one of the three products discussed. The purpose of this task was to develop three seperate cost estimates so that each of the three products could be evaluated on an independant basis. The estimate of the solution mining costs was performed by the author, while the estimates for the processing facilities were provided by Nielsen Resources Corporation.

Task 2- Estimate the economic viability of producing each product. The second task was to use the cost estimates to determine the economics of producing each product. Using the present market prices of competing products (determined in chapter 4), 20 year cash flows were developed to determine the DCFROR, net present value (NPV), and break-even price per ton for each product. The DCFROR is calculated from current (inflated) dollar cash flows as is the NPV and break-even price. The NPV is calculated at an 18 percent nominal rate of return and the break-even price is the price necessary to yield an 18 percent DCFROR. Following this, sensitivity analyses were performed by changing capital costs, operating costs, and price to determine the importance of factor of production. This task was performed by the author and is shown in chapter 3.

Task 3 - Determine the potential market for recrystallized nahcolite, refined soda ash, and unrefined soda ash. The purpose of this final task was to determine the market demand, competing sources of supply, the market price, and the market area for the three nahcolite-based products. This task was performed by the author and is shown in chapter 4.

1.5 PREVIOUS INVESTIGATIONS

The enormous sodium mineral deposits of the lower Green River Formation were discovered by Irvin Nielsen in 1964.

Since that time, several methods have been developed to leach the nahcolite for the sole purpose of developing pore space for the recovery of shale oil using in-situ pyrolysis techniques. To date, there has not been any information published regarding the economics of selectively recovering nahcolite using solution mining techniques. The only company that has shown any interest in selectively recovering and marketing nahcolite from a solution mining operation is Industrial Resources Incorporated (IRI) of Colorado. Early in 1983, IRI publicly announced their intentions of developing and testing solution mining technology for the purpose of recovering nahcolite. However, no further information has been released.

The most detailed work concerning the leaching of nahcolite for the in-situ recovery of shale oil has been done by Shell Oil Company. In 1972, Shell Oil Company conducted a field test for in-situ recovery of shale oil and found that nahcolite could be leached efficiently using hot water injected at high pressure. This test resulted in the issuance of U.S. patents 3,502,372, 3,572,838, 3,700,280, 3,709,208, 3,779,601, 3,779,602, 3,894,769, and 3,957,306. Other comprehensive studies that have been published concerning the leaching of nahcolite are "In Situ Recovery of Oil and Minerals from Piceance Creek Basin Oil Shale" by Cowles and Boughton (1976), "Soluble-salt Processes for In-situ Recovery of Hydrocarbons from Oil Shale" (Prats, 1977), and "In-place Recovery of Multiple Products from Colorado's Saline-mineral-bearing Piceance Basin" by Beard and Smith.

Extensive work has been conducted on the economics of mining nahcolite using conventional underground mining techniques. In 1972 the U.S. Bureau of Mines published a report entitled "An Economic Analysis of a White Nahcolite Installation in Colorado". The study is a detailed evaluation of mining and processing 11,680 short tons of nahcolite per day. Other work concerning the underground recovery of nahcolite has been done by Multi Mineral Corporation. Since it's formation in 1978, the Multi Mineral Corporation has conducted 2 1/2 years of extensive underground mining in oil shale and nahcolite horizons at the experimental Horse Draw Mine. This work resulted in the development of proprietary detailed mine and plant designs and cost estimates for the production of nahcolite, dawsonite, and oil shale.

CHAPTER 2

MINING AND PROCESSING: DESCRIPTIONS AND COST ESTIMATES

2.1 OVERVIEW

To determine the economics of solution mining and processing nahcolite, preliminary engineering design and cost estimates had to be completed. The in-situ recovery process used in this study is based on existing field and laboratory data developed by Shell Oil Company and is tailored to the salt capped nahcolite deposit at the depocenter of the Piceance Creek Basin. The cost estimates for the solution mining operation include the cost of drilling and installing the necessary field piping. All other costs, including the hot water injection system, are included in the cost of the processing facilities.

The conceptual designs and cost estimates for three alternative processing facilities were supplied by Nielsen Resources Corporation from previous prefeasibility work. Due to the proprietary nature of this data, only cost summaries and general estimating techniques are shown in this study. The three products, recrystallized nahcolite, unrefined soda ash, refined soda ash, were selected as marketable products because they can be produced relatively easily from the solution mined brine. The cost figures used in this thesis were developed from the prefeasibility stage. Therefore, the results of the economic analysis should be used only to determine whether or not further investigations are warranted.

2.2 THE RESOURCE

The Green River Formation in the Piceance Creek Basin in northwestern Colorado is the world's largest deposit of nahcolite (see figure 2-1). The formation covers 4,300 square kilometers, has a thickness of 1,100 meters at its center, and contains a massive amount of nahcolite, dawsonite, and oil shale (Roehler, 1974). Although oil shale is found throughout much of the Piceance Creek Basin, major occurrences of nahcolite are limited to the depocenter of the basin between the depths of 520 and 915 meters (see figure 2-2).

In the Piceance Creek Basin, the Green River Formation is divided, in ascending order, into the Anvil Points (also referred to as Douglas Creek), Garden Gulch, and Parachute

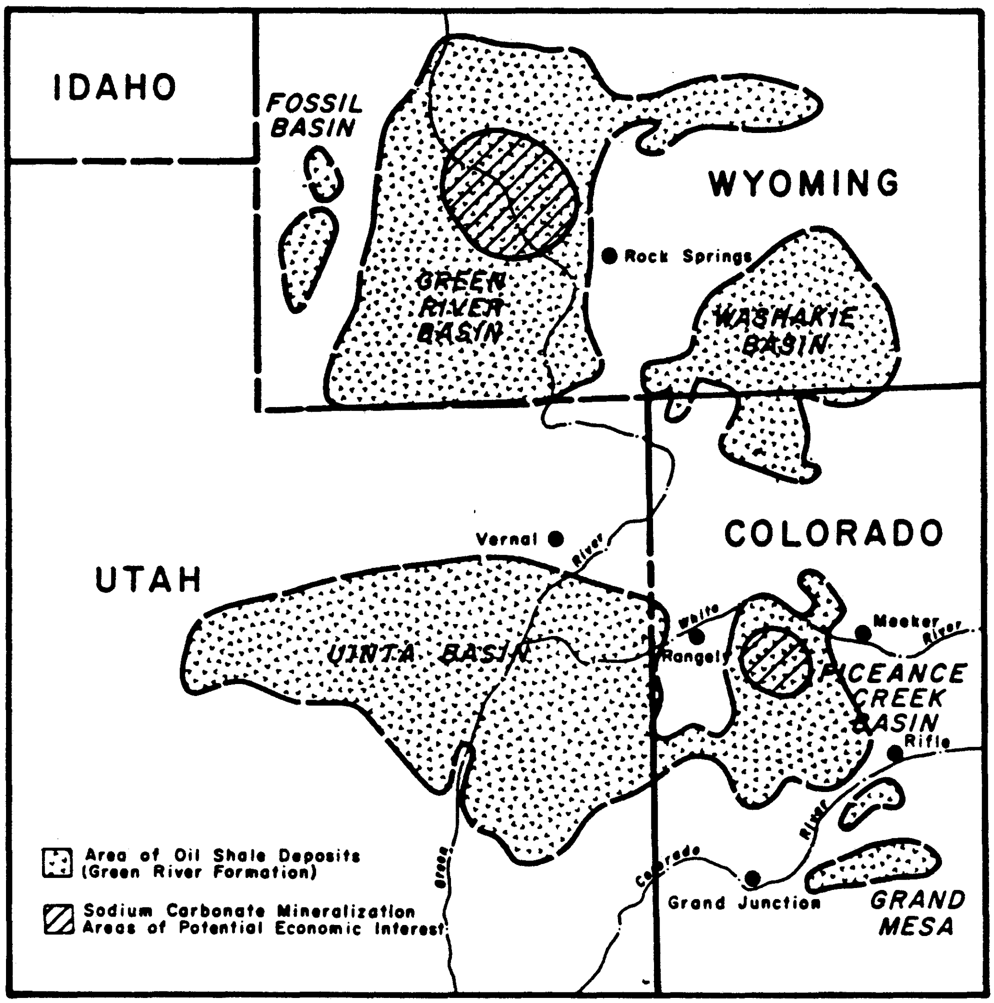


Figure 2-1. Location of Green River Formation and occurrences of sodium mineral deposits.

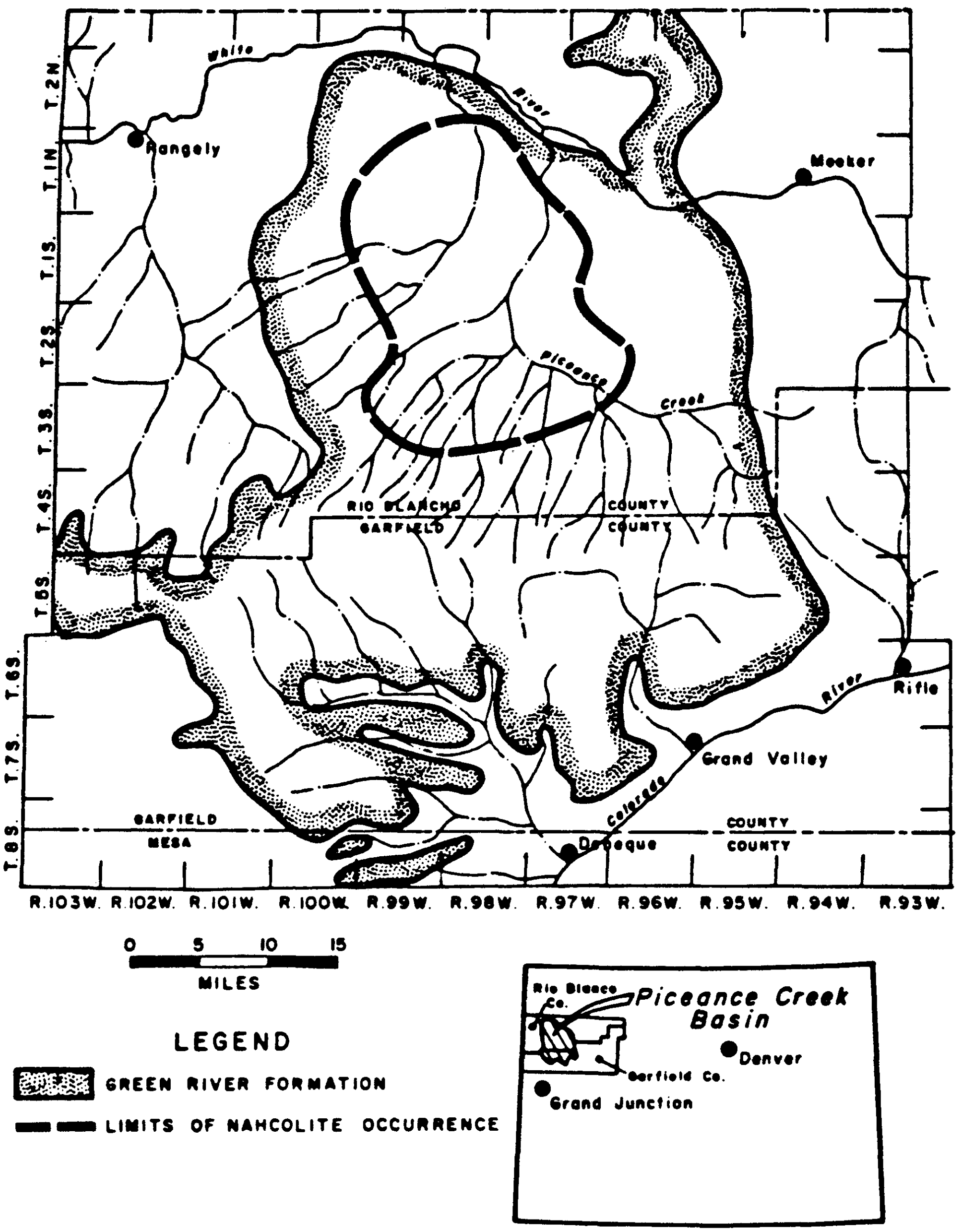
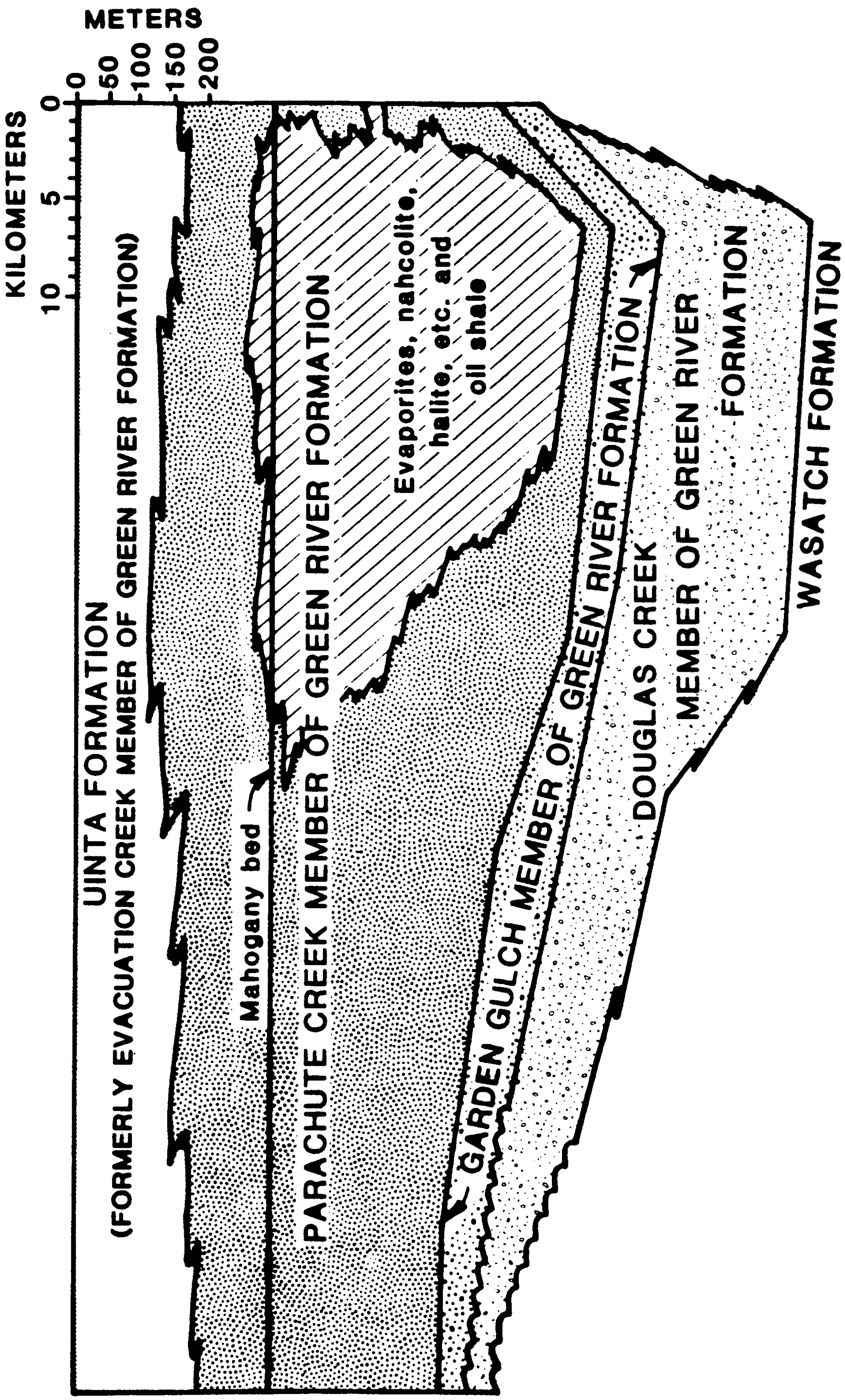


Figure 2-2. Piceance Creek Basin and extent of nahcolite occurrence.

Creek Members (see figure 2-3). The Parachute Creek Member contains the major portion of the nahcolite, dawsonite, and oil shale reserves, and has an estimated thickness of 490 to 540 meters. The lower unleached part of the saline facies extends from near the base of the Parachute Creek Member, upward into the Mahogany oil shale zone (which is near the top of the member) and contains the largest quantities of nahcolite. Here, the nahcolite occurs in non-bedded coarse-crystalline aggregates scattered through oil shale, laterally continuous units of fine-grained crystals disseminated in oil shale, and white coarse-grained beds. Where nahcolite occurs in beds, it is commonly associated with bedded halite (NaCl). The lower unleached part of the saline facies ranges in thickness from 160 to 330 meters (Dyni, 1981). The nahcolite zone is overlain by a leached zone which is characterized by solution cavities, open fractures, local breccia zones, and intervals of porous marlstone. The nahcolite originally present in this zone has been leached out by ground water. The zone is now saturated with water of a highly saline composition.

The optimal zone available for the application of solution mining techniques is an interval found between the depths of 520 and 670 in the saline zone. Here, the



Southwest-northeast cross section of Eocene rocks in the Piceance Creek Basin showing stratigraphic units

Figure 2-3

formation is gas tight, free of aquifers, and rich in soluble salts. The average mineral composition in this zone is 48.1 weight percent carbonate minerals, 33.1 percent silicate minerals, and 18.8 percent kerogen (Dyni, 1981). One important factor about the composition is that nahcolite is the only water-soluble mineral. This means that the nahcolite-laden brine that is produced in the solution mining operation will contain very few impurities. With very little purification, the brine will yield a relatively pure product.

Another unique feature of this deposit is the halite beds capping a large portion of the nahcolite deposit. Once a cavity is formed from a solution mining operation, fractures can develop from thermal expansion and roof failure. If the fractures migrate upward, they could penetrate the overlying aquifer. However, due to the ductile nature of the halite, the fractures are prevented from migrating upward (Dyni, 1981).

2.3 DESCRIPTION OF THE SOLUTION MINING PROCESS

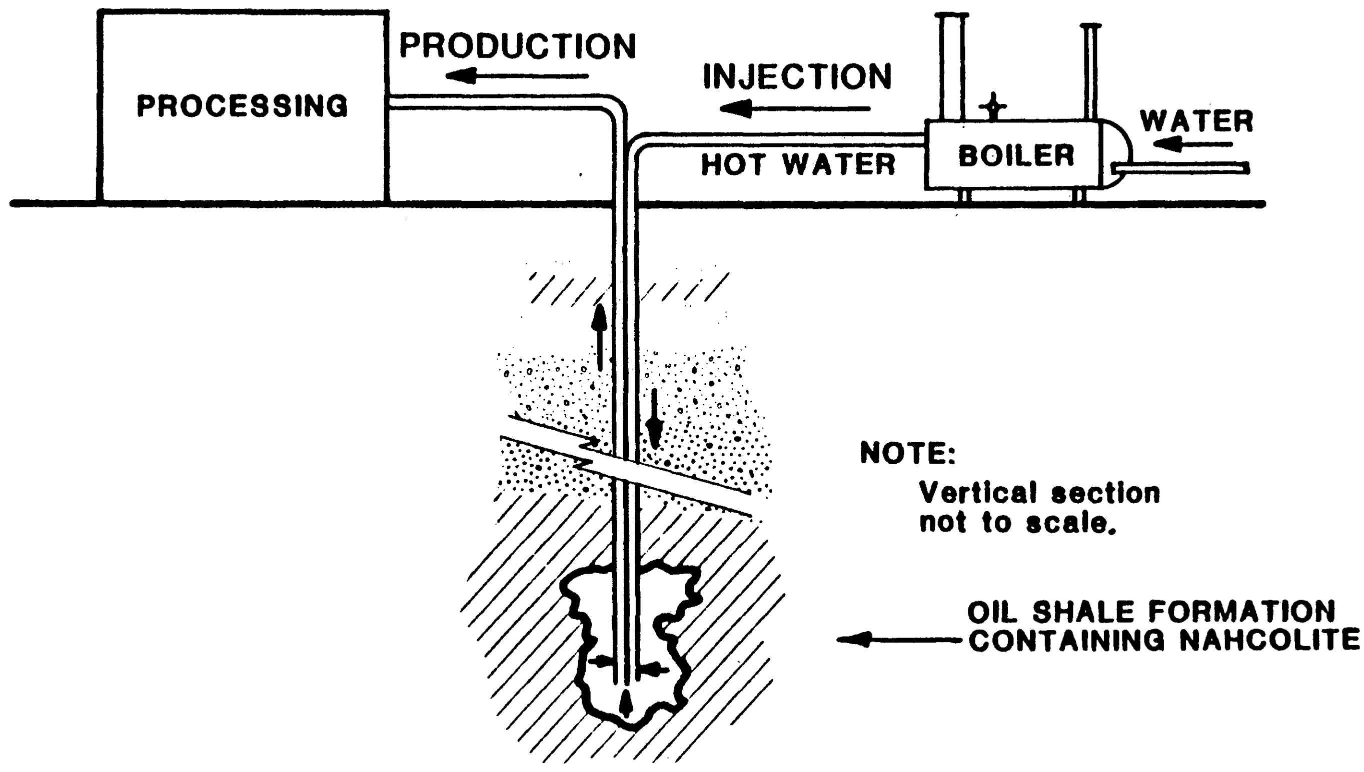
The recovery of water-soluble minerals from subsurface deposits by solution mining with aqueous fluids is well known. In such a process, aqueous fluid is injected down a well into contact with a subsurface deposit. The solution dissolves some of the soluble mineral, and is then flowed to the surface where it is treated to remove the dissolved mineral. As is common with most water-soluble minerals, the solubility of nahcolite increases with increasing temperature. Therfore, the aqueous fluid is heated to increase it's mineral carrying capacity before it is injected into the subsurface mineral deposit.

In-situ recovery of nahcolite offers several potential advantages over conventional mining operations. Nahcolite most commonly occurs in the deeper part of the basin as dispersed nodules, which can be easily accessed using solution mining techniques. Conventional mining methods are limited to the less common, thick-bedded nahcolite. Solution mining of the bedded and non-bedded occurrences of nahcolite gives a greater resource extraction rate resulting in greater conservation of the resource. Another advantage of in-situ development is that it inherently has fewer materials handling and environmental problems.

The solution mining techniques used in this thesis were modified from the process developed and tested by Shell Oil

Company in 1972 (Beard, 1973). The solution mining process involves drilling two wells (or a single, dually completed well) into the Saline Zone to leach a nahcolite horizon between 520 and 670 meters (depth changes with geographic location). Hot water is then injected underground at 405° F and 1000 psig, which heats the formation and dissolves the nahcolite. The nahcolite-laden brine is then brought to the surface through the production string where it is processed. As the nahcolite is removed from the formation, a swiss cheese-like cavity is produced (see figure 2-4).

The results of the Shell test showed that nahcolite can be efficiently leached using a high temperature, high pressure injection system. Cavities of 175-foot-diameter each, seperated by 50-foot-thick pillars are recommended for sustaining the overburden and rubble loads. It was also found that the radius of the cavity will grow at a rate of about 0.3 feet per day (Prats, 1977). With a diameter of 175 feet, the average life of a single cavity would be approximately 1 year. With an average nahcolite concentration of 20 percent and specific gravity of 2.5, each cavity would produce about 200,000 tons of nahcolite per year.



NAHCOLITE SOLUTION MINING PROCESS
PROCESS - (SCHEMATIC)
Figure 2-4

2.4 PROCESSING DESCRIPTIONS

Three products have been analyzed as potential outputs from the nahcolite-laden solution: processed nahcolite, unrefined soda ash, and refined soda ash. All three products can be produced by cooling and crystallizing the hot solution mined brine.

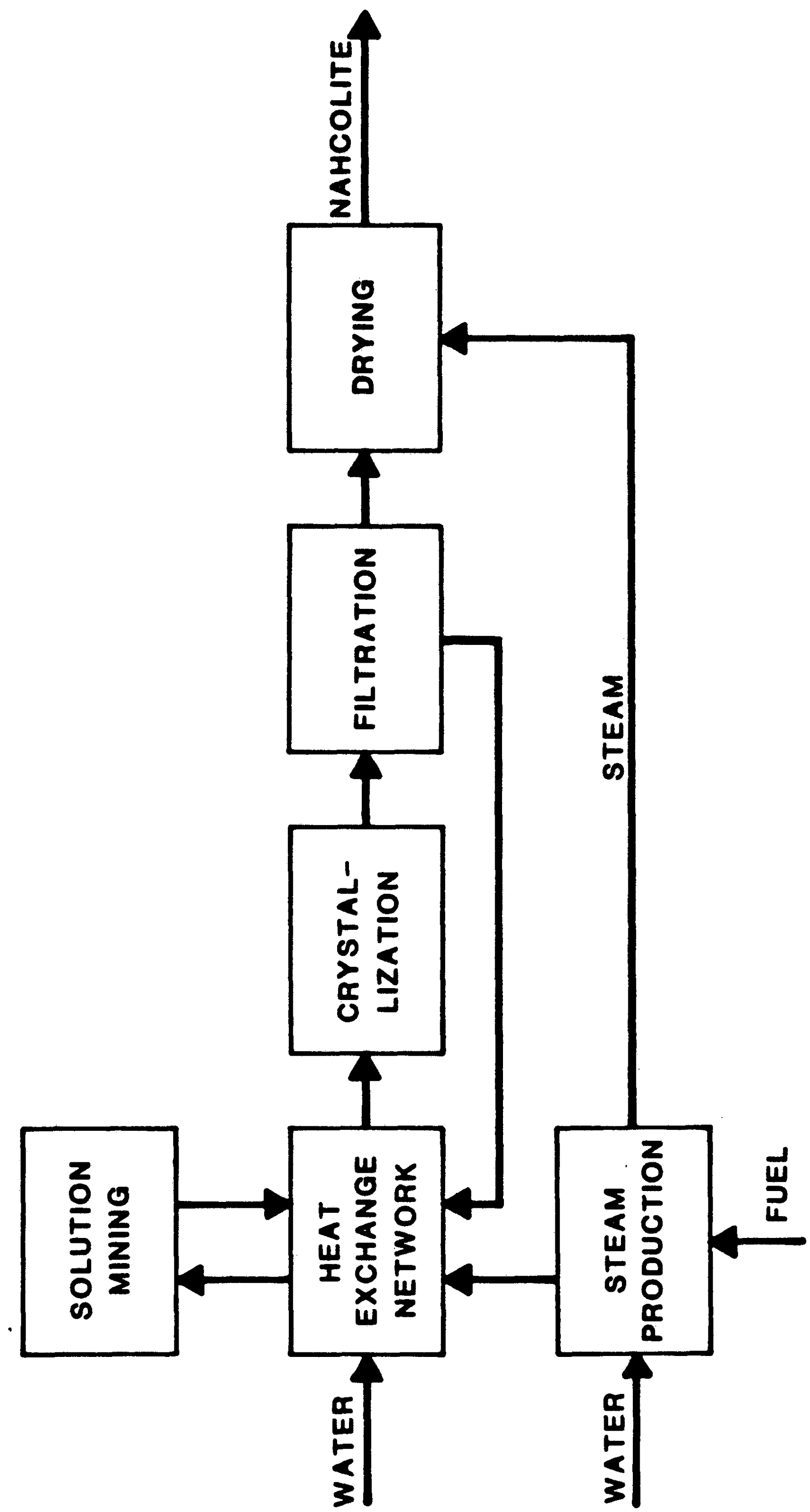
2.4.1 NAHCOLITE PROCESSING

When producing nahcolite, the temperature and pressure of the brine must be controlled during the crystallization process to insure the formation of only sodium bicarbonate crystals. If the proper operating conditions are maintained during crystallization and drying, a 98 percent pure dry nahcolite will be produced. This product, recrystallized nahcolite, will have about 40 percent by weight more active sodium than the natural occuring nahcolite which is 30 percent inert material. Recent tests performed by Iowa State University have demonstrated that the recrystallized nahcolite is just as effective as the natural mineral for removing SO_2 from power plant flue gases (De La Cruz, 1982). Consequently, the recrystallized product will enjoy a 40 percent weight advantage over the natural nahcolite at 70 percent purity.

The nahcolite processing facility is designed to produce 755,000 tons (assume short tons unless otherwise specified) of nahcolite annually. Once the fluid is recovered from the production well, nahcolite is crystallized by reducing the pressure and temperature. The crystals are then removed from the solution by filtration, and dried in low temperature steam tube dryers. The product (98% $NaHCO_3$/2% Na_2CO_3) is conveyed pneumatically to vertical silos for storage prior to truck shipment. This relatively simple crystallization process is depicted in Figure 2-5.

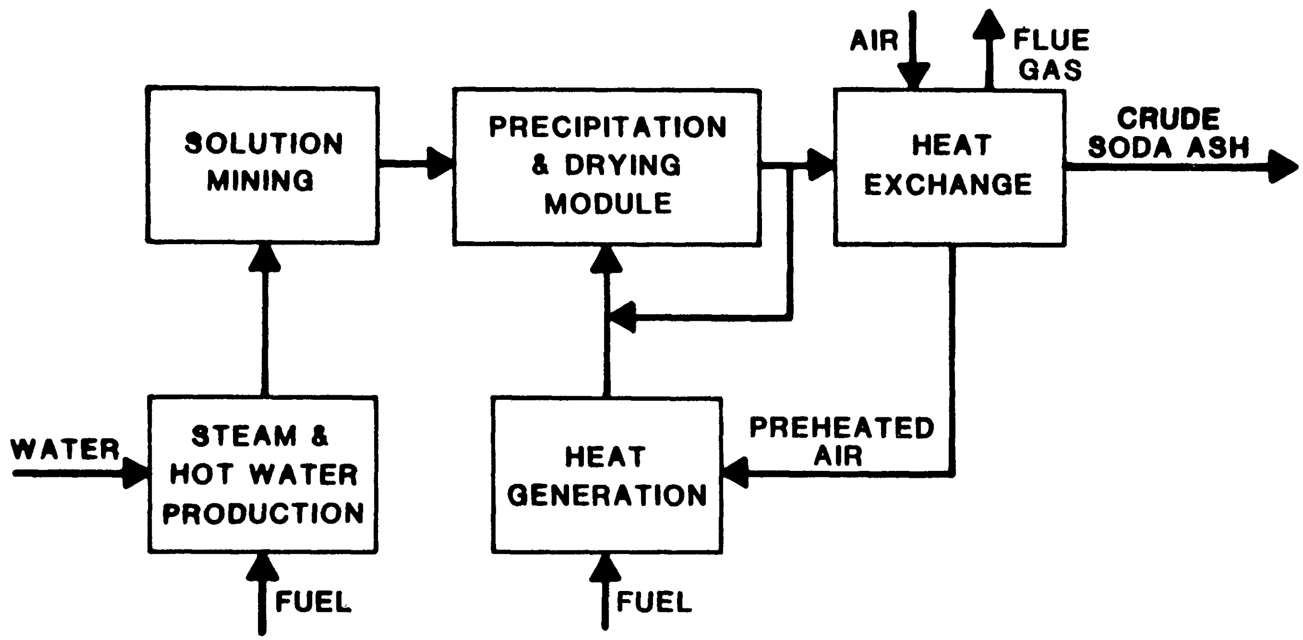
2.4.2 UNREFINED SODA ASH PROCESSING

As indicated in Figure 2-6, the production of crude soda ash is very similar to the sodium bicarbonate process, with only two major differences. To produce sodium carbonate, the solution is not kept under pressure as in the bicarbonate process. This allows the CO_2 to escape from the solution so that sodium carbonate forms instead of sodium bicarbonate. Also, as the crystallized product is dried, it is heated to about 600-800° F to decompose any remaining nahcolite to sodium carbonate according to the following



Nahcolite crystallization process
capacity 755,000 tons/yr.

Figure 2-5



Unrefined soda ash process
capacity 500,000 tons/yr.

Figure 2-6

reaction:

$$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$$

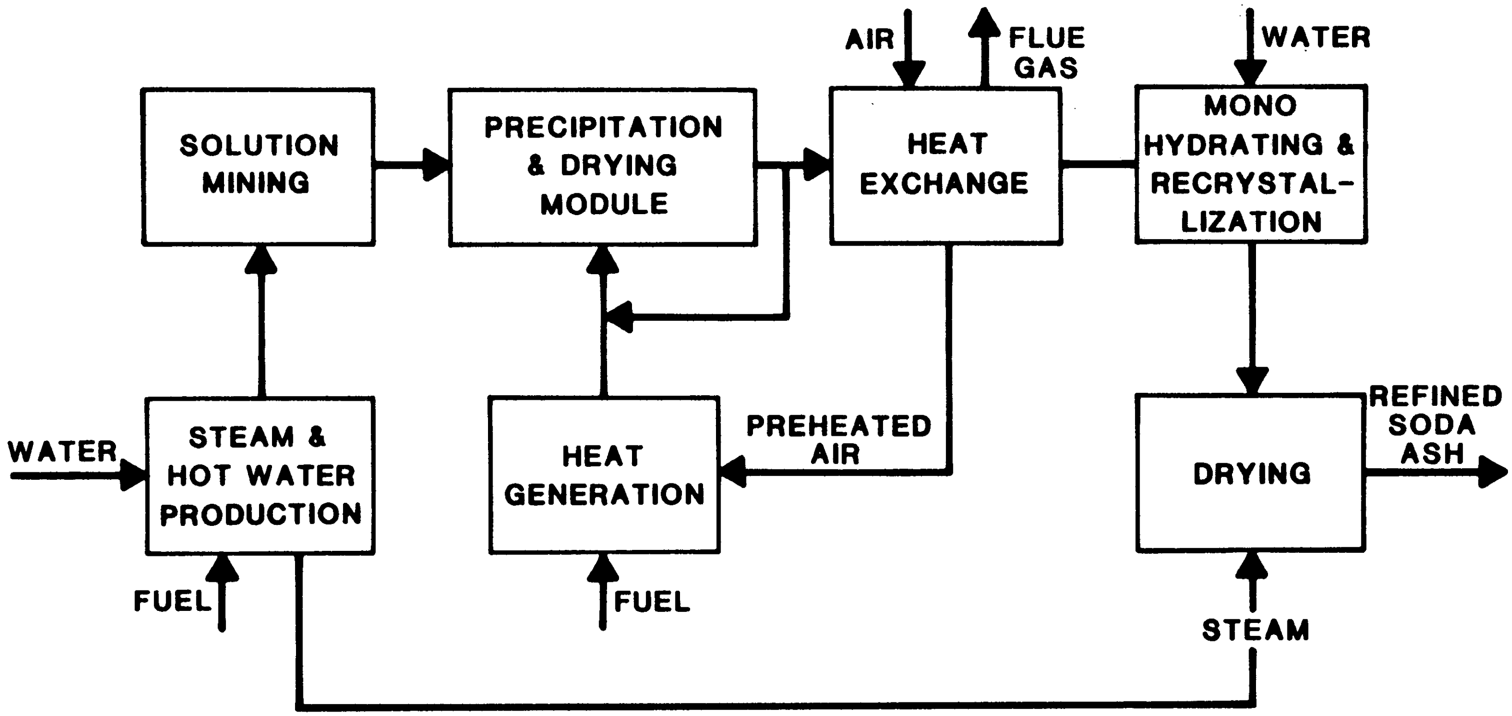
This processing facility is designed to produce 500,000 annual tons of a fine, light crude soda ash that is approximately 98 percent Na_2CO_3 and 2 percent $NaHCO_3$.

2.4.3 REFINED SODA ASH PROCESSING

The refined soda ash processing plant is designed to process 755,000 tons of raw nahcolite into 500,000 tons of refined soda ash annually. As indicated in Figure 2-7, the process is conventional state-of-the-art technology using the unrefined soda ash described above as feedstock. Once the crude soda ash is filtered, dried and bleached, the soda ash is then mixed with water to form a sodium carbonate monohydrate slurry. Excess surface moisture is removed from the slurry by centrifuging. The wet soda ash cake is then dried in a steam tube dryer to produce high purity, dense refined soda ash. This product can then be marketed in the existing soda ash market.

2.5 SOLUTION MINING COST ESTIMATE

The solution mining costs are directly proportional to



Refined soda ash process
capacity 500,000 tons/yr.

Figure 2-7

the quantity of raw nahcolite being produced. Since the processing plants were designed to handle 755,000 tons of nahcolite per year as input, it was assumed that four solution cavities would have to be mined annually. In addition, it was assumed that four wells would have to be drilled each year to monitor the solution mining activities. This gives a total of 12 holes that have to be drilled and cased annually. The capital costs for the solution mining activities consist of casing, well heads, and field piping. The operating costs include all costs that benefit the project for less than one year. This includes the cost of the rig, bulldozer operator, dynamite, well cement, bits, and pipe relocating. A summary of the capital and operating costs are shown in Table 2-1.

2.6 COST ESTIAMTES FOR PROCESSING PLANTS

This section presents the results of the capital and operating cost estimates for the processing plants previously described. Major equipment costs and operating costs were developed from in-house data and vendor quotes, with the less significant cost items being factored from major equipment costs using historical relationships. The summaries of the cost estimates were provided by Nielsen

TABLE 2-1

DRILLING CAPITAL COST SUMMARY
(1983 DOLLARS)

CASING	COSTS
Solution Wells (18,000 ft. of N-80,17lb.)	$540,000
Monitoring Wells (10,000 ft. at $1,500/100')	$150,000
WELL HEADS	
4 Injectors	$37,000
4 Producers	$74,000
FIELD PIPING	
2-20" Trunk Lines (4,250 ft. at $28/ft.)	$119,000
2-4" Inj. & Prod. Lines (3300 ft. at $5/ft.)	$16,500
CONTINGENCY (20%)	$187,300
TOTAL CAPITAL COSTS FOR DRILLING PROGRAM	$1,123,800

ANNUAL DRILLING OPERATING COSTS SUMMARY

	COSTS
RIG COSTS	
$5,500/day, 5days/hole, 12 holes	$330,000
BULLDOZER OPERATION	
$800 for each platform & access road	$9,600
DYNAMITE ($4,000/hole)	$32,000
WELL CEMENT ($8,500/hole)	$102,000
BITS ($800/bit, 3 bits/hole)	$28,800
CASING REPLACEMENT (500'/hole, av. $2,500/100')	$150,000
PIPE RELOCATING	
$38/ft. for 4,250 ft. of 20" pipe	$161,000
$7/ft. for 3300 ft. of 4" pipe	$22,000
TOTAL ANNUAL DRILLING OPERATING COSTS	$835,400

Resources Corporation, and are shown in Tables 2&3 in first quarter 1983 dollars. Detailed information is considered proprietary information and thus only the generalized estimating techniques can be discussed.

2.6.1 CAPITAL COST ESTIMATES

The processing plant capital cost estimates are provided in Table 2-2. These estimates were developed using the following techniques:

1) A technical definition was developed for each equipment item.
2) In-house data or telephone vendor quotes were used to price each item.
3) Equipment erection labor was factored from equipment costs based on historical relationships.
4) Bulk materials and labor were factored from equipment costs based on historical relationships.
5) Site development, buildings, and service facilities were estimated based on conceptual layouts.
6) Engineering and construction management were factored from direct costs based on historical relationships.
7) Allowance for indeterminents was estimated at 25 percent of estimated capital based on other projects at this stage of development.

TABLE 2-2

PROCESSING PLANTS CAPITAL COSTS
(1983 DOLLARS IN THOUSANDS)

	RECRYSTALLIZED NAHCOLITE	UNREFINED SODA ASH	REFINED SODA ASH
PRECIPITATION & DRYING	$ -0-	$16,000	$16,000
MAJOR EQUIPMENT	14,000	1,660	4,150
EQUIPMENT ERECTION LABOR	5,590	650	1,620
BULK MATERIAL & LABOR	11,140	1,290	3,220
ACCESS ROADS	90	90	90
BUILDINGS	1,000	200	200
SERVICE FACILITIES	5,100	4,250	4,250
SUBTOTAL	$37,220	$24,140	$29,530
ENGINEERING	3,340	2,070	2,530
CONSTRUCTION MANAGEMENT	2,240	1,550	1,900
CONTINGENCY (25%)	10,700	6,940	8,490
TOTAL	$53,500	$34,700	$42,450
WORKING CAPITAL (25% of total operating costs)	$4,130	$4,689	$5,866

2.6.2 OPERATING COST ESTIMATES

Table 2-3 provides a summary of the annual operating cost estimates in first quarter 1983 dollars. Royalties, taxes, working capital, and shipping costs are included in the economic evaluation in Chapter 3. Allowance for indeterminents are not included. The operating costs were developed using the following techniques:

1) Utilities costs are from the power and fuel requirements in the heat and material balance with power valued at $0.05/KWHR and natural gas valued at $4.00/MMBTU.

2) Operating labor costs are from historical data based on plant complexity, capacity, and current labor rates.

3) Direct supervison and clerical labor are from a historical relationship to operating labor.

4) Maintenance and repairs are 6 percent of processing plant capital cost.

5) Operating supplies are from a historical relationship to maintenance and repairs.

6) Laboratory charges are from a historical relationship to operating labor.

7) Local taxes and insurance are from a historical relationship to capital cost.

8) Overhead is from a historical relationship to operating labor and maintenance.

TABLE 2-3

PROCESSING PLANTS ANNUAL OPERATING COSTS
(1983 DOLLARS IN THOUSANDS)

	RECRYSTALLIZED NAHCOLITE	UNREFINED SODA ASH	REFINED SODA ASH
UTILITIES			
Electricity	$661	$240	$294
Fuel	6,500	11,530	14,000
Miscellaneous	100	100	100
TOTAL UTILITIES	$7,261	$11,870	$14,394
OPERATING LABOR	745	701	1,400
SUPERVISORY & CLERICAL LABOR	112	105	210
MAINTENANCE & REPAIRS	3,200	2,082	2,500
OPERATING SUPPLIES	482	312	374
LABORATORY CHARGES	112	105	210
TOTAL DIRECT CHARGES	$11,912	$15,175	$19,088
LOCAL TAXES	803	521	624
INSURANCE	535	347	416
OVERHEAD	2,434	1,730	2,500
TOTAL FIXED CHARGES	$3,772	$2,598	$3,540
TOTAL ANNUAL OPERATING COSTS	$15,684	$17,773	$22,628

CHAPTER 3

ECONOMIC ANALYSIS

3.1 ECONOMIC EVALUATION METHODOLOGY

In an effort to analyze the economic viability of producing recrystallized nahcolite, unrefined soda ash, and refined soda ash from solution mined nahcolite, the following economic parameters were determined for each project: 1) The internal rate of return (DCFROR), 2) net present value, and 3) break-even price for each project. These parameters were determined by developing current dollar cash flows for a twenty year project life for each of the base cases. The cash flow statements were developed from the cost estimates developed in Chapter 2. Also an 18 percent minimum rate of return (a currently accepted rate of return for prefeasibility studies by major engineering firms) and product prices of $81 per ton for recrystallized nahcolite, $61 per ton for crude soda ash, and $81 per ton for refined soda ash were assumed. Sensitivity analyses were then conducted on the base cases by changing product price, capital cost, and operating cost data by -40%, -20%, +20%, and +40%. The results of the economic analyses are used in

Chapter 4 to determine the marketability of each product.

3.2 ECONOMIC ASSUMPTIONS

An economic analysis computer program was used to develop and evaluate the cash flow statements (Peterson, 1982). The following assumptions were used as input parameters into the computer program:

Cash Flow Computation. The methodology used in computing the current dollar net cash flows is shown in Figure 3-1. The nominal discounted cash flow rate of return (DCFROR) is calculated by determining the discounting rate for all positive and negative cash flows that produces a net present value of zero. Break-even prices were determined by changing the product price used in the base cases, and recalculating the DCFROR. Once these two points were developed, linear regression was used to approximate the break-even price which would yield an 18 percent internal rate of return. Each project was evaluated on a 100 percent equity position to determine the economic viability of the overall project.

Project Schedule. It is assumed that the project will

TABLE 3-1

COMPONENTS OF AN ALL EQUITY ANNUAL CASH FLOW CALCULATION

CALCULATION	COMPONENT
	Revenue
Less	Operating Costs
	Net Income Before Depreciation and Depletion
Less	Depreciation and Amortization Allowance
	Net Income After Depreciation and Amortization
Less	Depletion Allowance
	Net Taxable Income
Less	Federal Income Tax
	Net Profit After Taxes
Add	Depreciation and Amortization Allowances
Add	Depletion Allowance
	Operating Cash Flow
Less	Capital Expenditures
Less	Working Capital
	Net Annual Cash Flow

begin in 1983, and that construction will continue through mid-1985. It is also assumed that 2.3 percent of the capital will be expended in 1983, 79.1 percent in 1984, and 18.6 percent in 1985. These percentages were extrapolated from historical data on similar processing facilities.

Escalation Factors. All costs were estimated in first quarter 1983 dollars. In order to develop current dollar cash flow statements, capital and operating costs were assumed to escalate at 5.4 percent a year for the 20 year evaluation period. Due to the present condition of the soda ash market, product prices were assumed to escalate at a slightly lower rate of 5 percent (escalation factors provided by Nielsen Resources Corporation).

Price. In the base case evaluations, product prices were assumed to be \$81/ton for nahcolite, \$61/ton for crude soda ash, and \$81/ton for refined soda ash (product prices are developed in detail in Chapter 4). With 755,000 tons of nahcolite being solution mined annually, 755,000 tons of recrystallized nahcolite or 500,000 tons of unrefined or refined soda ash can be produced for marketing.

Royalty. Royalty is paid to the lessor and is a percentage of gross revenue. The Federal government leases the sodium minerals at a royalty rate of 5 percent of gross revenue.

Depreciation. All capital expenditures were divided into their appropriate depreciation catagories based on the year the costs were incurred and depreciated using 175 percent declining balance switching to straight line.

Tax Depletion Allowance. Two methods of computing depletion allowance are cost depletion and statutory depletion. The taxpayer may select the amount that results in the largest deduction, however, the deduction cannot exceed 50 percent of the project's net income before depletion. The allowable statutory depletion, as specified in the Internal Revenue Service regulations, is 14 percent for sodium minerals. Since it was assumed that there are no acquisition costs or previous exploration costs, cost depletion is not applicable.

Effective Income Tax. State and Federal taxes were combined to give an effective tax rate of 50 percent. Since the nature of the project participation is not known, all losses were carried forward to generate deductions against future income.

Investment Tax Credits (ITC). Tax credit is taken on 10 percent of the eligible costs taken in the year incurred, or the first project year in which income taxes are paid. The ITC limit is 85 percent of the project's taxes in excess of $25,000. Also, 50 percent of the ITC was deducted from the investment cost in establishing the basis for computing ACRS depreciation deductions.

Severence Tax. Severence tax is calculated at 2.25 percent of all gross revenue that exceeds $11,000,000. Due to the limitations of the computer program, the severence tax rate was translated into an effective cost per ton.

Working Capital. Working capital was calculated as 25 percent of the annual operating cost.

Extraordinary Nonrecurring Operating Costs. It was assumed that $2,000,000 in research and development costs would be spent in a solution mining and processing pilot test. This test would be carried out from 1983-1984.

3.3 RESULTS OF THE ECONOMIC EVALUATIONS

Detailed economic analyses were performed on each project using the parameters presented in the previous sections and are shown in Appendices 1-3. A summary of the analyses are shown in Table 3-2 for an 18 percent discount rate.

Table 3-2

Summary of Economic Current Dollar Analyses
(1983 cost and price basis)

	Recrystallized Nahcolite	Unrefined Soda Ash	Refined Soda Ash
Annual Production	755,000 tons	500,000 tons	500,000 tons
Price/Unit f.o.b.- Rifle	$81/ton	$61/ton	$81/ton
Nominal DCFROR	52.55%	24.08%	27.9%
NPV ($MM) @ 18% ROR	$114.0	$12.6	$25.0
Required Price for 18% DCFROR @ plant	$38.25/ton	$54.74/ton	$68.44/ton
*Required Price for 18% DCFROR f.o.b. -Rifle	$42.75/ton	$59.22/ton	$72.94/ton

* Transportation costs to Rifle are assumed to be $4.50/ton as developed in Chapter 4.

3.4 SENSITIVITY ANALYSES

Sensitivity analyses were performed on the base cases to evaluate the effect on DCFROR of increases in price, operating costs, and capital costs. These parameters were changed by -40%, -20%, +20%, and +40% in the recalculations of the DCFROR for the sensitivity analyses. The results of the sensitivity analyses are listed in Table 3-3.

Graphing the results of the nahcolite sensitivity analysis illustrates that the rate of return is fairly insensitive to changes in capital and operating costs (see figure 3-1). With a product price of $81 per ton, the project will still exceed a 40 percent DCFROR with a 40 percent increase in either the capital or operating costs. This is advantageous to the producer since it increases the probability of the project remaining profitable even with undesirable changes in capital or operating costs. However, Figure 3-1 does show that the projects rate of return is sensitive to changes in price. Since the power industry is interested in obtaining a source of nahcolite for FGD, long-term contracts could be negotitated which would guarantee price stability, reducing the risk of unfavorable price changes. Also, possible further research should determine whether this sensitivity can be reduced by optimizing plant capacity.

The sensitivity analyses for the production of unrefined and refined soda ash show that the projects' rates

TABLE 3-3

SENSITIVITY OF DCFROR TO CHANGES IN
PRICE, OPERATING COSTS, AND CAPITAL COSTS

RECRYSTALLIZED NAHCOLITE PRODUCTION

	DCFROR		
% CHANGES IN PARAMETERS	PRICE	OPERATING COSTS	CAPITAL COSTS
- 40 %	28.8%	58.0%	75.5%
- 20 %	41.5%	55.2%	61.8%
0 %	52.6%	52.6%	52.6%
+ 20 %	63.0%	49.8%	46.0%
+ 40 %	72.7%	47.0%	41.2%

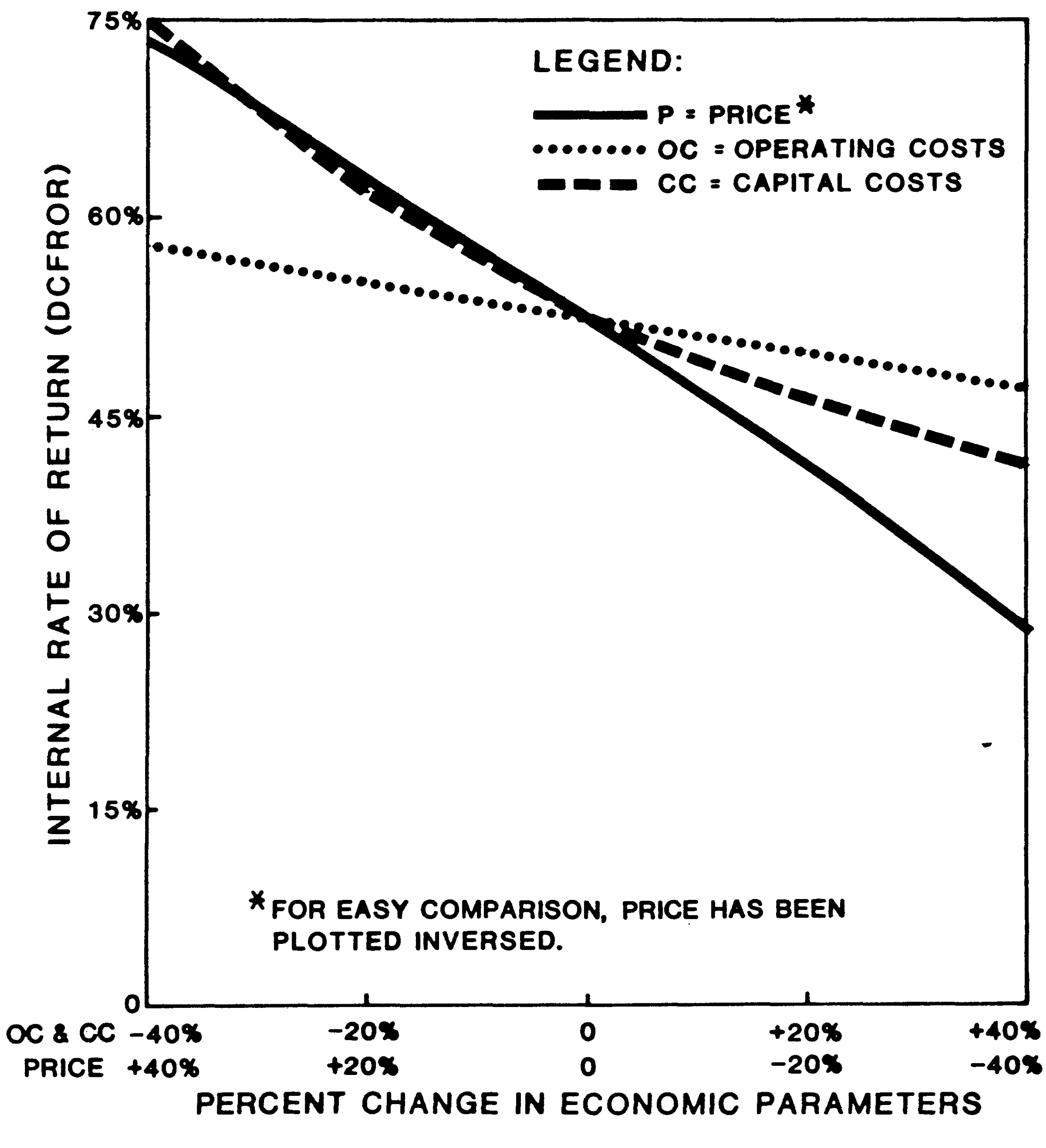
UNREFINED SODA ASH PRODUCTION

	DCFROR		
% CHANGES IN PARAMETERS	PRICE	OPERATING COSTS	CAPITAL COSTS
- 40 %	neg.	36.5%	35.8%
- 20 %	10.6%	31.0%	28.8%
0 %	24.1%	24.1%	24.1%
+ 20 %	34.9%	15.9%	20.7%
+ 40 %	50.6%	5.0%	18.1%

REFINED SODA ASH PRODUCTION

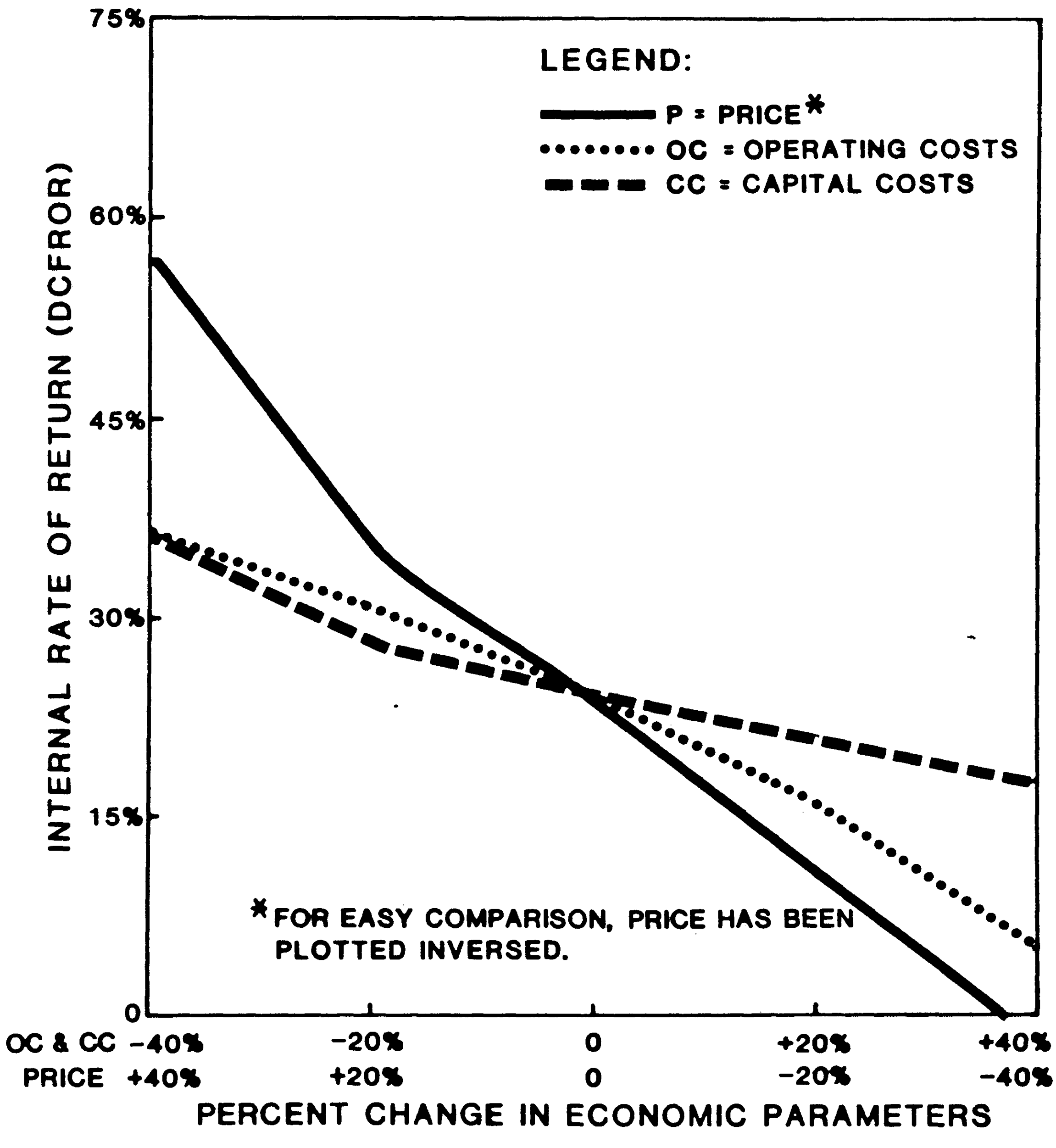
	DCFROR		
% CHANGES IN PARAMETERS	PRICE	OPERATING COSTS	CAPITAL COSTS
- 40 %	neg.	39.9%	41.5%
- 20 %	14.3%	34.7%	33.3%
0 %	27.9%	27.9%	27.9%
+ 20 %	39.0%	20.1%	24.0%
+ 40 %	47.3%	10.3%	21.2%

of return are much more sensitive to changes in operating costs than in the previous case (see figures 3-2 & 3-3). This increase in sensitivity is a result of the higher energy costs. In the equipment specifications, natural gas boilers were chosen because the installation of coal boilers would require a much larger capital investment. After analyzing the results of the sensitivity analyses, it may be found that the use of coal-fired boilers may reduce fuel costs enough to justify the higher capital cost. Further research should determine the economics of alternative fuel sources along with optimal plant size.



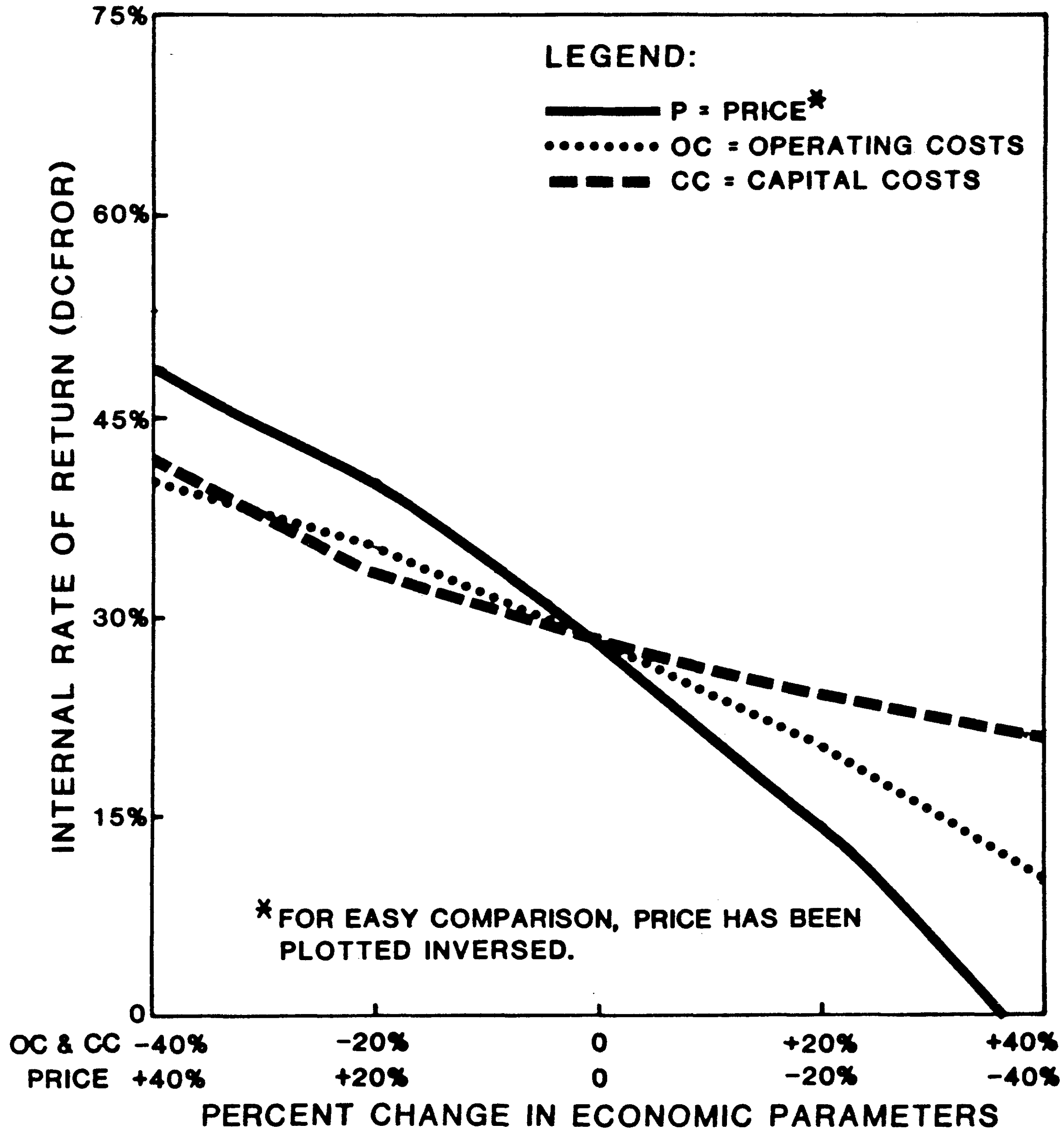
Recrystallized nahcolite production
sensitivity analysis

Figure 3-1



Unrefined soda ash production
sensitivity analysis

Figure 3-2



Refined soda ash production
sensitivity analysis

Figure 3-3

CHAPTER 4

MARKET POTENTIAL FOR SOLUTION MINED NAHCOLITE

4.1 POTENTIAL MARKETS

The primary markets for recrystallized nahcolite lie in its use as a flue gas desulfurization reagent and as a raw material for the production of unrefined and refined soda ash. The potential for nahcolite in these markets is obviously based on inherent physical and chemical properties. However, the acceptance of nahcolite into these specific market places is dependent upon the price that the consumer must pay for the delivered product. Therefore, the processing and transportation costs directly effect the demand for nahcolite. The purpose of this marketing analysis is to determine the marketability of nahcolite and its derivatives, based on the competitiveness of the delivered price of nahcolite with the delivered price of substitute products.

4.2 FLUE GAS DESULFURIZATION

Present desulfurization technologies include the conventional wet scrubbers, the newly developed spray dryer and dry injection systems. The problems of wet scrubbing sulfur dioxide from power plant flue gases has been well documented (Lutz, 1979). Capital costs for the conventional wet scrubbing flue gas desulfurization (FGD) equipment has been about equal to the cost of the entire boiler for a new unit. As a result of the high investment cost and low reliability of the wet scrubber systems, the utility industry has been interested in developing new processes for the removal of SO_2. While spray dryer technology for FGD may alleviate many of the problems associated with conventional wet scrubbing, this concept still has problems similar to wet processes. Dry injection FGD takes the development process one step further to a totally dry system, thus eliminating the difficulties of handling the wet slurries (EPRI, 1983).

In the dry injection process (see figure 4-1), a soduim-based sorbent such as nahcolite is injected into the flue gas ductwork upstream of the fabric filter. The reagent and fly ash are then collected on the fabric filter bags forming a filter cake. The major portion of the SO_2 is absorbed by the reagent as it passes through the filter cake according to the following two reactions:

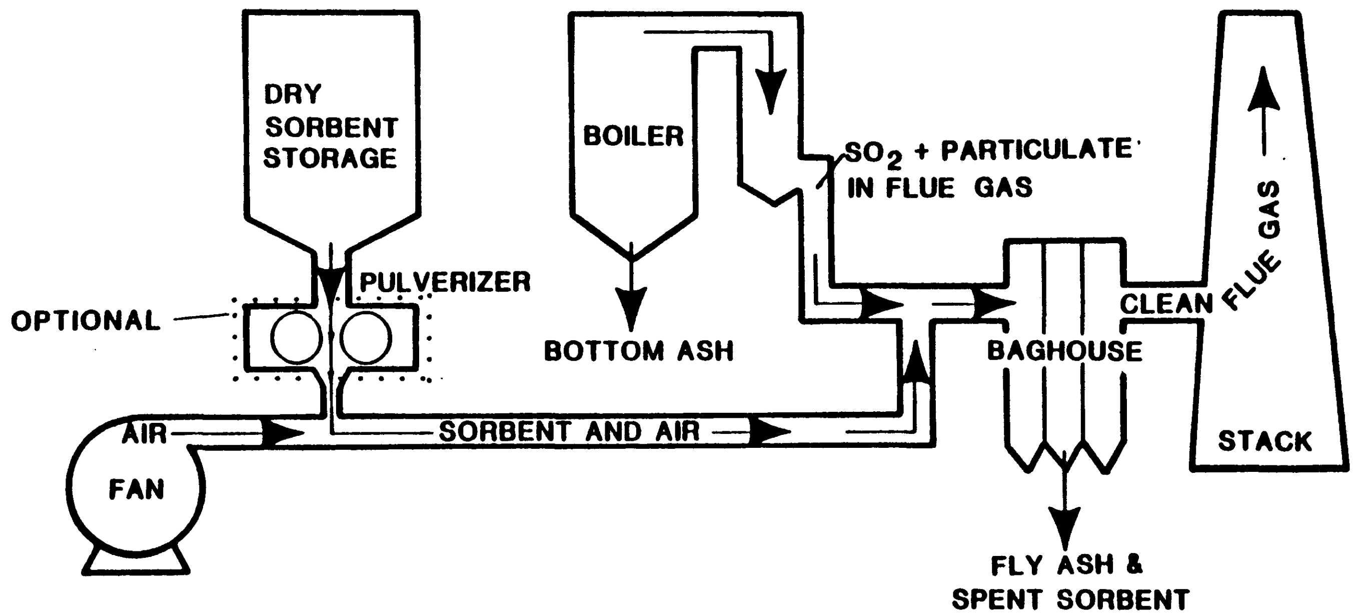


Figure 4-1. Nahcolite dry injection process

1) $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

2) $Na_2CO_3 + SO_2 + 1/2\ O_2 \rightarrow Na_2SO_4 + CO_2$

The carbonate generated from the thermal decomposition of nahcolite is considerably more effective in the removal of sulfur dioxide than commercial soda ash. This is because as the nahcolite gives off water and carbon dioxide, a porous carbonate crystal is formed that has significantly greater specific surface area than commercial soda ash. The result is a much more reactive carbonate for SO_2 removal (Bechtel, 1978). The nahcolite dry injection process offers many advantages over spray drying and wet scrubbing systems. These advantages are as follows:

1) A milder steel construction, than is used in wet scrubbing systems can be used.

2) It offers capital cost savings and lower maintenance costs.

3) There are significant energy and water savings.

4) 10 to 40 percent of the oxides of nitrogen can be removed.

5) It is a simple dry process that the utilities are familiar with.

6) Dry injection systems also meet opacity regulations.

These advantages have developed a substantial interest in dry scrubbing systems within the utility industry.

The only major disadvantage in the application of dry injection technology is the high reagent cost. In comparison with wet scrubber and spray dryer processes, dry injection systems require more reagent to remove each pound of sulfur. In scrubbing the stack gases of power plants burning low sulfur coal, the low capital costs associated with the dry injection system more than compensate for the additional reagent cost, thus the dry injection system is more economical than wet scrubber or spray dryer systems. However, in scrubbing the stack gases generated by utilities using higher sulfur coal, the reagent costs of the dry injection system increase much faster than those of the competing systems. This makes dry injection uneconomical when burning high sulfur coal.

The associated economics of dry injection systems are site specific due to the sulfur content of the coal being burned and the delivered price of nahcolite. In previous evaluations of nahcolite dry injection systems, it was assumed that raw nahcolite with a purity of 70 percent would be used. If recrystallized nahcolite with a 98 percent purity were used by the utilities, transportation costs per ton of reactive material would be reduced by 28 percent. This will enhance the economics of scrubbing higher sulfur coal using dry injection systems. Additionally, it is believed that many new power plants will be designed to burn lower sulfur coal due to the associated costs of sulfur removal. This will enhance the potential market for nahcolite as a FGD reagent.

4.2.1 PROJECTED NAHCOLITE DEMAND IN THE FGD INDUSTRY

The assessment of the potential demand for nahcolite was based on existing and future power plants that burn coal and have fabric filters to remove particulate matter. The existing power plant information was obtained from an Electric Power Research Institute (EPRI) report of July 1981. EPRI is updating this study, however, the results were unavailable at the time of this study. The future power plant information was based on the Power Engineering report of April 1982.

The demand for dry sorbents for FGD is highly sensitive to the geographic location of the power plant, sorbent price, sulfur content of coal, removal required, and potential changes in regulations due to pending acid rain legislation. In order to simplify the determination of potential demand, the following assumptions were made:

1) 50 percent of the new power plants that are planned will actually be built.

2) The nahcolite will be used at a rate of 200 tons/year/MW (assumes coal @ 0.9% sulfur content).

3) All future plants are potential users of dry injection scrubbing systems.

4) All existing plants with fabric filters can retrofit dry injection scrubbing systems.

The existing power plant capacity totals 338,345 megawatts (MW). The EPRI study shows that only 1.8 percent of this capacity uses fabric filters, and that about 90 percent of these are in the western United States. A summary of the annual new plant completions through the mid-1990's is provided in Table 4-1. As indicated in the table, about 42 percent of the new U.S.plants planned through 1995 will be installed in the Western U.S.

By combining the new and existing coal-fired power plant capacities, it is estimated that by the mid-1990's total demand for nahcolite for FGD will be 11,970,000 tons per year (see table 4-2). This demand for nahcolite is contingent upon an available source being developed within the next few years. Unless there is a dependable supply of nahcolite available to the power industry, alternate scrubbing systems will be designed into the plants.

TABLE 4-1

FUTURE COAL FIRED POWER PLANT CONSTRUCTION

SOURCE: POWER ENGINEERING, APRIL 1982

	CAPACITY RATING, MW		
	WESTERN USA	EASTERN USA	TOTAL USA
1982 - 1984	11,379 MW	17,271 MW	28,650 MW
1985	2,583	5,459	8,042
1986	3,535	2,280	5,815
1987	2,770	3,660	6,430
1988	3,790	3,720	7,510
1989	3,470	5,840	9,310
1990 +	17,310	24,463	41,773
TOTAL	44,837	62,693	107,530

TABLE 4-2

EQUIVALENT NAHCOLITE CONSUMPTION

Basis: 1) CONSUMPTION BASED ON 200 TONS/YR/MW

2) EXISTING COAL FIRED POWER PLANT CAPACITY: EPRI REPORT, JULY 1981 FOR PLANTS WITH FABRIC FILTERS

3) FUTURE COAL FIRED POWER PLANT CAPACITY: POWER ENGINEERING APRIL 1982. ASSUME 50% PROBABILITY FOR APPROVAL AND INSTALLATION AS FORECASTED.

	PROJECTED NAHCOLITE CONSUMPTION, TONS/YR		
	WESTERN USA	EASTERN USA	TOTAL USA
EXISTING PLANTS	1,098,000	122,000	1,220,000
FUTURE PLANTS	4,500,000	6,250,000	10,750,000
TOTAL	5,598,000	6,372,000	11,970,000

4.2.2 PRODUCTS COMPETITIVE WITH NAHCOLITE DRY INJECTION SYSTEMS

Alternative desulfurization processes and chemical reagent substitutes for dry injection are the source of basic competition to nahcolite in the desulfurization industry. This competition will be impacted by scrubber technology advancements and the market factors that impact the sodium oxide demand and supply.

Alternate desulfurization technologies include wet scrubber and spray dryer processes. According to current literature, wet scrubbing will not be able to compete with dry injection or spray dryer scrubbing of low sulfur coal due to a number of problems inherent to the wet scrubbing process, which include problems with corrosion, erosion, and plugging and also the characteristic high costs of the wet scrubbing process.

In the spray drying process, the flue gas is contacted with a slurry of concentrated sorbent solution and then evaporated to a dry powder. The dry product salts and fly ash are then collected in a down-stream fabric filter. The sorbent used is generally a calcium based slurry (lime) or a sodium solution (soda ash). Although the spray drying process is very effective in removing SO_2 from flue gas, it is not as cost effective as a dry injection system for scrubbing the stack gases of power plants burning low sulfur coal. Levelized capital costs of spray drying systems are about $115/kW as compared to $25/kW for trona and nahcolite dry injection systems (Naulty, 1983).

The only known chemical reagents that are effective in removing SO_2 from flue gas in a dry injection system are nahcolite and trona. In 1981 a full scale demonstration was conducted at Public Service of Colorado's Cameo Unit No.1 (Muzio, 1981). In this test, nahcolite and trona were tested to determine their effectiveness in removing SO_2 from flue gas. The results of this test showed that in order to remove 70 percent of the SO_2, nahcolite had to be injected at a normalized stoichiometric ratio (NSR) of 0.75 and trona at an NSR injection rate of 1.6. According to these results, nahcolite is twice as reactive, i.e., effective, as trona in the removal of SO_2.

Following the Cameo test in 1982, EPRI evaluated the economics of using nahcolite and trona in dry injection systems (Naulty, 1983). For evaluation purposes, a theoretical plant located in Keosha, Wisconsin, was analyzed using the following assumptions:

	SO Removal	Design NSR	Reagent % Purity	Required Regent	Price Per Ton
Nahcolite	75%	.85	70.3%	19.6 TPH	$100
Trona	70%	1.2	85.9%	20.3 TPH	$75

According to the EPRI report, the plant would spend $1,960.00/hour for nahcolite or $1,522.50/hour for trona. Based on these results, EPRI concluded that although trona is not as reactive as nahcolite, it is commercially more economical.

The values assigned to the variables used in the EPRI economic analysis are not set parameters. For example, if solution mined nahcolite (98 percent pure) were substituted for the raw nahcolite (70.3 percent pure), the power plant in the above analysis would only have to pay $1,410 per hour for nahcolite. This would make nahcolite more cost effective. Other variable parameters are the prices of the reagents. Using the break-even price for nahcolite developed in Chapter 3 and the transportation costs from section 4.2.3, the delivered price to the plant in Wisconsin would be approximately \$90 per ton (a \$10 per ton savings from the price used by EPRI). It is also questionable as to what price the soda ash producers in Wyoming would be willing to sell trona. Since the statutory depletion is based on the first salable product, the sale of trona at a low price could reduce the allowable depletion on soda ash.

4.2.3 PRICING AND MARKET AREA

The value of nahcolite for FGD is largely dependent on the amount of sulfur in the coal burned, location of the power plant and the cost of the least expensive alternate scrubbing technology. Due to the complexity in evaluating the value of nahcolite, the price of \$81 per ton F.O.B Rifle, Colorado, which was used in the economic evaluations, was supplied by Nielsen Resources Corporation from proprietary information.

In developing the market area for solutuion mined nahcolite, transportation costs were added to the break-even price developed in Chapter 3. Quotes were obtained to determine the cost of transporting the nahcolite from the mine site to the nearest rail head. These costs were estimated to be \$0.11 per-ton-mile for an average distance of 40 miles. Quotes of single-car rail costs were then obtained to determine the cost of transporting the nahcolite to a number of cities. These costs were then added to the break-even price for nahcolite to determine the delivered price for nahcolite at several different cities (see table 4-3).

Table 4-3 shows the delivered price for nahcolite to several major citites. Since there is not an existing market for nahcolite, or any close substitutes, the maximum acceptable delivered price cannot be determined. However, it is illustrated in Table 4-3 that the delivered price of nahcolite to any domestic market will fall between \$65.55 and \$125.45 per ton.

4.3 UNREFINED SODA ASH

The use of soda ash has been known since early times. The Egyptians recovered soda ash from dry lake beds for use in making glass containers. In other parts of the world, soda ash was recovered from the ash of burnt wood and marine plants. In the late 18th century, LeBlanc developed a process for producing synthetic soda ash from salt, sulfuric acid, coal, and limestone. This process was improved by

TABLE 4-3

DELIVERED PRICE FOR RECRYSTALLIZED NAHCOLITE
(1983 DOLLARS)

DESTINATION	TRANSPORTATION COSTS FROM RIFLE, CO. TO DESTINATION	*DELIVERED PRICE
DENVER, CO.	$22.80	$65.55
BRUSH, CO.	$26.38	$69.13
HAYS, CO.	$36.00	$78.75
SANTA FE, NM.	$36.82	$79.57
ALBUQUERQUE, NM	$38.88	$81.63
LUBBOECK, TX.	$41.90	$84.65
EL PASO, TX	$46.94	$89.69
PHOENIX, AZ.	$55.60	$98.35
TUCSON, AZ.	$55.10	$97.85
CHICAGO, IL.	$57.14	$99.89
ST. LOUIS, MO.	$54.36	$97.11
NEW ORLEANS, LA.	$63.79	$106.54
ATLANTA, GA.	$69.38	$112.13
PITTSBURGH, PA.	$70.22	$112.97
WASHINGTON, DC.	$78.34	$121.09
NEW YORK CITY, NY.	$82.70	$125.45
BOSTON, MA.	$85.70	$128.45
NEEDLES, CA.	$50.62	$93.37
ELKE, NV.	$36.00	$78.75
VALMY, NV.	$38.88	$81.63
SALT LAKE CITY, UT.	$28.80	$71.55
BOISE, ID.	$41.80	$84.55
BILLINGS, MT.	$48.98	$91.73
CASPER, WY.	$28.80	$71.55
CHEYENNE, WY.	$26.38	$69.13
RAPID CITY, ND.	$38.88	$81.63
SCOTTSBLUFF, NE.	$32.38	$75.13

* BASED ON PRICE OF $42.75 f.o.b. RIFLE, COLORADD

Ernest and Alfred Solvay in the 1860's by using ammonia as a catalyst. The Solvay process gained popularity, and is the basic method used throughout the world for making synthetic soda ash. With the discovery of the Wyoming trona deposits and development of lake brines, natural soda ash production has replaced almost all synthetic soda ash in the United States.

Thermal decomposition of raw nahcolite yields a crude soda ash quite similar to that produced from trona in the first stage of manufacturing refined soda ash. According to the prefeasibility work perfomed by Nielsen Resources Corporation, the unrefined soda ash produced from a nahcolite solution mine would be 98 percent soda carbonate and 2 percent sodium bicabonate. Initially, this unrefined soda ash could be sold to those consumers that do not require expensive refined soda ash, but are forced to purchase refined soda ash since it is the only source of sodium carbonate available. Examples of markets that can accept less than fully refined soda ash are in the manufacture of green and amber container glass, glass wool fiber, and water treatment. Once a supply of unrefined soda ash is available, other manufacturers using refined soda ash may switch to unrefined soda ash if the price differential can justify any capital and operating costs incurred in the switch.

4.3.1 POTENTIAL DEMAND FOR UNREFINED SODA ASH

The initial market for unrefined soda will be that part of the conventional soda ash market not requiring the only high grade product available. In an effort to determine the potential degree of product substitution, a number of major users of refined soda ash were contacted in a market survey. The details of this survey are proprietary information; however, the results do indicate that there is an interest in 750,000 to 935,000 tons of unrefined soda ash per year. Since this survey only covered a fraction of the potential consumers, the actual market for unrefined soda ash is potentially much larger. A more detailed market survey should be the basis of further investigations.

4.3.2 PRICING AND MARKET AREA

Determining the value of unrefined soda ash is difficult since there is not an existing market or any close product substitutes. Thus, the price used in the base case economic evaluations in Chapter 3 was selected somewhat arbitrarily at 75 percent of the price of refined soda ash. It is believed that this price reduction would be enough to stimulate a substantial market demand.

In determining the market area for unrefined soda ash, a price ceiling had to be determined. Since a market for crude soda ash does not exist, the price of delivered soda ash is used as the price ceiling for unrefined soda ash. As in section 4.2.3, the break-even price for unrefined soda ash, which was developed in Chapter 3, was added to transportation costs to determine the delivered price for unrefined soda ash (see table 4-4). As illustrated in Table 4-4, the delivered price for unrefined soda ash ranges from $82.02 to $144.92 per ton. It is assumed that the upper end of this range is not economical since refined soda ash can be delivered nationally within this price range. Consequently, the market area for unrefined soda ash is limited to the states west of the Mississippi River. It should be pointed out that the transportation costs used in this study were quotes for single-car rail rates. These transportaion costs may be reduced once shipping contracts are negotiated.

TABLE 4-4

DELIVERED PRICE FOR UNREFINED SODA ASH
(1983 DOLLARS)

DESTINATION	TRANSPORTATION COSTS FROM RIFLE, CO. TO DESTINATION	*DELIVERED PRICE
DENVER, CO.	$22.80	$82.02
BRUSH, CO.	$26.38	$85.60
HAYS, CO.	$36.00	$95.22
SANTA FE, NM.	$36.82	$96.04
ALBUQUERQUE, NM	$38.88	$98.10
LUBBOECK, TX.	$41.90	$101.12
EL PASO, TX	$46.94	$106.16
PHOENIX, AZ.	$55.60	$114.82
TUCSON, AZ.	$55.10	$114.32
CHICAGO, IL.	$57.14	$116.36
ST. LOUIS, MO.	$54.36	$113.58
NEW ORLEANS, LA.	$63.79	$123.01
ATLANTA, GA.	$69.38	$128.60
PITTSBURGH, PA.	$70.22	$129.44
WASHINGTON, DC.	$78.34	$137.56
NEW YORK CITY, NY.	$82.70	$141.92
BOSTON, MA.	$85.70	$144.92
NEEDLES, CA.	$50.62	$109.84
ELKE, NV.	$36.00	$95.22
VALMY, NV.	$38.88	$98.10
SALT LAKE CITY, UT.	$28.80	$88.02
BOISE, ID.	$41.80	$101.02
BILLINGS, MT.	$48.98	$108.20
CASPER, WY.	$28.80	$88.02
CHEYENNE, WY.	$26.38	$85.60
RAPID CITY, ND.	$38.88	$98.10
SCOTTSBLUFF, NE.	$32.38	$91.60

* BASED ON PRICE OF $59.22 f.o.b. RIFLE, COLORADD

4.4 REFINED SODA ASH

Refined soda ash is the most obvious chemical product which can be made starting with the nahcolite solution since it is an existing, mature market. Refined soda ash is preferred over crude soda ash by many producers of glass and detergents since it is free of impurities, and is denser than unrefined soda ash which saves transportaion costs. Since the soda ash market is currently over-supplied, nahcolite-based soda ash must offer some advantage over the current supply of soda ash in order to gain a market share.

4.4.1 SUPPLY/DEMAND BALANCE

In an effort to determine the status of the present soda ash industry and to identify any market trends, a market survey of all domestic soda ash producers was conducted. The results of this survey showed that domestic soda ash capacity ia approximately 10.83 million tons per year. This capacity is divided among the producers as shown in Table 4-5.

In 1982, the domestic consumption of soda ash was approximately 7.83 million tons which is only 72 percent of

TABLE 4-5

CAPACITY OF DOMESTIC SODA ASH PRODUCERS
(IN MILLIONS OF SHORT TONS)

COMPANY		CAPACITY
Stauffer, WY.		1.98
Allied, WY.		2.00
FMC, WY.		2.85
Texasgulf, WY.		1.00
Tenneco, WY.		1.00
Allied, NY.		.70
Kerr-McGee, Ca..		1.30
	Total	10.83

the domestic capacity (Kostick, 1982). Due to this industry over-capacity, the price of soda ash f.o.b. Green River, Wyoming, dropped from $91 per ton in late 1981 to $81 per ton in late 1982. The reason for this down-turn in an otherwise stable industry was the recent recession. Approximately 50 to 53 percent of the soda ash in the United States is used in the manufacture of glass (see figure 4-2). With the drastic reduction in the number of homes being built, flat glass and fiber consumption dropped off significantly. This, along with the substitution of glass bottles with plastic (PET) bottles, has accounted for a large portion of the reduction in demand.

In the last few years, several producers have expanded production capacity in anticipation of developing the potential in foreign markets. Although this is a huge market potential, U.S. producers have been obstructed by foreign political barriers. To date, these political barriers have not been overcome.

Due to the present condition of the soda ash market, the growth in demand is only expected to grow at zero to one percent per annum, with prices escalating below the rate of inflation for the next few years (Leiser, 1982).

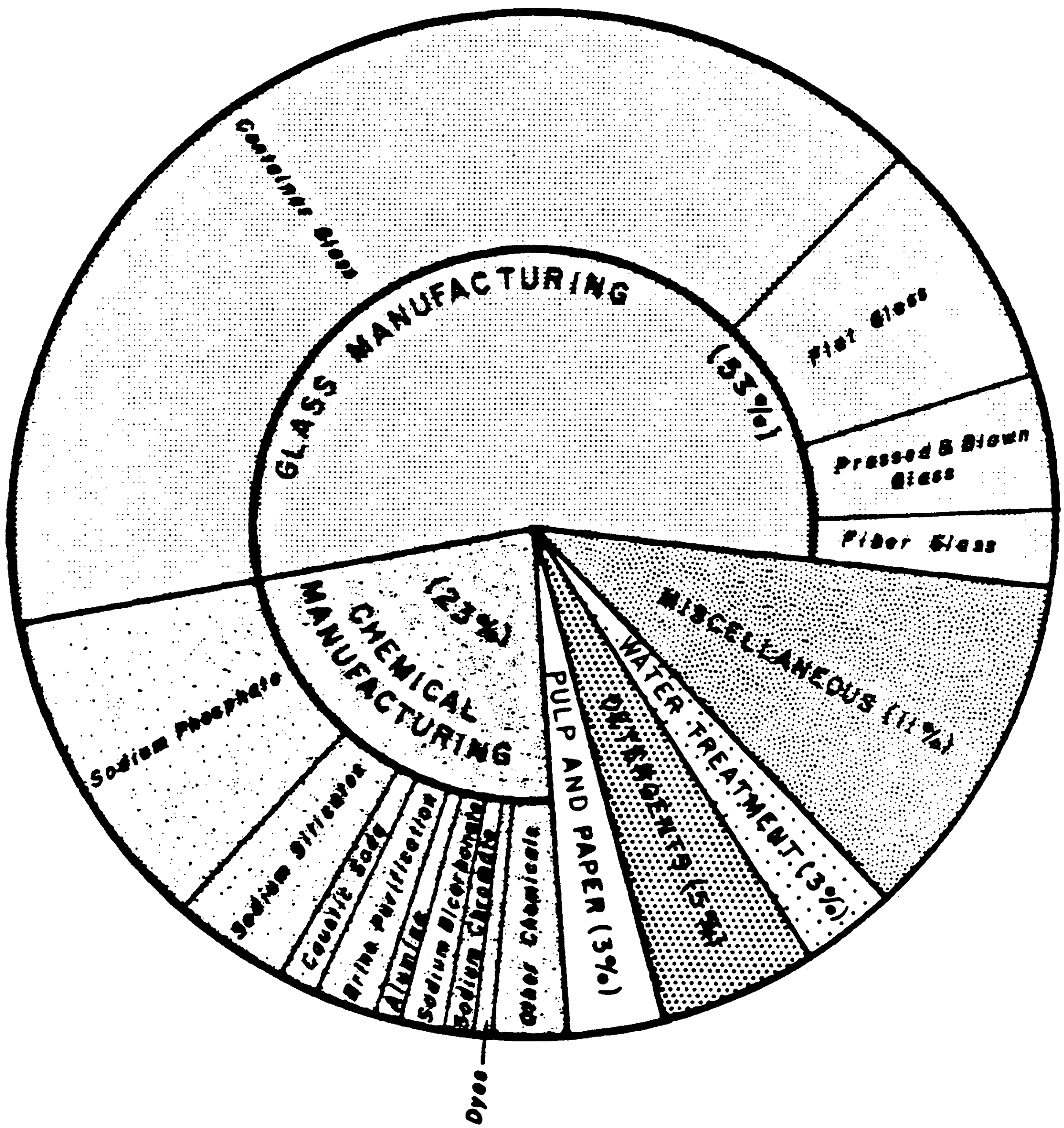


Figure 4-2. End uses of soda ash

4.4.2 POTENTIAL DEMAND FOR NAHCOLITE-BASED SODA ASH

The a status of the soda ash industry has made entry of new producers unattractive. However, most of the domestic soda ash is shipped from Green River, Wyoming, along only one rail system. As a result, there has been an expressed interest among large consumers of soda ash in a second source of soda ash to lower the dependency on one railroad.

In an effort to determine the market potential for a second source of soda ash, several large consumers were surveyed. Although the details of this survey are proprietary information, the results show an interest in 1,400,00 to 1,650,000 tons of soda ash annually to be shipped by an alternate railraod.

4.4.3 PRICING AND MARKET AREA

The price for the refined soda ash was set at the present market price for soda ash for the economic analyses in Chapter 3. From the break-even analysis conducted in Chapter 3, it was determined that refined soda ash could be sold for $72.75 per ton f.o.b. Rifle, Colorado. With the current market price for soda ash at $81 per ton f.o.b., it was concluded that nahcolite-based refined soda ash could gain a significant share of the market by offering an alternative source.

The market area for the refined soda ash is shown in Table 4-6. The delivered price for refined soda ash ranges from $95.74/ton to $158.64/ton. Although these prices are slightly higher than the Wyoming soda ash prices, it is believed that once transportaion costs are negotiated, nahcolite-based refined soda ash will be able to compete with Wyoming soda ash since they are virtually the same distance from the major soda ash consumers.

TABLE 4-6

DELIVERED PRICE FOR REFINED SODA ASH
(1983 DOLLARS)

DESTINATION	TRANSPORTATION COSTS FROM RIFLE, CO. TO DESTINATION	*DELIVERED PRICE
DENVER, CO.	$22.80	$95.74
BRUSH, CO.	$26.38	$99.32
HAYS, CO.	$36.00	$108.94
SANTA FE, NM.	$36.82	$109.76
ALBUQUERQUE, NM	$38.88	$111.82
LUBBOECK, TX.	$41.90	$114.84
EL PASO, TX	$46.94	$119.88
PHOENIX, AZ.	$55.60	$128.54
TUCSON, AZ.	$55.10	$128.04
CHICAGO, IL.	$57.14	$130.08
ST. LOUIS, MO.	$54.36	$127.30
NEW ORLEANS, LA.	$63.79	$136.73
ATLANTA, GA.	$69.38	$142.32
PITTSBURGH, PA.	$70.22	$143.16
WASHINGTON, DC.	$78.34	$151.28
NEW YORK CITY, NY.	$82.70	$155.64
BOSTON, MA.	$85.70	$158.64
NEEDLES, CA.	$50.62	$123.56
ELKE, NV.	$36.00	$108.94
VALMY, NV.	$38.88	$111.82
SALT LAKE CITY, UT.	$28.80	$101.74
BOISE, ID.	$41.80	$114.74
BILLINGS, MT.	$48.98	$121.92
CASPER, WY.	$28.80	$101.74
CHEYENNE, WY.	$26.38	$99.32
RAPID CITY, ND.	$38.88	$111.82
SCOTTSBLUFF, NE.	$32.38	$105.32

* BASED ON PRICE OF $72.94 f.o.b. RIFLE, COLORADD

CHAPTER 5

SUMMARY AND CONCLUSIONS

The onset of acid rain over the past few years has prompted the power industry to develop new stack gas scrubbing systems that are effective, reliable, and more cost effective than conventional wet scrubbing systems. To date, dry injection of nahcolite is the most effective scrubbing system for the removal of sulfur dioxide from low sulfur coal. The potential market for nahcolite as an FGD reagent has led to extensive interest in the economics of producing nahcolite from the Piceance Creek Basin of western Colorado.

This thesis was conducted to determine the economic feasibility of recovering and processing nahcolite to produce FGD reagents, and unrefined and refined soda ash. Due to the characteristics of the nahcolite resource, solution mining is believed to be the optimal mining method for recovering nahcolite. Cost estimates were developed for the mining and processing facilities and were used in determining the economics of producing and marketing nahcolite.

5.1 MINING AND PROCESSING COST SUMMARY

The costs of the mining and processing facilities, which were developed in a prefeasibility study, are shown in Table 5-1 in millions of dollars. Costs are first quarter 1983 current dollars, and are expected to have an accuracy of (+) or (-) 25 percent.

TABLE 5-1

CAPITAL COST ESTIMATE SUMMARY

(1983 MILLION DOLLARS)

	Nahcolite	Unrefined Soda Ash	Refined Soda Ash
Processing Plant	\$53.5	\$34.7	\$42.5
Drilling Program	\$1.2	\$1.2	\$1.2
Total	\$54.7	\$35.9	\$43.7

ANNUAL OPERATING COST ESTIMATE SUMMARY

	Nahcolite	Unrefined Soda Ash	Refined Soda Ash
Processing Plant	\$15.7	\$17.8	\$22.6
Drilling Program	\$0.9	\$0.9	\$0.9
Total	\$16.6	\$18.7	\$23.5

5.2 SUMMARY OF ECONOMIC EVALUATION

Using the estimated costs shown above, 20 year cash flows were developed to determine the DCFROR, net present value (NPV), and break-even price per ton for each product. The DCFROR is calculated from current (inflated) dollar cash flows as is the NPV and break-even price. The NPV was calculated using an 18 percent nominal rate of return and the break-even price is that price necessary to yield an 18 percent DCFROR. The results of the economic analyses are summarized in the Table 5-2.

TABLE 5-2

SUMMARY OF ECONOMIC CURRENT DOLLAR ANALYSES
(1983 cost and price basis)

	Nahcolite	Unrefined Soda Ash	Refined Soda Ash
Annual Production	755,000 tons	500,000 tons	500,000 tons
Price/Unit f.o.b.- Rifle	$81/ton	$61/ton	$81/ton
Nominal DCFROR	52.6%	24.1%	27.9%
NPV ($MM) @18% ROR	$114.0	$12.6	$25.0
Required Price for 18% DCFROR @ plant	$38.25/ton	$54.74/ton	$68.44/ton
Required Price for 18% DCFROR f.o.b.- Rifle	$42.75/ton	$59.22/ton	$72.94/ton

5.3 SUMMARY OF MARKETING ANALYSES

The objective of the marketing study was to determine the market potential for nahcolite as a FGD reagent, and as a source of unrefined and refined soda ash. The market potential for nahcolite in the FGD market was assumed to be the amount nahcolite needed to scrub the flue gas in all existing and future power plants that are or will be burning coal and equipped with baghouse filters. The market potentials for nahcolite in the unrefined and refined soda ash markets were determined by surveying several major soda ash consumers. The results of the marketing analysis showed that the demand for nahcolite as a FGD reagent may reach 11,970,000 tons by the mid-1990's. However, it is important to note that this is a conservative estimate since it was assumed that the power plants would be burning low sulfur coal (0.9% sulfur content). If higher sulfur were used, more nahcolite would be required to remove the sulfur increasing the potential demand for nahcolite. The marketing analysis also showed that there is an immediate annual demand for 750,000 to 935,000 tons of unrefined soda ash, and 1,400,000 to 1,650,000 tons of refined soda ash.

5.4 CONCLUSIONS

This thesis has shown that sufficient resources and market potential exist to warrant further investigations regarding the solution mining of nahcolite. Additionally, it has been shown on a prefeasibility basis that a nahcolite solution mining project is economically viable.

The results of the economic analyses show that the break-even prices for recrystallized nahcolite, unrefined soda ash, and refined soda ash are $42.75, $59.22, and $72.94 per ton f.o.b. Rifle, Colorado, respectively. Each of these prices would give the project an 18 percent DCFROR.

The marketing analysis showed that nahcolite dry injection systems are more cost effective in scrubbing low sulfur coal than the currently used spray dryer and wet scrubbing systems. The only potential substitute for nahcolite in dry injection systems is trona. It cannot be determined whether or not nahcolite is more cost effective than trona at a price of $42.75 per ton since trona is not a currently marketed product and thus does not have an established market price. However it is believed that the purity differential between trona and recrystallized nahcolite will enhance the marketability of nahcolite relative to trona. With the purities of nahcolite and trona at 98 percent and 85 percent, respectively, transportation costs per unit of reactive material will be higher for trona than for nahcolite.

The market survey of several soda ash consumers showed that there is large market potential for unrefined soda ash. Since there is not a source of unrefined soda ash, all soda ash consumers must purchase expensive refined soda ash even if they do not require a high-grade product. From the economic and technical analyses, it was determined that unrefined soda ash, with a composition of 98 percent sodium carbonate and 2 percent sodium bicarbonate, could be sold for $59.22 per ton f.o.b. Rifle, Colorado, while maintaining an 18 percent DCFROR. With a $22.00 per ton cost savings over refined soda ash, it is believed that unrefined soda ash could capture a significant portion of the conventional soda ash market.

The economic and technical analyses indicate that refined soda ash can be produced from nahcolite for a price of $72.94 per ton f.o.b. Rifle, Colorado while maintaining an 18 percent DCFROR. At the present time, refined soda ash is being sold for $81.00 per ton f.o.b. Green River, Wyoming. Since both both sources of soda ash are virtually the same distance from the large consumers of soda ash, it was assumed that the delivered cost of the nahcolite-based soda ash could compete with the existing producers. In the marketing analysis it was established that although the soda ash market is presently over-supplied, nahcolite-based soda ash could gain a substantial share of the existing market by supplying another source of soda ash on a different rail system.

5.5 RECOMMENDATIONS FOR FURTHER INVESTIGATIONS

The prefeasibility work outlined in this study indicates that the solution mining of Colorado nahcolite is economically viable, thus, feasibility work should be undertaken. The following tasks, which were identified in the prefeasibility stages, should be analyzed in the feasibility program:

1) Solution mining pilot tests should be undertaken to further develop the recovery process, and to provide a saturated nahcolite brine for processing tests, and to also provide samples of nahcolite to potential consumers for their own testing purposes.

2) A more thorough marketing analysis should be conducted, and letters of intent should be obtained from potential consumers to better ascertain the demand for nahcolite.

3) Project economics were found to be sensitive to price changes. Research regarding the optimization of plant size should be conducted to determine whether price sensitivity can be reduced and whether the project economnics can be improved.

4) Further analyses should be conducted on the use of recrystallized nahcolite (98 percent pure) and trona (85 percent pure) in dry injection FGD systems.

5) Alternative products should be analyzed for their marketing potential (i.e. caustic soda, food grade sodium bicarbonate).

6) The economics of alternative fuel sources should be analyzed.

7) Transportation contracts should be negotiated to minimize the transportation costs.

8) Determine the effect that the revenue from a nahcolite solution mining operation will have in the overall economic viability of an oil shale operation.

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APPENDIX 1

DETAILED ECONOMICS OF PRODUCING RECRYSTALLIZED NAHCOLITE

RECRYSTALLIZED NAHCOLITE

ECONOMIC PARAMETERS

1) Project evaluation life - 20 years

2) Calender year in which project begins - 1983

3) Values expressed in thousands of dollars

4) Capital or investment costs

   5 year depreciable personal property
   (today's dollar with a 5.4% escalation rate)

Year	Cost
1983	$1,217
1984	$41,869
1985	$9,845

   15 year life, depreciable real property
   (today's dollar with a 5.4% escalation rate)

Year	Cost
1983	$39
1984	$1,338
1985	$315

   Non-depreciable investments (land & working capital)
   (today's dollar with a 5% escalation rate)

Year	Cost
1985	$4,170 (W.C.)

5) Project revenue specification

Year	Production
1985	378,000 tons
1986-2002	755,000 tons

6) Unit price input

   $90/ton in 1985 dollars
   annual price escalation - 5%

7) Routine operating costs

$24.35/ton in 1985 dollars

8) Extraordinary operating costs (R&D costs)

Year	Cost
1983	$1,000
1984	$1,000

9) Additional information

Salvage value - $5,462

No loans on project (100% equity evaluation)

Projects minimum rate of return -18%

Percent depletion - 14%

Royalty - 5% of gross revenue

Effective tax rate - 50%

Capital gains taxed at alternative corporate rate of 28%

Severence tax - effective rate of $0.83/ton, escalating at 5% annually

NAHCOLITE

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(TIME 'Ø' THRU YEAR 5)

	TIME Ø	END YR 1	END YR 2	END YR 3	END YR 4	END YR 5
REVENUE	Ø	Ø	34020	71348	74915	78661
-ROYALTY	Ø	Ø	1701	3567	3746	3933
NET REVENUE	Ø	Ø	32319	67780	71169	74728
-OPER COSTS	Ø	Ø	9204	19303	20269	21282
-EXTR'OR EXP	1000	1000	Ø	Ø	Ø	Ø
-INTEREST	Ø	Ø	Ø	Ø	Ø	Ø
-INDIR TAX	Ø	Ø	346	725	762	800
-DEP & AMORT	Ø	Ø	6631	11226	11500	11376
INC BEFORE DEPLETION	-1000	-1000	16137	36525	38638	41269
-% DEPLET'N	Ø	Ø	4525	9489	9964	10462
-% DEPL LMT	Ø	Ø	8069	18262	19319	20635
-COST DEPL	Ø	Ø	Ø	Ø	Ø	Ø
-LOSS FORW	Ø	1000	2000	Ø	Ø	Ø
TAXABLE INC	-1000	-2000	9613	27036	28675	30807
-TAX	Ø	Ø	4806	13518	14337	15404
+ITC	Ø	Ø	4089	1539	Ø	Ø
NET INCOME	-1000	-2000	8895	15057	14337	15404
+DEP & AMORT	Ø	Ø	6631	11226	11500	11376
+DEPLETION	Ø	Ø	4525	9489	9964	10462
+LOSS FORW	Ø	1000	2000	Ø	Ø	Ø
-PRIN PAID	Ø	Ø	Ø	Ø	Ø	Ø
OPERATING CF	-1000	-1000	22052	35773	35801	37242
SALVAGE REV	Ø	Ø	Ø	Ø	Ø	Ø
-SALV. TAX	Ø	Ø	Ø	Ø	Ø	Ø
SALVAGE CF	Ø	Ø	Ø	Ø	Ø	Ø
INVEST REQD	1256	45540	15884	Ø	Ø	Ø
-LOANS RECD	Ø	Ø	Ø	Ø	Ø	Ø
INVESTM'T CF	1256	45540	15884	Ø	Ø	Ø
NET C.F.	-2256	-46540	6167	35773	35801	37242

NAHCOLITE

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(YEAR 6 THRU YEAR 10)

	END YR 6	END YR 7	END YR 8	END YR 9	END YR 10
REVENUE	82594	86723	91059	95612	100393
-ROYALTY	4130	4336	4553	4781	5020
NET REVENUE	78464	82387	86507	90832	95373
-OPER COSTS	22346	23463	24637	25868	27162
-EXTR'OR EXP	0	0	0	0	0
-INTEREST	0	0	0	0	0
-INDIR TAX	840	882	926	972	1021
-DEP & AMORT	11360	2298	102	95	94
INC BEFORE DEPLETION	43918	55744	60842	63896	67096
-% DEPLET'N	10985	11534	12111	12716	13352
-% DEPL LMT	21959	27872	30421	31948	33548
-COST DEPL	0	0	0	0	0
-LOSS FORW	0	0	0	0	0
TAXABLE INC	32934	44210	48731	51179	53744
-TAX	16467	22105	24366	25590	26872
+ITC	0	0	0	0	0
NET INCOME	16467	22105	24366	25590	26872
+DEP & AMORT	11360	2298	102	95	94
+DEPLETION	10985	11534	12111	12716	13352
+LOSS FORW	0	0	0	0	0
-PRIN PAID	0	0	0	0	0
OPERATING CF	38811	35937	36578	38402	40319
SALVAGE REV	0	0	0	0	0
-SALV. TAX	0	0	0	0	0
SALVAGE CF	0	0	0	0	0
INVEST REQD	0	0	0	0	0
-LOANS RECD	0	0	0	0	0
INVESTM'T CF	0	0	0	0	0
NET C.F.	38811	35937	36578	38402	40319

NAHCOLITE

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(YEAR 11 THRU YEAR 15)

	END YR 11	END YR 12	END YR 13	END YR 14	END YR 15
REVENUE	105413	110683	116218	122028	128130
-ROYALTY	5271	5534	5811	6101	6406
NET REVENUE	100142	105149	110407	115927	121723
-OPER COSTS	28520	29946	31443	33015	34666
-EXTR'OR EXP	0	0	0	0	0
-INTEREST	0	0	0	0	0
-INDIR TAX	1072	1125	1182	1241	1303
-DEP & AMORT	94	94	94	94	94
INC BEFORE DEPLETION	70456	73983	77687	81576	85660
-% DEPLET'N	14020	14721	15457	16230	17041
-% DEPL LMT	35228	36992	38844	40788	42830
-COST DEPL	0	0	0	0	0
-LOSS FORW	0	0	0	0	0
TAXABLE INC	56436	59262	62230	65347	68619
-TAX	28218	29631	31115	32673	34309
+ITC	0	0	0	0	0
NET INCOME	28218	29631	31115	32673	34309
+DEP & AMORT	94	94	94	94	94
+DEPLETION	14020	14721	15457	16230	17041
+LOSS FORW	0	0	0	0	0
-PRIN PAID	0	0	0	0	0
OPERATING CF	42332	44447	46667	48998	51445
SALVAGE REV	0	0	0	0	0
-SALV. TAX	0	0	0	0	0
SALVAGE CF	0	0	0	0	0
INVEST REQD	0	0	0	0	0
-LOANS RECD	0	0	0	0	0
INVESTM'T CF	0	0	0	0	0
NET C.F.	42332	44447	46667	48998	51445

NAHCOLITE

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(YEAR 16 THRU YEAR 20)

	END YR 16	END YR 17	END YR 18	END YR 19	END YR 20
REVENUE	134536	141263	148326	155743	163530
-ROYALTY	6727	7063	7416	7787	8176
NET REVENUE	127810	134200	140910	147956	155353
-OPER COSTS	36400	38220	40131	42137	44244
-EXTR'OR EXP	0	0	0	0	0
-INTEREST	0	0	0	0	0
-INDIR TAX	1368	1436	1508	1584	1663
-DEP & AMORT	94	18	0	0	0
INC BEFORE DEPLETION	89948	94526	99271	104235	109447
-% DEPLET'N	17893	18788	19727	20714	21749
-% DEPL LMT	44974	47263	49636	52117	54723
-COST DEPL	0	0	0	0	0
-LOSS FORW	0	0	0	0	0
TAXABLE INC	72054	75738	79544	83521	87697
-TAX	36027	37869	39772	41761	43849
+ITC	0	0	0	0	0
NET INCOME	36027	37869	39772	41761	43849
+DEP & AMORT	94	18	0	0	0
+DEPLETION	17893	18788	19727	20714	21749
+LOSS FORW	0	0	0	0	0
-PRIN PAID	0	0	0	0	0
OPERATING CF	54015	56675	59499	62474	65598
SALVAGE REV	0	0	0	0	5462
-SALV. TAX	0	0	0	0	432
SALVAGE CF	0	0	0	0	5030
INVEST REQD	0	0	0	0	0
-LOANS RECD	0	0	0	0	0
INVESTM'T CF	0	0	0	0	0
NET C.F.	54015	56675	59499	62474	70628

NAHCOLITE

SUMMARY OF INVESTMENT COSTS REQUIRED
BY ASSET CLASS AND YEAR
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

YEAR	CLASS 1 10-YR LIFE PERSONAL	CLASS 2 5-YR LIFE PERSONAL	CLASS 3 3-YR LIFE PERSONAL	CLASS 4 15-YR LIFE REAL	CLASS 5 AMORTIZED INTANGIBLE	CLASS 6 NON-DEPRECIABLE
0	0	1217	0	39	0	0
1	0	44130	0	1410	0	0
2	0	10937	0	350	0	4597
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0

DEPRECIATION DEDUCTIONS
BY ASSET CLASS AND PROJECT YEAR

YEAR	CLASS 1	CLASS 2	CLASS 3	CLASS 4	CLASS 5
0	0	0	0	0	0
1	0	0	0	0	0
2	0	6462	0	170	0
3	0	11036	0	190	0
4	0	11333	0	168	0
5	0	11229	0	148	0
6	0	11229	0	131	0
7	0	2182	0	116	0
8	0	0	0	102	0
9	0	0	0	95	0
10	0	0	0	94	0
11	0	0	0	94	0
12	0	0	0	94	0
13	0	0	0	94	0
14	0	0	0	94	0
15	0	0	0	94	0
16	0	0	0	94	0
17	0	0	0	18	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0

NAHCOLITE

PRODUCTION, PRICE, AND UNIT COST SUMMARY

YEAR	THOUS. ANNUAL UNITS	PRICE/UNIT	OPER. COST/UNIT
0	0	0.00	0.00
1	0	0.00	0.00
2	378	90.00	24.35
3	755	94.50	25.57
4	755	99.23	26.85
5	755	104.19	28.19
6	755	109.40	29.60
7	755	114.87	31.08
8	755	120.61	32.63
9	755	126.64	34.26
10	755	132.97	35.98
11	755	139.62	37.77
12	755	146.60	39.66
13	755	153.93	41.65
14	755	161.63	43.73
15	755	169.71	45.92
16	755	178.19	48.21
17	755	187.10	50.62
18	755	196.46	53.15
19	755	206.28	55.81
20	755	216.60	58.60

INITIAL RESERVES 15200

FINAL RESERVES 1232

ORIGINAL BASIS OF
COST DEPLETION 0

NAHCOLITE
DCFROR ANALYSIS RESULTS
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

THE ANNUAL COMPOUND INTEREST RATE THAT MAKES PROJECT NET PRESENT VALUE EQUAL TO ZERO IS : 52.55%.

THIS IS THE PROJECT DCFROR OR INTERNAL ROR !!

PROJECT YEAR	CUM CASH POSITION
0	-2256
1	-49982
2	-70080
3	-71134
4	-72715
5	-73684
6	-73595
7	-76332
8	-79867
9	-83435
10	-86962
11	-90329
12	-93350
13	-95738
14	-97051
15	-96606
16	-93358
17	-85743
18	-71302
19	-46298
20	0

NAHCOLITE

NET PRESENT VALUE RESULTS
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

THE PROJECT NET PRESENT VALUE AT YOUR SPECIFIED
MINIMUM RATE-OF-RETURN OF 18% IS : 114022.005

APPENDIX 2

DETAILED ECONOMICS OF PRODUCING UNREFINED SODA ASH

UNREFINED SDOA ASH

ECONOMIC PARAMETERS

1) Project evaluation life - 20 years

2) Calender year in which project begins - 1983

3) Values expressed in thousands of dollars

4) Capital or investment costs

5 year depreciable personal property
(today's dollar with a 5.4% escalation rate)

Year	Cost
1983	$817
1984	$28,102
1985	$6,608

15 year life, depreciable real property
(today's dollar with a 5.4% escalation rate)

Year	Cost
1983	$7
1984	$234
1985	$55

Non-depreciable investments (land & working capital)
(today's dollar with a 5% escalation rate)

Year	Cost
1985	$4,689 (W.C.)

5) Project revenue specification

Year	Production
1985	250,000 tons
1986-2002	500,000 tons

6) Unit price input

$67/ton in 1985 dollars
annual price escalation - 5%

7) Routine operating costs

$41.35/ton in 1985 dollars

8) Extraordinary operating costs (R&D costs)

Year	Cost
1983	$1,000
1984	$1,000

9) Additional information

Salvage value - $3,582

No loans on project (100% equity evaluation)

Projects minimum rate of return -18%

Percent depletion - 14%

Royalty - 5% of gross revenue

Effective tax rate - 50%

Capital gains taxed at alternative corporate rate of 28%

Severence tax - effective rate of $0.78/ton, escalating at 5% annually

UNREFINED SODA ASH

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(TIME '0' THRU YEAR 5)

	TIME 0	END YR 1	END YR 2	END YR 3	END YR 4	END YR 5
REVENUE	0	0	16750	35175	36934	38780
-ROYALTY	0	0	838	1759	1847	1939
NET REVENUE	0	0	15913	33416	35087	36841
-OPER COSTS	0	0	10338	21709	22794	23934
-EXTR'OR EXP	1000	1000	0	0	0	0
-INTEREST	0	0	0	0	0	0
-INDIR TAX	0	0	215	451	474	498
-DEP & AMORT	0	0	4367	7441	7636	7562
INC BEFORE DEPLETION	-1000	-1000	993	3815	4183	4847
-% DEPLET'N	0	0	2228	4678	4912	5158
-% DEPL LMT	0	0	497	1908	2092	2424
-COST DEPL	0	0	0	0	0	0
-LOSS FORW	0	1000	2000	1503	0	0
TAXABLE INC	-1000	-2000	-1503	404	2092	2424
-TAX	0	0	0	202	1046	1212
+ITC	0	0	0	176	893	1034
NET INCOME	-1000	-2000	-1503	378	1938	2246
+DEP & AMORT	0	0	4367	7441	7636	7562
+DEPLETION	0	0	497	1908	2092	2424
+LOSS FORW	0	1000	2000	1503	0	0
-PRIN PAID	0	0	0	0	0	0
OPERATING CF	-1000	-1000	5360	11229	11666	12232
SALVAGE REV	0	0	0	0	0	0
-SALV. TAX	0	0	0	0	0	0
SALVAGE CF	0	0	0	0	0	0
INVEST REQD	824	29866	12572	0	0	0
-LOANS RECD	0	0	0	0	0	0
INVESTM'T CF	824	29866	12572	0	0	0
NET C.F.	-1824	-30866	-7212	11229	11666	12232

UNREFINED SODA ASH

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(YEAR 6 THRU YEAR 10)

	END YR 6	END YR 7	END YR 8	END YR 9	END YR 10
REVENUE	40719	42755	44893	47138	49495
-ROYALTY	2036	2138	2245	2357	2475
NET REVENUE	38683	40618	42649	44781	47020
-OPER COSTS	25131	26387	27706	29092	30546
-EXTR'OR EXP	0	0	0	0	0
-INTEREST	0	0	0	0	0
-INDIR TAX	523	549	576	605	635
-DEP & AMORT	7559	1485	18	17	17
INC BEFORE DEPLETION	5471	12197	14348	15067	15822
-% DEPLET'N	5416	5686	5971	6269	6583
-% DEPL LMT	2735	6098	7174	7534	7911
-COST DEPL	0	0	0	0	0
-LOSS FORW	0	0	0	0	0
TAXABLE INC	2735	6510	8377	8798	9239
-TAX	1368	3255	4189	4399	4620
+ITC	1166	509	0	0	0
NET INCOME	2534	3765	4189	4399	4620
+DEP & AMORT	7559	1485	18	17	17
+DEPLETION	2735	5686	5971	6269	6583
+LOSS FORW	0	0	0	0	0
-PRIN PAID	0	0	0	0	0
OPERATING CF	12829	10936	10177	10685	11219
SALVAGE REV	0	0	0	0	0
-SALV. TAX	0	0	0	0	0
SALVAGE CF	0	0	0	0	0
INVEST REQD	0	0	0	0	0
-LOANS RECD	0	0	0	0	0
INVESTM'T CF	0	0	0	0	0
NET C.F.	12829	10936	10177	10685	11219

UNREFINED SODA ASH

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(YEAR 11 THRU YEAR 15)

	END YR 11	END YR 12	END YR 13	END YR 14	END YR 15
REVENUE	51969	54568	57296	60161	63169
-ROYALTY	2598	2728	2865	3008	3158
NET REVENUE	49371	51840	54432	57153	60011
-OPER COSTS	32074	33677	35361	37129	38986
-EXTR'OR EXP	0	0	0	0	0
-INTEREST	0	0	0	0	0
-INDIR TAX	667	700	735	772	811
-DEP & AMORT	17	17	17	17	17
INC BEFORE DEPLETION	16614	17445	18318	19235	20198
-% DEPLET'N	6912	7258	7620	8001	8402
-% DEPL LMT	8307	8723	9159	9618	10099
-COST DEPL	0	0	0	0	0
-LOSS FORW	0	0	0	0	0
TAXABLE INC	9702	10188	10698	11234	11796
-TAX	4851	5094	5349	5617	5898
+ITC	0	0	0	0	0
NET INCOME	4851	5094	5349	5617	5898
+DEP & AMORT	17	17	17	17	17
+DEPLETION	6912	7258	7620	8001	8402
+LOSS FORW	0	0	0	0	0
-PRIN PAID	0	0	0	0	0
OPERATING CF	11779	12368	12986	13635	14316
SALVAGE REV	0	0	0	0	0
-SALV. TAX	0	0	0	0	0
SALVAGE CF	0	0	0	0	0
INVEST REQD	0	0	0	0	0
-LOANS RECD	0	0	0	0	0
INVESTM'T CF	0	0	0	0	0
NET C.F.	11779	12368	12986	13635	14316

UNREFINED SODA ASH

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(YEAR 16 THRU YEAR 20)

	END YR 16	END YR 17	END YR 18	END YR 19	END YR 20
REVENUE	66328	69644	73126	76783	80622
-ROYALTY	3316	3482	3656	3839	4031
NET REVENUE	63011	66162	69470	72943	76591
-OPER COSTS	40935	42982	45131	47387	49757
-EXTR'OR EXP	0	0	0	0	0
-INTEREST	0	0	0	0	0
-INDIR TAX	851	894	939	986	1035
-DEP & AMORT	17	3	0	0	0
INC BEFORE DEPLETION	21208	22283	23400	24570	25799
-% DEPLET'N	8822	9263	9726	10212	10723
-% DEPL LMT	10604	11141	11700	12285	12900
-COST DEPL	0	0	0	0	0
-LOSS FORW	0	0	0	0	0
TAXABLE INC	12387	13020	13675	14358	15076
-TAX	6193	6510	6837	7179	7538
+ITC	0	0	0	0	0
NET INCOME	6193	6510	6837	7179	7538
+DEP & AMORT	17	3	0	0	0
+DEPLETION	8822	9263	9726	10212	10723
+LOSS FORW	0	0	0	0	0
-PRIN PAID	0	0	0	0	0
OPERATING CF	15032	15776	16563	17391	18261
SALVAGE REV	0	0	0	0	3582
-SALV. TAX	0	0	0	0	-794
SALVAGE CF	0	0	0	0	4376
INVEST REQD	0	0	0	0	0
-LOANS RECD	0	0	0	0	0
INVESTM'T CF	0	0	0	0	0
NET C.F.	15032	15776	16563	17391	22637

UNREFINED SODA ASH

SUMMARY OF INVESTMENT COSTS REQUIRED
BY ASSET CLASS AND YEAR
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

YEAR	CLASS 1 10-YR LIFE PERSONAL	CLASS 2 5-YR LIFE PERSONAL	CLASS 3 3-YR LIFE PERSONAL	CLASS 4 15-YR LIFE REAL	CLASS 5 AMORTIZED INTANGIBLE	CLASS 6 NON-DEPRECIABLE
0	0	817	0	7	0	0
1	0	29620	0	247	0	0
2	0	7341	0	61	0	5170
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0

DEPRECIATION DEDUCTIONS
BY ASSET CLASS AND PROJECT YEAR

YEAR	CLASS 1	CLASS 2	CLASS 3	CLASS 4	CLASS 5
0	0	0	0	0	0
1	0	0	0	0	0
2	0	4337	0	30	0
3	0	7407	0	33	0
4	0	7606	0	29	0
5	0	7537	0	26	0
6	0	7537	0	23	0
7	0	1465	0	20	0
8	0	0	0	18	0
9	0	0	0	17	0
10	0	0	0	17	0
11	0	0	0	17	0
12	0	0	0	17	0
13	0	0	0	17	0
14	0	0	0	17	0
15	0	0	0	17	0
16	0	0	0	17	0
17	0	0	0	3	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0

UNREFINED SODA ASH

PRODUCTION, PRICE, AND UNIT COST SUMMARY

YEAR	THOUS. ANNUAL UNITS	PRICE/UNIT	OPER. COST/UNIT
0	0	0.00	0.00
1	0	0.00	0.00
2	250	67.00	41.35
3	500	70.35	43.42
4	500	73.87	45.59
5	500	77.56	47.87
6	500	81.44	50.26
7	500	85.51	52.77
8	500	89.79	55.41
9	500	94.28	58.18
10	500	98.99	61.09
11	500	103.94	64.15
12	500	109.14	67.35
13	500	114.59	70.72
14	500	120.32	74.26
15	500	126.34	77.97
16	500	132.66	81.87
17	500	139.29	85.96
18	500	146.25	90.26
19	500	153.57	94.77
20	500	161.24	99.51

INITIAL RESERVES 10000

FINAL RESERVES 750

ORIGINAL BASIS OF
COST DEPLETION 0

UNREFINED SODA ASH
DCFROR ANALYSIS RESULTS
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

THE ANNUAL COMPOUND INTEREST RATE THAT MAKES PROJECT NET PRESENT VALUE EQUAL TO ZERO IS : 24.08%.

THIS IS THE PROJECT DCFROR OR INTERNAL ROR !!

PROJECT YEAR	CUM CASH POSITION
0	-1824
1	-33129
2	-48318
3	-48722
4	-48788
5	-48303
6	-47105
7	-47511
8	-48773
9	-49831
10	-50611
11	-51017
12	-50933
13	-50211
14	-48666
15	-46068
16	-42128
17	-36496
18	-28720
19	-18244
20	0

UNREFINED SODA ASH

NET PRESENT VALUE RESULTS
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

THE PROJECT NET PRESENT VALUE AT YOUR SPECIFIED
MINIMUM RATE-OF-RETURN OF 18% IS : 12563.9602

APPENDIX 3

DETAILED ECONOMICS OF PRODUCING REFINED SODA ASH

REFINED SODA ASH

ECONOMIC PARAMETERS

1) Project evaluation life - 20 years

2) Calender year in which project begins - 1983

3) Values expressed in thousands of dollars

4) Capital or investment costs

5 year depreciable personal property
(today's dollar with a 5.4% escalation rate)

Year	Cost
1983	$995
1984	$34,225
1985	$8,048

15 year life, depreciable real property
(today's dollar with a 5.4% escalation rate)

Year	Cost
1983	$7
1984	$241
1985	$57

Non-depreciable investments (land & working capital)
(today's dollar with a 5% escalation rate)

Year	Cost
1985	$5,921 (W.C.)

5) Project revenue specification

Year	Production
1985	250,000 tons
1986-2002	500,000 tons

6) Unit price input

$90/ton in 1985 dollars
annual price escalation - 5%

7) Routine operating costs

$52.22/ton in 1985 dollars

8) Extraordinary operating costs (R&D costs)

Year	Cost
1983	$1,000
1984	$1,000

9) Additional information

Salvage value - $4,357

No loans on project (100% equity evaluation)

Projects minimum rate of return -18%

Percent depletion - 14%

Royalty - 5% of gross revenue

Effective tax rate - 50%

Capital gains taxed at alternative corporate rate of 28%

Severence tax - effective rate of $1.08/ton, escalating at 5% annually

REFINED SODA ASH

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(TIME 'Ø' THRU YEAR 5)

	TIME Ø	END YR 1	END YR 2	END YR 3	END YR 4	END YR 5
REVENUE	Ø	Ø	22250	46725	49061	51514
-ROYALTY	Ø	Ø	1113	2336	2453	2576
NET REVENUE	Ø	Ø	21138	44389	46608	48939
-OPER COSTS	Ø	Ø	13055	27416	28786	30226
-EXTR'OR EXP	1000	1000	Ø	Ø	Ø	Ø
-INTEREST	Ø	Ø	Ø	Ø	Ø	Ø
-INDIR TAX	Ø	Ø	298	625	656	689
-DEP & AMORT	Ø	Ø	5313	9056	9294	9205
INC BEFORE DEPLETION	-1000	-1000	2472	7293	7872	8818
-% DEPLET'N	Ø	Ø	2959	6214	6525	6851
-% DEPL LMT	Ø	Ø	1236	3646	3936	4409
-COST DEPL	Ø	Ø	Ø	Ø	Ø	Ø
-LOSS FORW	Ø	1000	2000	764	Ø	Ø
TAXABLE INC	-1000	-2000	-764	2882	3936	4409
-TAX	Ø	Ø	Ø	1441	1968	2205
+ITC	Ø	Ø	Ø	1229	1676	1696
NET INCOME	-1000	-2000	-764	2670	3644	3900
+DEP & AMORT	Ø	Ø	5313	9056	9294	9205
+DEPLETION	Ø	Ø	1236	3646	3936	4409
+LOSS FORW	Ø	1000	2000	764	Ø	Ø
-PRIN PAID	Ø	Ø	Ø	Ø	Ø	Ø
OPERATING CF	-1000	-1000	7785	16136	16874	17515
SALVAGE REV	Ø	Ø	Ø	Ø	Ø	Ø
-SALV. TAX	Ø	Ø	Ø	Ø	Ø	Ø
SALVAGE CF	Ø	Ø	Ø	Ø	Ø	Ø
INVEST REQD	1002	36327	15532	Ø	Ø	Ø
-LOANS RECD	Ø	Ø	Ø	Ø	Ø	Ø
INVESTM'T CF	1002	36327	15532	Ø	Ø	Ø
NET C.F.	-2002	-37327	-7747	16136	16874	17515

REFINED SODA ASH

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(YEAR 6 THRU YEAR 10)

	END YR 6	END YR 7	END YR 8	END YR 9	END YR 10
REVENUE	54090	56795	59634	62616	65747
-ROYALTY	2705	2840	2982	3131	3287
NET REVENUE	51386	53955	56653	59485	62459
-OPER COSTS	31737	33324	34990	36739	38576
-EXTR'OR EXP	0	0	0	0	0
-INTEREST	0	0	0	0	0
-INDIR TAX	724	760	798	838	880
-DEP & AMORT	9202	1805	18	17	17
INC BEFORE DEPLETION	9723	18067	20846	21891	22986
-% DEPLET'N	7194	7554	7931	8328	8744
-% DEPL LMT	4861	9033	10423	10945	11493
-COST DEPL	0	0	0	0	0
-LOSS FORW	0	0	0	0	0
TAXABLE INC	4861	10513	12915	13563	14242
-TAX	2431	5256	6458	6781	7121
+ITC	0	0	0	0	0
NET INCOME	2431	5256	6458	6781	7121
+DEP & AMORT	9202	1805	18	17	17
+DEPLETION	4861	7554	7931	8328	8744
+LOSS FORW	0	0	0	0	0
-PRIN PAID	0	0	0	0	0
OPERATING CF	16494	14615	14407	15127	15882
SALVAGE REV	0	0	0	0	0
-SALV. TAX	0	0	0	0	0
SALVAGE CF	0	0	0	0	0
INVEST REQD	0	0	0	0	0
-LOANS RECD	0	0	0	0	0
INVESTM'T CF	0	0	0	0	0
NET C.F.	16494	14615	14407	15127	15882

REFINED SODA ASH

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(YEAR 11 THRU YEAR 15)

	END YR 11	END YR 12	END YR 13	END YR 14	END YR 15
REVENUE	69034	72486	76110	79916	83911
-ROYALTY	3452	3624	3806	3996	4196
NET REVENUE	65582	68862	72305	75920	79716
-OPER COSTS	40505	42530	44657	46890	49234
-EXTR'OR EXP	0	0	0	0	0
-INTEREST	0	0	0	0	0
-INDIR TAX	924	970	1018	1069	1123
-DEP & AMORT	17	17	17	17	17
INC BEFORE DEPLETION	24137	25344	26612	27944	29342
-% DEPLET'N	9182	9641	10123	10629	11160
-% DEPL LMT	12068	12672	13306	13972	14671
-COST DEPL	0	0	0	0	0
-LOSS FORW	0	0	0	0	0
TAXABLE INC	14955	15704	16490	17315	18182
-TAX	7478	7852	8245	8658	9091
+ITC	0	0	0	0	0
NET INCOME	7478	7852	8245	8658	9091
+DEP & AMORT	17	17	17	17	17
+DEPLETION	9182	9641	10123	10629	11160
+LOSS FORW	0	0	0	0	0
-PRIN PAID	0	0	0	0	0
OPERATING CF	16676	17509	18385	19303	20268
SALVAGE REV	0	0	0	0	0
-SALV. TAX	0	0	0	0	0
SALVAGE CF	0	0	0	0	0
INVEST REQD	0	0	0	0	0
-LOANS RECD	0	0	0	0	0
INVESTM'T CF	0	0	0	0	0
NET C.F.	16676	17509	18385	19303	20268

REFINED SODA ASH

CASH FLOW FOR EACH
TIME IN THE EVALUATION PERIOD
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

(YEAR 16 THRU YEAR 20)

	END YR 16	END YR 17	END YR 18	END YR 19	END YR 20
REVENUE	88107	92512	97138	101995	107095
-ROYALTY	4405	4626	4857	5100	5355
NET REVENUE	83702	87887	92281	96895	101740
-OPER COSTS	51696	54281	56995	59845	62837
-EXTR'OR EXP	0	0	0	0	0
-INTEREST	0	0	0	0	0
-INDIR TAX	1179	1238	1300	1365	1433
-DEP & AMORT	17	3	0	0	0
INC BEFORE DEPLETION	30810	32365	33987	35686	37470
-% DEPLET'N	11718	12304	12919	13565	14244
-% DEPL LMT	15405	16182	16993	17843	18735
-COST DEPL	0	0	0	0	0
-LOSS FORW	0	0	0	0	0
TAXABLE INC	19092	20061	21067	22121	23227
-TAX	9546	10030	10534	11060	11613
+ITC	0	0	0	0	0
NET INCOME	9546	10030	10534	11060	11613
+DEP & AMORT	17	3	0	0	0
+DEPLETION	11718	12304	12919	13565	14244
+LOSS FORW	0	0	0	0	0
-PRIN PAID	0	0	0	0	0
OPERATING CF	21281	22338	23453	24626	25857
SALVAGE REV	0	0	0	0	4357
-SALV. TAX	0	0	0	0	-1085
SALVAGE CF	0	0	0	0	5442
INVEST REQD	0	0	0	0	0
-LOANS RECD	0	0	0	0	0
INVESTM'T CF	0	0	0	0	0
NET C.F.	21281	22338	23453	24626	31299

REFINED SODA ASH

SUMMARY OF INVESTMENT COSTS REQUIRED
BY ASSET CLASS AND YEAR
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

YEAR	CLASS 1 10-YR LIFE PERSONAL	CLASS 2 5-YR LIFE PERSONAL	CLASS 3 3-YR LIFE PERSONAL	CLASS 4 15-YR LIFE REAL	CLASS 5 AMORTIZED INTANGIBLE	CLASS 6 NON-DEPRECIABLE
0	0	995	0	7	0	0
1	0	36073	0	254	0	0
2	0	8941	0	63	0	6528
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0

DEPRECIATION DEDUCTIONS
BY ASSET CLASS AND PROJECT YEAR

YEAR	CLASS 1	CLASS 2	CLASS 3	CLASS 4	CLASS 5
0	0	0	0	0	0
1	0	0	0	0	0
2	0	5282	0	31	0
3	0	9021	0	34	0
4	0	9264	0	30	0
5	0	9179	0	27	0
6	0	9179	0	24	0
7	0	1784	0	21	0
8	0	0	0	18	0
9	0	0	0	17	0
10	0	0	0	17	0
11	0	0	0	17	0
12	0	0	0	17	0
13	0	0	0	17	0
14	0	0	0	17	0
15	0	0	0	17	0
16	0	0	0	17	0
17	0	0	0	3	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0

REFINED SODA ASH

PRODUCTION, PRICE, AND UNIT COST SUMMARY

YEAR	THOUS. ANNUAL UNITS	PRICE/UNIT	OPER. COST/UNIT
0	0	0.00	0.00
1	0	0.00	0.00
2	250	89.00	52.22
3	500	93.45	54.83
4	500	98.12	57.57
5	500	103.03	60.45
6	500	108.18	63.47
7	500	113.59	66.65
8	500	119.27	69.98
9	500	125.23	73.48
10	500	131.49	77.15
11	500	138.07	81.01
12	500	144.97	85.06
13	500	152.22	89.31
14	500	159.83	93.78
15	500	167.82	98.47
16	500	176.21	103.39
17	500	185.02	108.56
18	500	194.28	113.99
19	500	203.99	119.69
20	500	214.19	125.67

INITIAL RESERVES 10000

FINAL RESERVES 750

ORIGINAL BASIS OF
COST DEPLETION 0

REFINED SODA ASH
DCFROR ANALYSIS RESULTS
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

THE ANNUAL COMPOUND INTEREST RATE THAT MAKES PROJECT NET PRESENT VALUE EQUAL TO ZERO IS : 27.9%.

THIS IS THE PROJECT DCFROR OR INTERNAL ROR !!

PROJECT YEAR	CUM CASH POSITION
0	-2002
1	-39888
2	-58764
3	-59024
4	-58618
5	-57459
6	-56996
7	-58284
8	-60138
9	-61791
10	-63149
11	-64093
12	-64466
13	-64068
14	-62640
15	-59850
16	-55267
17	-48350
18	-38387
19	-24472
20	0

REFINED SODA ASH

NET PRESENT VALUE RESULTS
(MONETARY VALUES AS THOUSANDS OF DOLLARS)

THE PROJECT NET PRESENT VALUE AT YOUR SPECIFIED
MINIMUM RATE-OF-RETURN OF 18% IS : 25034.1569