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FINAL REPORT
PART ONE
OPTIMIZATION OF EL MEX SALINES SOLAR PONDS AND BY-PRODUCT INVESTIGATION
UNIDO AUTHORIZATION PROJECT

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ABSTRACT: This is Part One of a Two Part Final Report on pre-feasibility studies authorized by the United Nations Industrial Development Organization Project DP/EGY/87/017. This report provides a summary and conclusions written in non-technical language. The more technical information is shown in Part Two under separate cover. There are two main subjects discussed. The first is optimization of El Mex Salines sodium chloride production, and the second is a discussion of by-products.

1. SUMMARY AND CONCLUSIONS

In GSL's judgement, quality of sodium chloride at El Mex will continuously worsen unless the practice of recycling bitterns is stopped. Bitterns should be held in a holding pond or discharged back to the sea.

Formation of mixed K_2SO_4 salts by solar evaporation does not appear possible. The high humidity at El Mex site does not provide a high enough driving force to favor evaporation of water from concentrated bitterns.

The alternative to evaporation by solar energy is artificial heat. Use of artificial heat in evaporative crystallizers to produce K_2SO_4 from brine is not practiced by GSL or anyone else that we are aware of. This would need additional research.

Production of MgOH to form MgO could be possible by adding lime or dolomite. This is a possibility at El Mex. Some details are given in this report.

Sodium chloride production and quality can be improved at both El Mex and Borg El Arab. This can be achieved through use of sequential ponding methods and discontinuation of bitterns recycle.

One of the main areas of emphasis in this report is to change both pond operating procedures and pond configuration. This change will improve both the quantity and quality of sodium chloride and is necessary if by-product production becomes a reality in the future. GSL believes these changes will be absolutely necessary in the future if El Mex is to survive as a salt producing facility. Since the changes are needed even if by-products are not produced, GSL recommends they be made as soon as possible. The changes will require special planning and control as explained in this report.

2. RECOMMENDATIONS

The biggest problem facing El Mex Salines now is high $MgCl_2$ in feed to El Mex salt crystallizers ponds. This can be solved by preventing bitterns from recycling back to the preconcentration ponds. If recycling of bitterns is stopped, the following positive results will occur.

A. Better salt will crystallize because it will contain less encapsulated $MgCl_2$ and $MgSO_4$.

B. Salt production will increase because evaporation of crystallization ponds will increase when $MgCl_2$ content is lowered.

C. Potential for by-products will increase because bitterns can be concentrated to their maximum values permitted under El Mex weather conditions.

D. Technical information can be gained for later use in locations at Borg El Arab and Port Said in addition to El Mex.

It is therefore recommended that the following steps be taken.

1. Construct a canal or system to flow brine from the Alexandria Petrochemical Company to El Mex pre-concentration pond without mixing it with bitterns from the crystallizer.

2. Flow bitterns into a holding pond and let it concentrate to be used as by-product feed stock. If it is not used a by-product feed, it can be discharged back to the sea or dead-headed at the holding pond.

3. After $MgCl_2$ in the large pre-concentration pond has lowered, the pond should be divided in two. This will increase production of NaCl crystallizer feed brine and increase purity of salt in the crystallizer.

4. Manage bitterns concentration to do the following:

   a) Concentrate bitterns to maximum values permitted by El Mex weather.

   b) Obtain technical data from this brine as it concentrates to obtain evaporation information in detail and to follow mineral and brine chemistry.

   c) Make final plans for by-product manufacturing as data is obtained.

This last item, c, can be done without losing any time in the development of by-products. Development of by-products will require that all of the above items be implemented. Even if no by-products are to be made, Items 1 through 4 should be done if El Mex Salines is to survive. The $MgCl_2$ concentration is now approaching a critical point and salt quality will become worse if the practice of bitterns recycle is not stopped.

It should be understood that before any chance of economical development of by-products can be undertaken, salt bitterns must be managed differently and cannot be recycled. Therefore the recommendations of items 1 through 5 are a first step in by-product manufacturing. It will take several years to build the necessary dikes, structures and then concentrate the bitterns. The work should start immediately. If it is found that it is uneconomical to produce by-products, concentrated bitterns can simply be held in a pond. If the holding ponds are too full and more space cannot be found, the brine can be pumped back to the sea as it is done in other well designed facilities around the world.

If it is decided to pump brine back to the sea, the sea water feed line could be used in the evaporation months to feed sea water and in the winter months to pump bitterns back out from the ponds to the sea.

It is also recommended that plans be made at Borg El Arab to divide the large first pre-concentration pond in two parts and to either pump the bitterns back to the Mediterranean Sea or store it. Under no circumstances should it be recycled.

It is suggested that a marketing survey be made to determine how much $MgCl_2 \cdot 6H_2O$ flake could be sold in Egypt and adjacent countries. If enough sales could be made, El Mex is in a good position to produce it as a by-product.

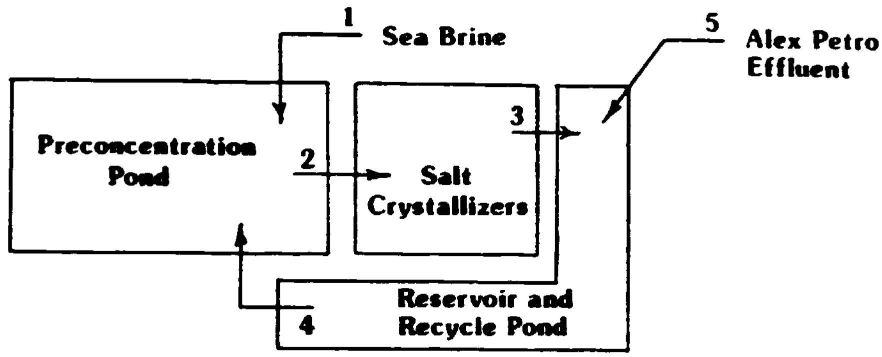
There is a good possibility of producing MgO, however more work must be done to determine whether high enough grade can be produced economically.

3. DISCUSSION

This information is written specifically for supervisors, personnel, managers and directors so they can have a better understanding of complex solar pond systems. This understanding is needed to follow the recommendations and proposals of this report.

3.1 Solar Ponds

The basic system of El Mex solar ponds is shown:



The system is called a closed one because there are no bleed streams or discharge of minerals except for the product, sodium chloride. With time, the other minerals will increase in concentration. These minerals will eventually build up to high levels in the pre-concentration pond. Subsequent feed to salt crystallizer will force contamination to unacceptable levels.

Concentration level of magnesium in the pre-concentration pond at El Mex is near 1.4% Mg^{++}. This is 10 times higher than comparable pre-concentration ponds of other large sea salt facilities. It is even higher than concentrated sea water that is saturating in NaCl.

Sea water at Port Said or Borg El Arab, for example, will begin to crystallize NaCl at a Mg++ concentration of 1.04%. This is significantly less than El Mex's 1.4%. Good quality salt can be made at 1.04% (26° Be) with relative ease. Quality salt can also be made at 1.4%, but only with a special sequential pond system that will be explained later. 1.4% Mg++ is equivalent to 1.23 specific gravity (27° Be). Brine is normally discarded at 28.5° Be. At El Mex, however, brine has been discarded at 29 and even 30° Be.

The effect of Mg++ on evaporation is significant. Evaporation of 1.4% brine at El Mex is 130 centimeters per year. Evaporation of sea water saturated brine is 156 centimeters. The difference is (156-130)/130 or 20%.

If a system is developed to stop the recycle of Mg++, evaporation can be increased by near 20%. As a result, production will also be increased and salt quality will improve.

Both production and quality can be increased by ending the practice of recycling salt bitterns. El Mex is not the only facility that recycles bitterns. GSL has observed other operations that do the same. The most common reasons given for recycling are (1) The bitterns contain NaCl and it is recycled to recover it, and (2) Operators don't know what else to do with it.

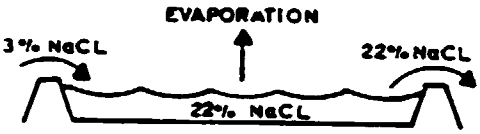
Bitterns contain NaCl, but it also contains $MgCl_2$, $MgSO_4$ and KCl, all of which are impurities to NaCl. Impurities slow down evaporation. It can be rigorously shown that saving bitterns for its NaCl content has an opposite effect.

Recycling bitterns because one doesn't know what else to do with it is a poor choice compared to other alternatives. One alternative is to use a salt crystallizer and store it. If more space is needed, a section of the pre-concentration pond should be diked off to make a reservoir pond where bitterns can be left to evaporate further and be stored. It should never be allowed to re-enter the regular salt producing system again. The evaporation area needed to store bitterns is more than offset by increased evaporation of pre-concentrated pond area not mixed with bitterns.

In the case of El Mex, bitterns could be pumped through the sea brine feed line back to the sea. This could be done in winter when the line is not being used.

3.1.1 Brine Sequencing

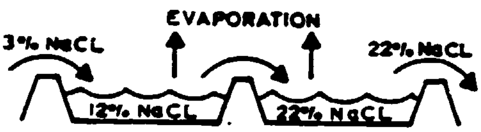
Suppose it is desired to evaporate brine and concentrate it from 3% NaCl to 22%. One way to do this would be to place it in a single pond as illustrated on the following page.



SINGLE POND CONCENTRATION

In order to extract a 22% NaCl solution, one must wait until the whole pond has concentrated to 22%.

Now assume the pond is divided in half as shown in the next illustration. Here we see that only one pond must be concentrated to 22% NaCl. The first pond need only be concentrated to 12%. The single pond has an average concentration of 22% but the double pond has a concentration of (12% + 22%)÷ 2 or 17%.



DOUBLE POND CONCENTRATION

A three pond system will lower concentration even further.

There are distinct advantages to lower average concentration. One is that it is obviously faster and easier to concentrate brine to 17% compared to 22%. This means brine is concentrated in the spring quickly and prepares brine for salt crystallizer earlier than could be done with a single pond system.

The other reason is that lower concentration means higher evaporation. High evaporation means more salt production.

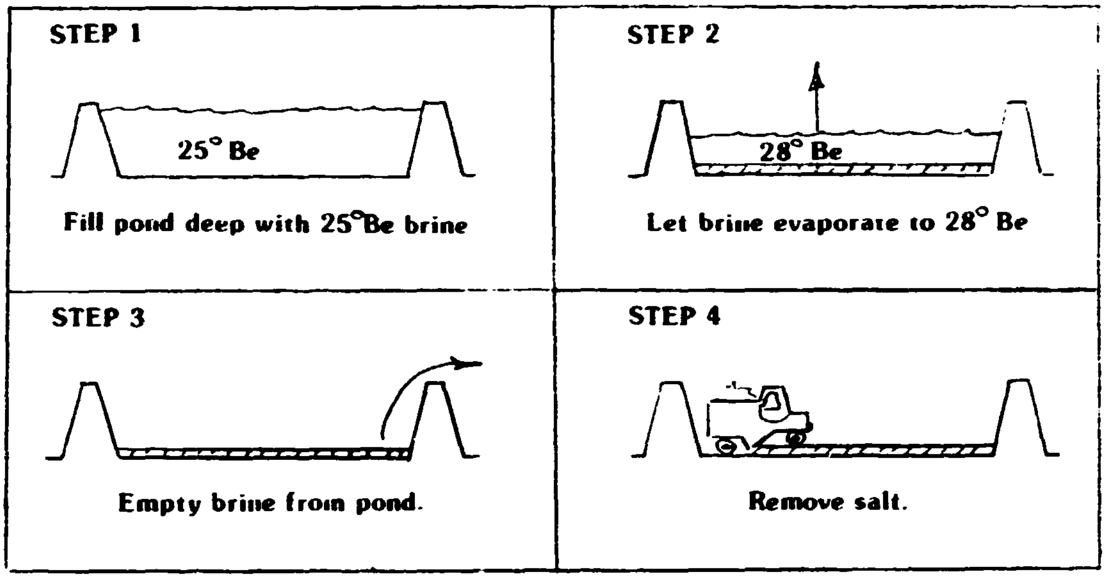
Technical details and mathematical proofs are shown in Part Two of the final report.

3.1.2 Continuous Flow Through Ponds.

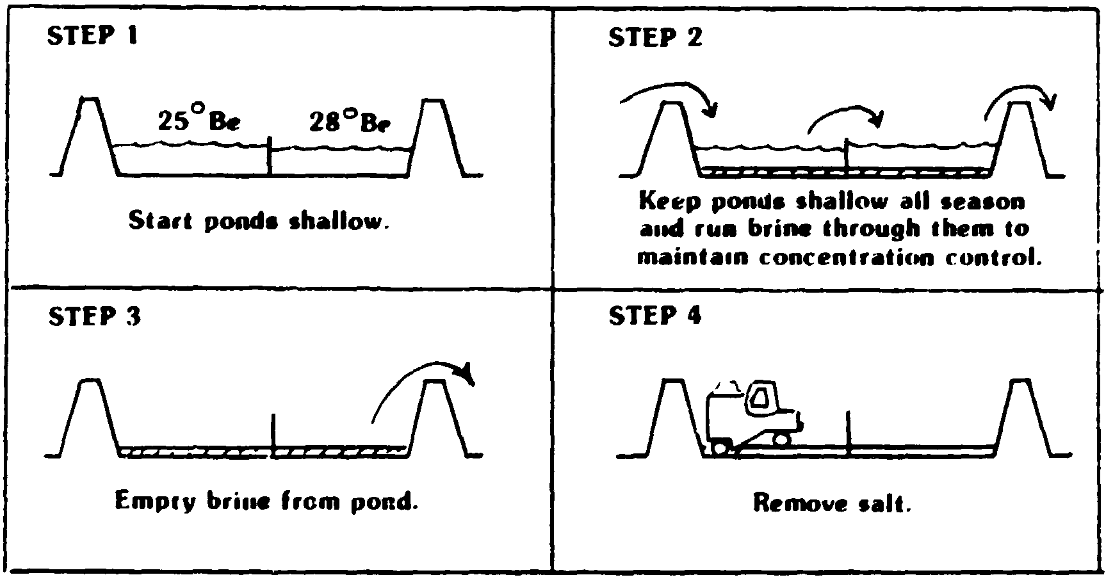
There are two flows generally used in solar ponds. One is a batch system where brine is flowed into a salt crystallizer to a predetermined depth and then allowed to evaporate down. At the end of the season, brine will have concentrated from 25°Be to its end point, 28° Be.

The other system is to start brine early in the season at a shallow depth and to continuously feed it brine all season. The rate one feeds the pond depends on brine concentration end point desired. Both systems are illustrated in the next figure.

System One. Batch



System Two, Continuous Flow



Continuous flow systems are better than batch for the following reasons:

1. Brine can be kept shallow which results in higher evaporation, larger salt crystals and higher purity. These are all explained in the technical section of this report (Part Two).

2. Brine can be flowed through a series of two or three salt crystallizers. This will also result in higher evaporation and higher purity.

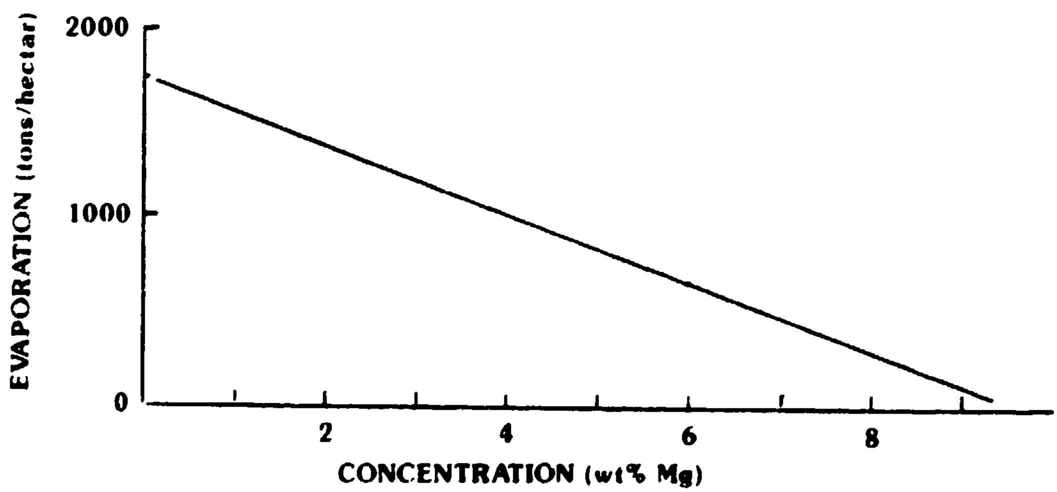
3. Flowing brine will result in better concentration control than can be obtained by batch systems.

4. Constant flow techniques through series ponds must be used to make highly concentrated brine needed in by-product manufacturing.

3.1.3 Evaporation Rates in Solar Ponds.

Water is transferred from a brine surface to the atmosphere when the vapor pressure of water is less in air than in the brine. The most significant method to increase vapor pressure in brine is to heat it. This is done by the sun. Another way is to reduce water vapor pressure in the air. This is also done indirectly by the sun and with wind. Another way still is to reduce concentration of minerals in the brine. This latter method is tricky because most solar pond objectives are to concentrate brines which produces just the opposite effect.

A typical evaporation curve on El Mex brine in July is shown.



Notice two very important parts to this curve. One is that evaporation decreases as brine concentrates. The second is that at a given concentration, brine ceases to evaporate. At El Mex, the high summer humidity causes magnesium chloride brines to cease evaporating at a relatively low concentration level. This level is too low to produce by-products K_2SO_4 and $MgCl_2 \cdot 6H_2O$ by conventional methods.

3.2 Suggested Procedure to Upgrade El Mex Solar Pond System

A decision to make or not to make arcanite, magnesium or both will not change the need to isolate bitterns at El Mex. Isolation of this brine is a necessary step and plans to do so should be made immediately.

Even if it were decided to go ahead with by-product manufacturer today, it would still require a few years to make all the needed changes and concentrate bitterns before any real by-product manufacture could begin.

Time is important because conversion of El Mex solar pond system will be slow and should be started now. In addition, operators must learn new methods of operation. The following plan is suggested.

Step One. Isolate Bitterns

Isolating bitterns will require a canal or pipeline for Alexandria's Petrochemical plant effluent. This should be done immediately. This is all that is needed to insure that El Mex salt quality will begin to improve in future years and so will production. At the same time, a positive step will have been taken for possible by-product production. Full scale data can be obtained from actual large pan bitterns ponds to verify evaporation rates that are now only estimated from small pans. As soon as the bitterns are isolated, magnesium concentration in all other ponds will begin to decrease and crystallized salt quality will begin to improve.

Step Two. Run Salt Crystallizer in series with continuous brine flow.

Brine should be run continuously from pond to pond for the entire summer. Set weirs, pumps and canals such that brine can flow from pond to pond until it is discharged into the bitterns holding area.

Step Three. Preconcentration Pond Sub-division

When step one is complete, magnesium in the pre-concentration pond will begin to decrease. This is desired. It will take a minimum of one season and preferably two evaporation seasons before the magnesium is at a low enough level to sub-divide the pre-concentration pond. If the pond is sub-divided before this time, magnesium concentration will begin to increase uncontrollably with possible disastrous results. It is important that the effects of pond sub-division be understood. Computer runs and descriptions are given in Part Two of the final report to help the reader more fully understand the outcome of pond sub-division.

Even more sub-divisions should be considered in 4 or 5 years to maximize production of sodium chloride and grade.

Step Four. By-Product production.

It will require at least two seasons after bitterns are isolated to generate a reserve of brine for by-product production. During this time data can be collected and feasibility studies continued to make a final decision on the best alternatives for production or feasibility.

Steps 1, 2 and 3 should be taken even if it is desired not to produce by-products. In GSL's opinion, Step 1 is absolutely needed and should be planned immediately. Steps 2 and 3 are optional if only NaCl is produced. Better quality NaCl will result, however, and quantity will improve. If by-products are to be made, Step 1 will be necessary and Steps 2 and 3 will also be needed. It is therefore suggested that all these steps be planned now. If it is desired later not to produce by-products, then nothing will be lost. However, if the steps are not implemented and it is later desired to make by-products, a delay of several years will result.

3.2.1 Illustrations

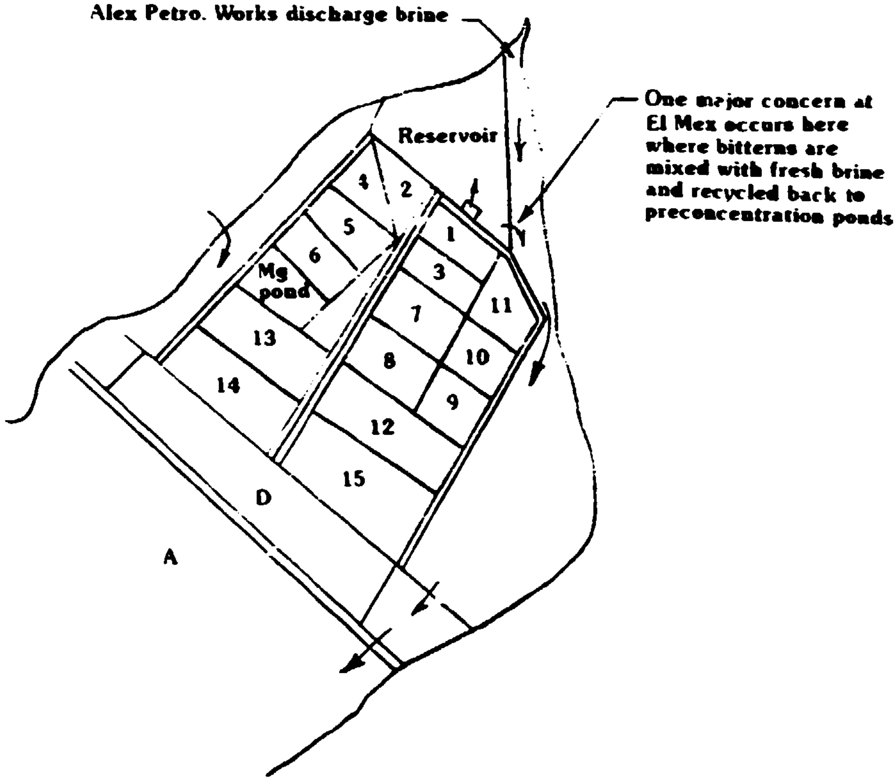
The following few pages show some illustrations of upgrading El Mex ponds. These illustrations are based on the limited knowledge GSL has of El Mex pond system. The main points are to isolate bitterns and place salt ponds in series flow.

Alex Petrochemical Company effluent brine must be separated from bitterns by making a flow path down one side of the pond system. This will require capital cost for diking.

Additional capital will be needed to construct bitterns holding ponds and to convert salt ponds into series flow. In addition, special training will be needed to show operators and engineers the art of continuous series flow of brine to produce high quality NaCl.

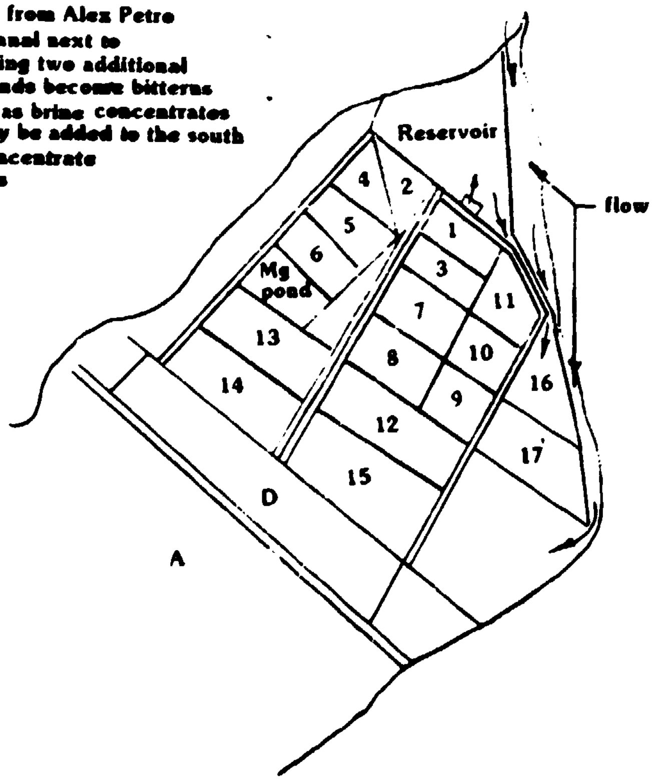
PRESENT STATUS OF EL MEX PONDS

GSL has not been given a detailed drawing of El Mex pond system with locations of all canals, pump stations, bridges and buildings.
The sketches shown are estimated by GSL and may not contain all details



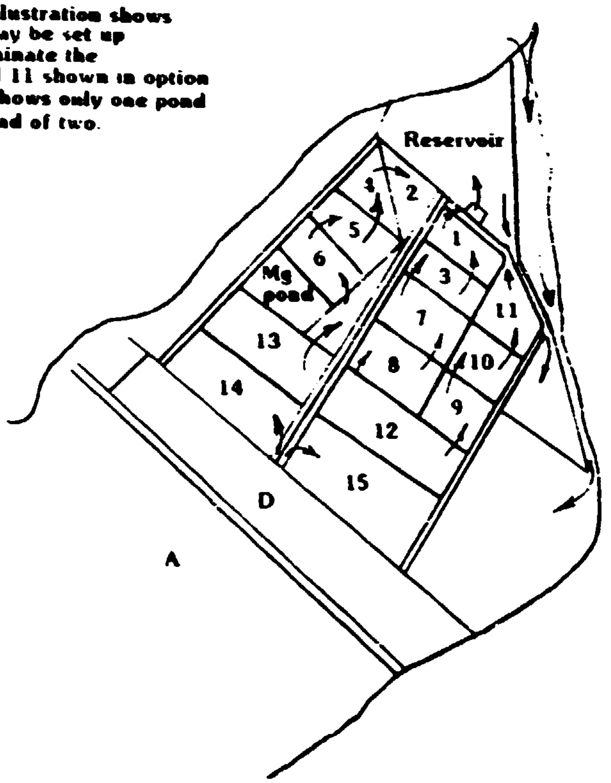
OPTION ONE

Bitterns are isolated from Alex Petro brine by making a canal next to pond 11 and by making two additional ponds. These two ponds become bitterns holding areas. Later as brine concentrates additional ponds may be added to the south if it is desired to concentrate more for by-products



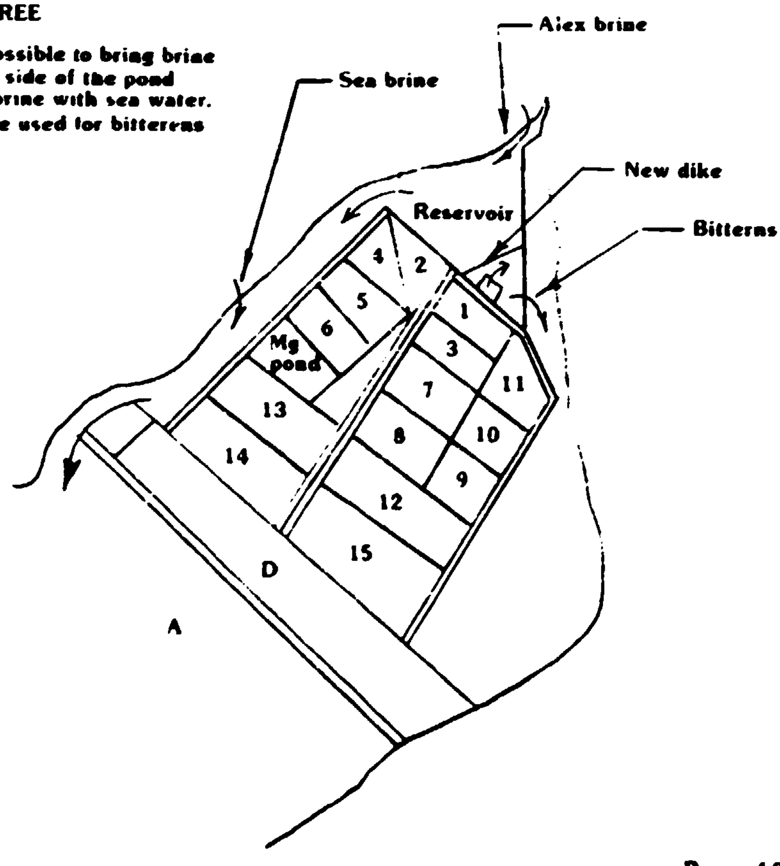
OPTION TWO

There are a variety of ways bitterns can be isolated. This illustration shows how how salt ponds may be set up in series flow and eliminate the the canal East of pond 11 shown in option one. This illustration shows only one pond made to the east instead of two.



OPTION THREE

Perhaps it would be possible to bring brine around the north west side of the pond system and mix Alex brine with sea water. The east pond would be used for bitterens holding.



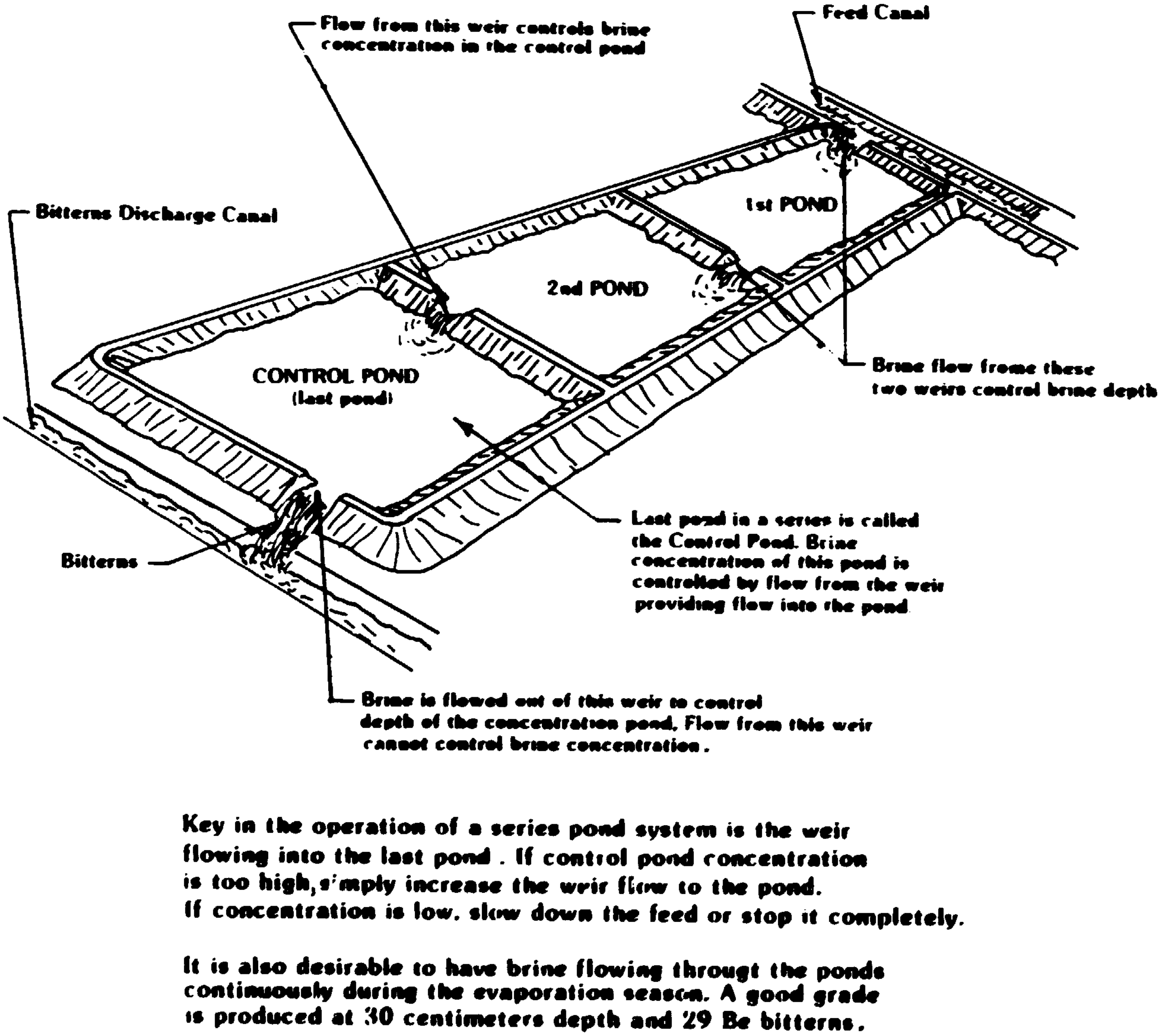
Series Flow System

Ponds should be run all season at a low level of about 30 centimeters where possible. Flow rate into ponds will be continuous and controlled by two indicators. The first is concentration in the last pond of the flow series. If the concentration is high, then more flow will be introduced into the pond. If the concentration is low, then flows will be reduced or stopped until concentration increases to the desired level.

This control is easily done at El Mex. The large intermediate pond labeled "D" in the illustration is a good surge area. This brine is allowed to flow into Pond 15 via the canal as snown. Brine from 15 flows through an open weir to Pond 9. Brine is Pond 9 is held between 29 and 30° Be (2.6 to 3% Mg). If Pond 9 is too high in concentration, more brine from Pond 12 is allowed to enter. The water evaporated from Pond 12 and the brine flowed from 12 to 9 is replaced by brine flow from 15. Brine lost from 15 is replaced by brine from Pond D.

The following figure illustrates these control principles. Series flow through at least two ponds will increase purity of salt and production. Three or four ponds in series will increase it even more.

ILLUSTRATION OF SERIES FED PONDS

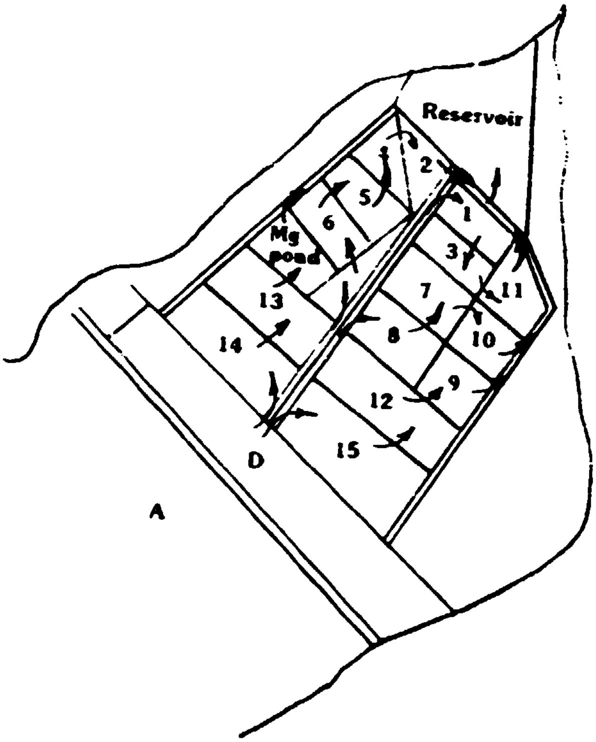


Key in the operation of a series pond system is the weir flowing into the last pond . If control pond concentration is too high, simply increase the weir flow to the pond. If concentration is low, slow down the feed or stop it completely.

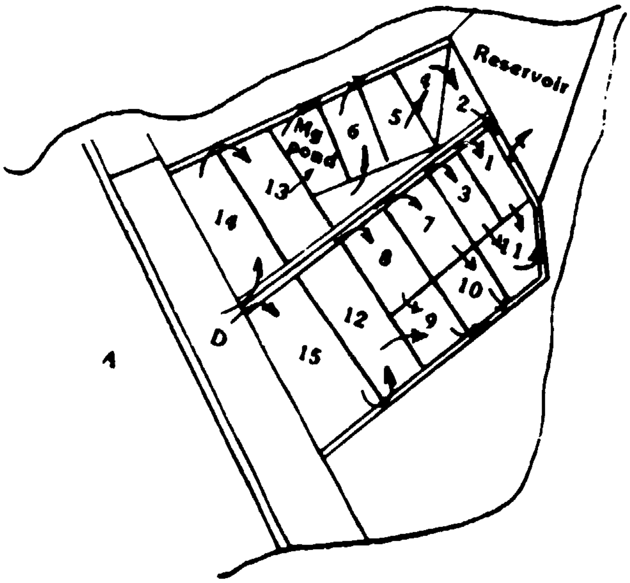
It is also desirable to have brine flowing througt the ponds continuously during the evaporation season. A good grade is produced at 30 centimeters depth and 29 Be bitterns.

SEQUENTIAL FLOW AT EL MEX

The ponds at El Mex would produce more salt and better quality if they run in series. At least three ponds should be run together and the flow should be continuous. This procedure is different than now practiced at El Mex. The following figure illistrates one possibility.



The actual flow will depend on many factors. GSL does not know where the weir placements are. It may be easier to use canals as shown in the next illustration.



3.3 Discussion of K_2SO_4 Production

El Mex Salines is a solar pond system producing a bitterns brine containing potassium, magnesium, sulfate, sodium and chloride ions. Since capital money has already been spent on this large complex, a study has been made to investigate the possibility of concentrating these bitterns in the same solar ponds. The concentrated brine would then be used to deposit mixed salts of epsomite, kainite, carnallite, and halite. The salt mixture would contain 8-10% potassium and near 20% sulfate. This mixture would be removed from solar ponds, purified in a refinery and sold as potassium sulfate.

Great Salt Lake Minerals & Chemicals Corporation (GSL) has the technology to produce potassium sulfate as described above. They are the worlds largest producers of K_2SO_4 from solar ponds.

It has been found however that brine at El Mex will not evaporate well at high concentrations. Evaporation studies made by GSL from El Mex data indicates that brine saturated in potassium will not evaporate. The rate at which brine will evaporate depends on its concentration and time of year. The best time of year is June, July and August. Evaporation of brine at this period of time is:

$$\text{Evaporation} = 18 - .26x$$

where $x = \text{moles } MgCl_2/1000 \text{ moles } H_2O$

If this equation is solved for x when evaporation is 3 centimeters per month, $x = 57.7$ moles $MgCl_2/1000$ H_2O. At this concentration, brine is not even saturated in potassium and salt production per hectare is low. At higher concentration, evaporation ceases before sufficient potassium salts can be crystallized to finish off the brine. <u>These conditions do not favor an economical production of potassium bearing salts.</u>

It is recommended however that an attempt be made to concentrate salt bitterns to as high a concentration as possible for the following reasons.

1. Bitterns should be isolated from the system even if by-products are not made. The reasons for this have already been explained.

2. Actual evaporation of highly concentrated brine has not been verified. Isolation of bitterns as suggested could provide needed information to see exactly how far brines can be concentrated and how to better design for possible K_2SO_4 and magnesium salt production.

3.3.1 Possible K_2SO_4 Production Rates

El Mex has a reserve of brine and a salt bed. Normally sea water will be concentrated from very low values of sodium and magnesium. At El Mex, sea water is flowed over a salt floor where salts are dissolved and the sea brine is enriched. It is estimated that there are 10,000,000 ton of salt in the bed. It is also estimated that salt in the ocean feed brine is 500,000 to 1,000,000 ton of salt per year depending on whether draining water (15,000,000 ton per year) contains salt or not. It appears that a rate of 1,000,000 ton per year of halite can easily be sustained for the next 15 to 20 years.

According to El Mex personnel, evaporation can support a feed rate from the sea of 37,000,000 ton per year. Since sea brine contains 0.038% potassium, then 37 x 10^6 x .00038 = 14,060 ton is entering into the solar pond area each year. Once a bittern concentration area is set up, plant efficiencies and brine entrainment losses are considered, production rate from sea brine alone can only be 7,030 ton per year of potassium or 15,500 ton K_2SO_4.

The present reserve in the ponds is estimated at 24 million ton in the pre-concentration pond. The concentration of this brine is 0.3 percent of potassium. This is less than 1/2 the concentration expected from previous reports given to GSL (See reference 3). The total reserve of K is only 72,000 ton. In the 7 square kilometers salt crystallizer, the 3,500,000 million ton of brine contains only 24,500 ton of potassium. This is a combined equivalent of 215,017 ton K_2SO_4. Since only 50% can be recovered as solid product, then 107,500 ton K_2SO_4 is a potential product.

If this 107,500 ton were to be harvested over ten years and combined with the potential of 15,500 ton per year from sea brine, only 26,250 ton can be produced. Possible conversion of an external recycle of muriate of potash (KCl) could boost production to 40,000 ton per year. In GSL's opinion, this is a small amount and it would be difficult to justify the capital expense.

It is also well to note that ten years after production starts, the present reserve of K_2SO_4 will be depleted and only 15,500 ton per year from the sea could be produced.

The use of Borg El Arab to supplement El Mex K_2SO_4 does not appear feasible. A plant could not be justified at both places. This means that salts from Borg El Arab would need to be transported from there to El Mex. Mixed salts would contain less than 9% potassium and it would require about 13 ton of salts to make one ton of K_2SO_4. At best, cost of harvest and haul plus handling at Borg El Arab and El Mex would place the cost at well over 7 dollars per ton. The expenditure to get it into a plant at El Mex would be \$7.00 times 13 or \$91 per ton K_2SO_4. Add this to a processing cost at the plant of \$30 plus depreciation of the plant and it would exceed the sale price of K_2SO_4. There would be no payback.

In the case of MgO production, it could be possible to use Borg El Arab bitterns. The brine could be treated with lime to make MgOH. The MgOH could then be filtered and sent to El Mex where MgO could be produced from it. More details on this are given in another section of this report.

3.4 K_2SO_4 Plant Process

Assume that salts can be obtained. These salts will be processed in a plant having the flow as shown on Figure 4. The process has several advantages because only water is used as a conversion media. If the flow of Figure 4 is simplified to only flow stream in and out of the plant, a simple picture of the process can be seen. The following illustration shows these streams.

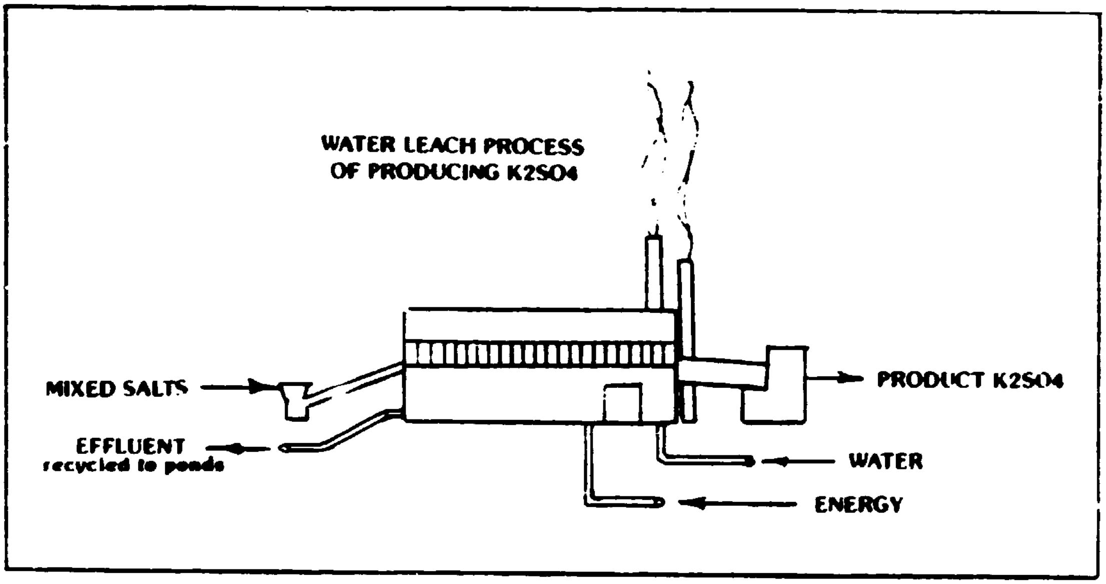
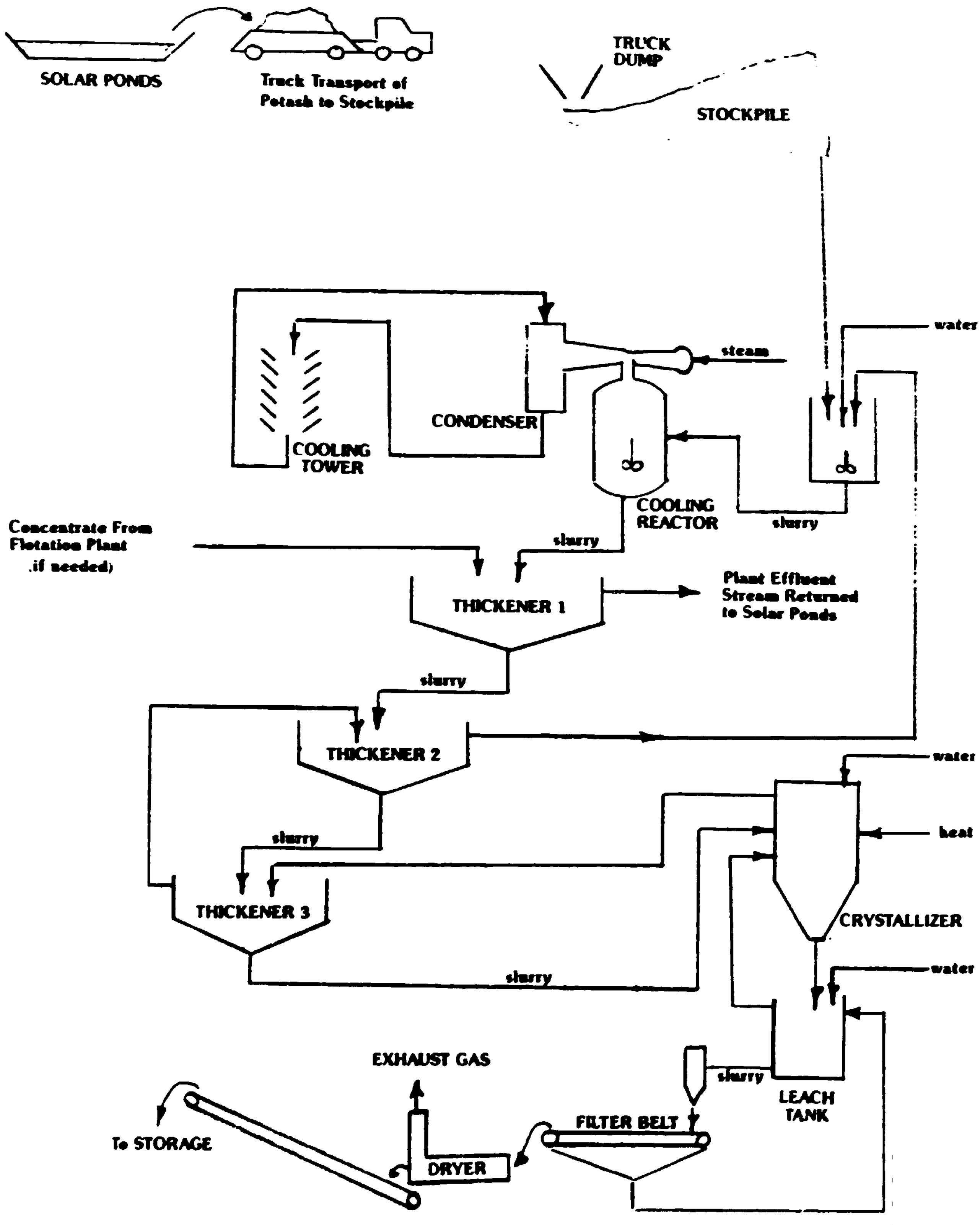


FIGURE 4

POTASSIUM SULFATE PLANT CIRCUIT

PURIFICATION, CLEANING, AND CRYSTALLIZATION OF POTASSIUM SULFATE, K_2SO_4, FROM MIXED SALTS



There are only four streams plus the energy input. Water flows counter-current to solids. The water dissolves out impurities resulting in a purified product K_2SO_4. The cleansing water becomes saturated in potassium and sodium. It also contains impurities of magnesium sulfate and chlorides.

The overall efficiency is not very good because a lot of potassium is dissolved with the impurities and discharged from the plant with the effluent. This effluent is recycled back to the solar ponds where the impurities are separated out and the potassium is re-deposited and returned back to the plant a year later. Figure 4 shows the overall pond flow with the refinery included.

In an attempt to reduce potassium losses via the plant effluent and increase plant efficiency, the effluent is cooled. This is done at GSL with stream evactors and evaporation cooling. The weather in Alexandria however, does not favor evaporative cooling and plant operation would need to be limited during the colder months of December, January and February or artificial cooling would be necessary. Potassium salts are sensitive to temperature and impurities NaCl and $MgCl_2$ are not. Thus losses of potassium are reduced by cooling the effluent stream and forcing potassium salts (usually schoenite) to crystallize while NaCl and $MgCl_2$ remain in the effluent and are rejected back to the pond system.

Even though the production of K_2SO_4 does not look promising from a solar pond standpoint, the plant flow and capital expenditure has been given as a measuring stick. GSL is not aware of anyone else producing K_2SO_4 from sea brine. This indicates that production from sea water is not easily accomplished. It has been tried at some of the largest salt works in the world, such as Exportadora del Sal in Baja, Mexico, but without success. It was also tried at Lake McLeod in Western Australia by Texada Corporation. It too was unsuccessful.

It is understood, however, that the French are having some limited success in production of K_2SO_4 and MgO from their salt works. Perhaps they could be approached for technology. The director of technology at Salines du Midi is Mr. Denis Drummond. His address is shown later in this report.

Other methods of making K_2SO_4 are discussed in Appendix One.

COST ESTIMATE FOR A K_2SO_4 PLANT

Basis:
1. Plant runs December through April only.
2. Production rate is 300 ton per hour.
3. 14,000 ton of KCl will be converted to K_2SO_4 each year.
4. Total yearly production is 40,000 ton.

This cost estimate for a K_2SO_4 plant is based on a cost if the plant were to be built at GSL's site in Ogden, Utah. The following summarizes costs.

A. EQUIPMENT COSTS

Conveyors	$1,014,862
Cooling Tower	106,714
Crystallizer	437,226
Field Erected Tanks	573,348
Hoppers	314,000
Spouting	120,000
Apron Feeders	184,450
Screw Conveyors	16,500
Bag Conveying Equipme :	26,670
Secondary Crusher	20,180
Primary Crushers	47,870
Shop Fabricated Tanks	27,224
Belt Scales	61,386
Track Scales	45,044
Vibrating Feeder	11,614
Roll Crusher	5,770
Bag Crusher	23,848
Agitators	128,904
Dryer	215,430
Thickeners	490,598
Belt Extractor	74,000
DSM Screens	27,036
Belt Filter	174,884
Vibrating Screens	35,522
Wet Cyclone	16,922
Heat Exchanger	36,980
Fire Pump	12,818
Jet Slinger	6,626
Pumps, Cast Iron	15,634
Pumps, Vertical	26,680
Pumps, Slurry	57,500
Sealine for Thickener Tanks	8,000

Lump Breaker with Conveyor	147,870
Tramp Metal Remover	12,738
Gates and Diverters	49,750
Dust Collectors (Scrubbers)	32,808
Bin System	68,000
Condensor Pumps	10,000
Bridge Cranes and Hoists	62,000
Heating Equipment	80,000
Raw Water Supply	13,000
Plant Supply Equipment	240,800
Total	$5,081,286
Tax	120,000
Freight	140,000
Erection Costs	600,000
Grand Total Erected Equipment	$5,941,286 U.S.

B.	Earthwork	600,000
C.	Concrete	500,000
D.	Structural	1,775,000
E.	Electrical	1,220,000
F.	Piping	1,440,000
G.	Insulation	166,000
H.	Instrumentation	538,300
I.	Painting	318,000
J.	Miscellaneous	1,400,000
	Total Direct Cost	$13,893,586

Construction Overhead	980,000
Engineering	1,600,000
Contractor Fees	650,000
Owners Supervision	650,000
Contingency (20%)	2,800,000
Subtotal	$20,573,386
Spare Parts	2,000,000
Grand Total for Turn Key Plant	$22,500,000

Notes:

1) Connected horsepower is 4200.
2) Capacity is 300 tph.
3) Granulation of product is not included in cost.
4) Changes to ponds or harvest equipment is not included in cost. Stockpile and reclaim are included.

Direct Operation Manpower

Operation
- 4 shift foremen

- 29 plant operators as follows:
  - 5 crusher operators
  - 5 wet process operators
  - 5 control board operators
  - 5 dryer operators
  - 5 laborers
  - 4 loadout operators

- Support personnel
  - 4 stockpile and reclaim operators
  - 13 maintenance personnel (experienced)
  - 1 General Foreman
  - 1 Instrumentation Engineer
  - 2 Electricians
  - 5 Laboratory Technicians
  - 2 Support Engineers

Total direct manpower 61

Indirect manpower as needed:

- Sales force
- Accounting
- Plant Manager
- Superintendent

Note that harvest, pond operations and pond modification costs are not included in the above outline.

3.4 Discussion of $MgCl_2$ and MgO production.

El Mex brines can be concentrated to contain 6% Mg in the ponds. This magnesium can be removed by reacting it with lime.

$$MgCl_2 + CaO \rightarrow Mg(OH)_2 + CaCl_2$$

The MgOH solids are then filtered and impurities of $CaSO_4$, $CaCl_2$, $MgSO_4$, NaCl, etc. are removed. The purified MgOH is then converted to MgO:

$$Mg(OH)_2 \xrightarrow[heat]{} MgO$$

$MgCl_2 \cdot 6H_2O$ Flake can also be easily produced from the brine.

$$MgCl_2 \xrightarrow[heat]{} MgCl_2 \text{ concentrate}$$

$$MgCl_2 \text{ Concentrate} \xrightarrow[cool]{} MgCl_2 \cdot 6H_2O$$

$MgCl_2 \cdot 4H_2O$, $MgCl_2 \cdot 2H_2O$ or other hydrated forms can be made depending on how much water is removed in the heating step.

Figure 5 shows a flow sheet for $MgCl_2$ flake. This product is produced at GSL in several grades. Production of $MgCl_2 \cdot 6H_2O$ is relatively easy and would be a good product for El Mex if it can be marketed.

The flake can be made into 6,5,4 or 3 water of hydration by controlling the concentration of magnesium in the evaporator. A concentration of 12% magnesium will produce bischoffite ($MgCl_2 \cdot 6H_2O$). Concentration of higher magnesium will produce a flake with lower water.

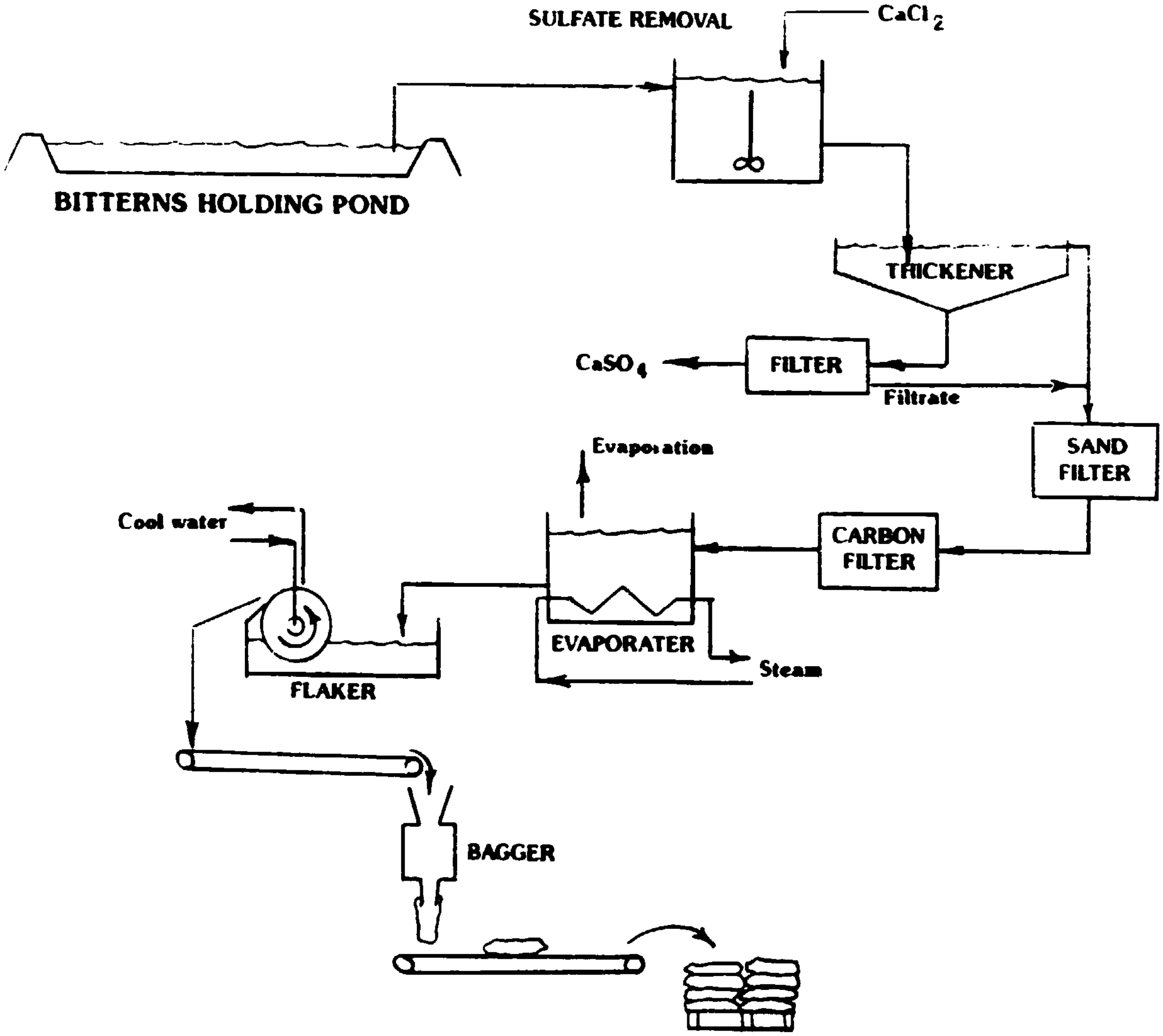
All flake must be bagged immediately because it is hydroscopic. Magnesium chloride is used in oxychloro cements, ion exchange resins and certain specialty chemicals applications.

3.4.1 Magnesium Reserves and Production at El Mex.

Magnesium is 1.35% in reserve brine and 0.13 in the sea. Applying the same principles of production as K_2SO_4, there is an equivalent of 37×10^6 x .0013 = 48,100 ton Mg per year in the feed and 24,000,000 x .0135 + 3,500,000 x .015 = 376,500 ton or 37,650 ton over a ten year depletion. Total potential for the first ten years at 50% recovery is 70,000 ton per year MgO. Long range is 40,000 ton MgO per year from El Mex.

FIGURE 5

MAGNESIUM CHLORIDE FLAKING CIRCUIT
$MgCl_2 6H_2O$



Add this to possible feed stock from Borg El Arab and a long range MgO production facility at El Mex could be a possibility.

Capital and Operating Expenses to Produce $MgCl_2 \cdot 6H_2O$

At GSL flaked $MgCl_2$ must be low in sulfate and sodium and it must be white. $CaCl_2$ is added to reduce SO_4 levels. The resulting gypsum particles are fine and difficult to separate from the solution. Thickening and filtering are needed to remove particles. A carbon filter and a sand filter are used to remove the dark color usually associated with highly concentrated bitterns.

Capital expense is based on a system as shown in the flow diagram. There are several alternatives however. SO_4 can be removed by heating, for example. The sulfate ion has a reverse solubility and heating drives out kieserite ($MgSO_4 \cdot 6H_2O$).

Basis: Plant runs all year. 10,000 ton per year $MgCl_2 \cdot 6H_2O$
6% Bitterns can be made in ponds.

Equipment Cost

Sulfate removal tanks		30,000
Thickener		100,000
Drum Filter		75,000
Sand Filter		50,000
Carbon Filter		50,000
Evaporator tanks (two)		30,000
Boiler		85,000
Heating Equipment		20,000
Flaker		25,000
Bagger		80,000
Pumps		55,000
Bridge cranes and hoists		12,000
Agitator		18,000
Heat exchanger		10,000
Conveyor belts		35,000
Bin systems		15,000
Screw conveyors		10,000
Plant supply		50,000
	Total	750,000
	Tax	
	Freight	23,000
	Erection	100,000
		873,000

Earthwork		20,000
Concrete		50,000
Structural		34,000
Electrical		25,000
Piping		75,000
Insulation		5,000
Instrumentation		12,000
Painting		22,000
Miscellaneous		50,000
	Total Direct Cost	1,166,000
Construction Overhead		100,000
Engineering		120,000
Contractors Fees		100,000
Owners, Supervisors		50,000
Contingency (20%)		250,000
	SubTotal	1,786,000
Spare Parts		50,000
	Grand Total	$1,836,000

Discussion of MgO Production, Flow and Capital Expenses.

GSL has not produced MgO. There are several facilities that do produce it from brine however. The Israelis have been doing it from $MgCl_2$ brines at their Dead Sea Works operation. They were assisted by Sulzer Escher Wyss and by Babcock International. They may possibly have the technology. Possible contacts to each facility are listed below.

Dr. Edward Kratz
Senior Technologist
Sulzer Escher Wyss
P.O. Box
CH-8023
Zurich, Switzerland

Mr. Derek Gosden
Babcock Woodall-Duckham Ltd.
11 The Boulevard
Crawley, Sussex
RH10 10X
England

It is also understood that the French are doing some work in developing MgO from sea brine and they may be willing to joint venture or supply technology through an arrangement of mutual benefit.

Dennis Drummond
Compagnie Des Saline du Midi
Et Salines De L'est
51 Rue D'Anjou F 75008
Paris, France

Magnesium Oxide Plant Flow Description

One major possibility for magnesium production at El Mex is the reaction of lime with $MgCl_2$ brine. This is done commercially by several companies. At Freeport, Texas lime is reacted with sea brine. Sea brine has only 2.2 g/l of MgO equivalent where El Mex brine at 6% Mg contains over 100 g/l.

Production of magnesium compounds from bitterns water is made possible by the almost complete insolubility of $Mg(OH)_2$ in water. Reaction of lime of dolomite with bitterns produces Mg(OH) from $MgCl_2$ or $MgSO_4$ in solution.

$$MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCl_2$$
$$MgSO_4 + Ca(OH)_2 + 2H_2O \rightarrow Mg(OH)_2 + CaSO_4 \cdot 2H_2O$$

FIGURE 6

MAGNESIA FROM EL MEX BITTERNS

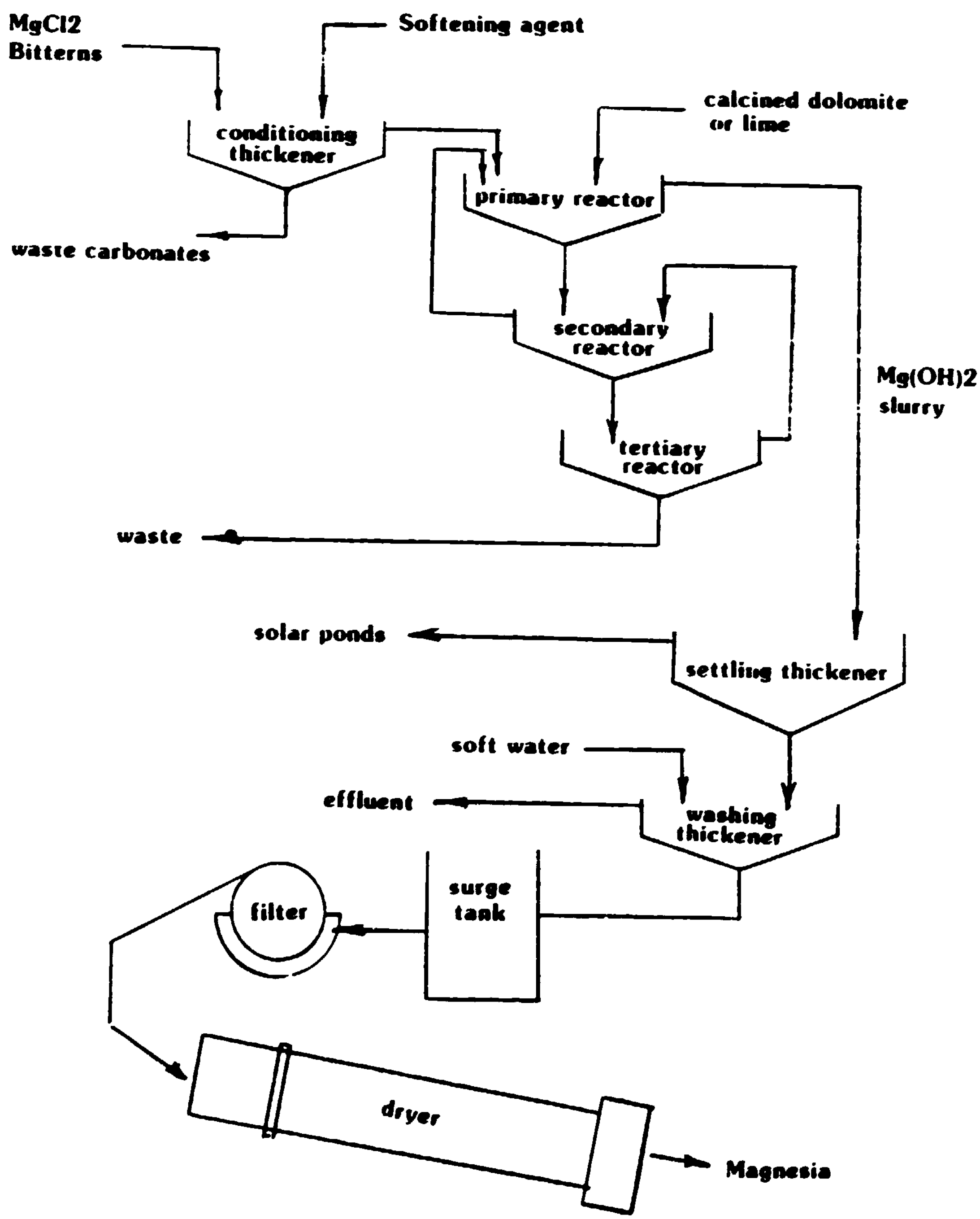


Figure 7 shows a flow chart for producing magnesium compounds used in pharmaceuticals, tooth powders, antacid remedies, anti-caking agents (for table salt) and paint fillers.

MgOH becomes the basis for making MgO via calcination

$$Mg(OH)_2 \rightarrow MgO + H_2O$$

Other processes require the following steps:

1. Water softening with lime or calcined dolomite
2. Preparation of a purified lime or slurry
3. Removal of precipitated $Mg(OH)_2$
4. Purification of $Mg(OH)_2$
5. Filtering of slimes
6. Firing of $Mg(OH)_2$ to form MgO

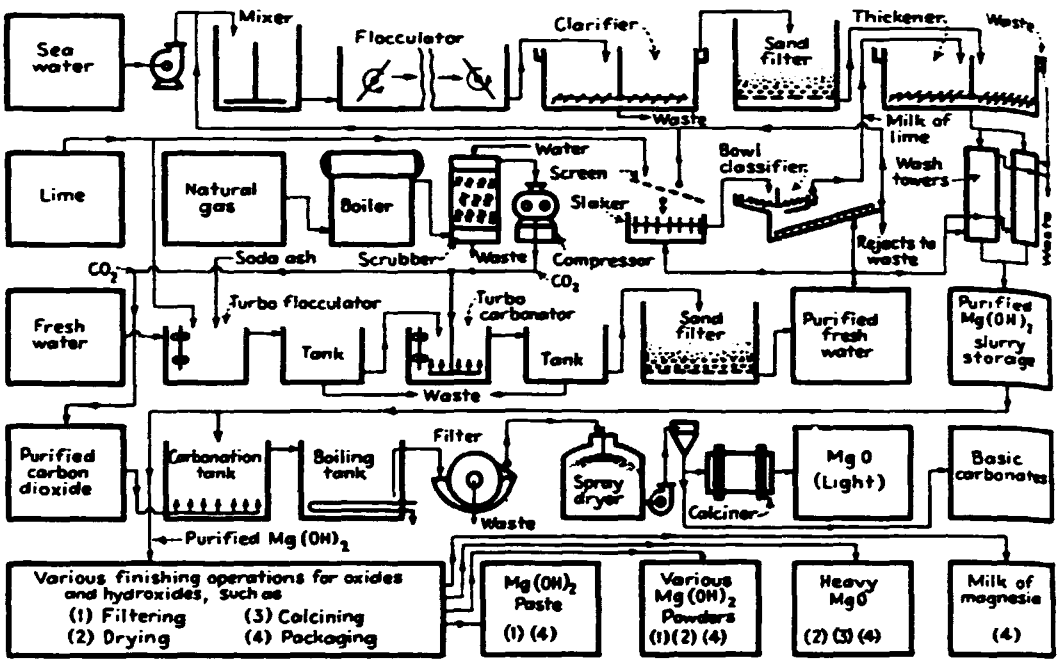
Magnesium compounds have been made from sea water or concentrated sea brine by the following companies.

Dow Chemical Company at Freeport and Velaco, Texas
Merck and Company, San Francisco, California
FMC, Newark, California
Kaiser Chemical Division, Moss Landing, California
H.K. Porter Co., Pascagoula, Florida

Figure 7 shows a flow chart for $Mg(OH)_2$ from sea water and dolomite. Calcined dolomite is added in enough quantity to pre-test the brine bitterns and remove any carbonate. At El Mex this may not be necessary because carbonates have mostly been removed by concentrating the sea water in solar ponds. Any remaining calcined dolomite would work well to soften the brine. The softened bitterns then flow to reactors where more dolomite (or lime) is added to precipitate $Mg(OH)_2$.

$Mg(OH)_2$ is a very fine particle suspension which overflows with liquors from the reactor. The fine $Mg(OH)_2$ is difficult to collect and dewater. Several thickening steps are required and considerable space is needed for these thickeners. Even with thickening and filtration, the $Mg(OH)_2$ cake still contains high moisture. The cake is then dried at temperatures up to 1800°F to produce various grades of magnesia.

FIGURE 7



Purified magnesium compounds from sea water at South San Francisco. (Merck & Co.)

REFERENCES

1. Concentration Path of El Mex Brine and Ocean Brine by GSL Solar Consultants & Advisors, Inc., September, 1988.

2. Brine Evaporation at El Mex Salines, November, 1988.

3. Field Report of El Mex Salines Salt Works and its potential to produce potassium sulfate and other by-products, by David Butts, April, 1987.

APPENDIX ONE

VARIOUS METHODS USED TO PRODUCE K_2SO_4

It is possible to float schoenite as done at Great Salt Lake Minerals but efficiency of a kainite float is reported to be much better than schoenite. Floating the two at the same time is inefficient. It is therefore important to remain in the kainite phase.

2.1.2 Conversion of Kainite to Schoenite

The second step in the process is to convert kainite to schoenite as shown in the following equation:

$$2KCl \cdot MgSO_4 \cdot 2.75H_2O + Mg + SO_4^{=} \rightarrow K_2SO_4 \cdot MgSO_4 \cdot 6H_2O + Mg^{++} + Cl^-$$

(Kainite) (Schoenite)

Of course this conversion must be done in conditions where schoenite is stable and kainite is unstable. A source of sulfate is also needed. This needed sulfate is made later in the schoenite decomposition step. Kainite cannot be efficiently decomposed into K_2SO_4 directly. The conversion to schoenite however is relatively easy.

Figure 2 shows all of the process flow steps after flotation. Enriched kainite is transferred into an agitated reactor tank where it is mixed with high sulfate brine. This brine is saturated in schoenite and arcanite having just come from the schoenite decomposition crystallizer circuit. (See the figure). This reactor mixture is next pumped to a thickener where conversion of any unreacted kainite is completed.

Conversion of kainite to schoenite is relatively easy and fast. Enriched kainite is already of small particle (-28 mesh). A high sulfate brine is mixed with it and therefore conversion is rapid.

2.3.3 Schoenite Conversion Enhancement

The final process step is conversion of schoenite to arcanite. Both the conversion of kainite to schoenite and schoenite to arcanite are dependent on the sulfate concentrated in the liquor. High sulfate forces kainite to schoenite and high K_2SO_4 forces higher efficiency in the conversion of schoenite to arcanite. For this reason an enhancement step is used in the process called syngenite.

Liquid from the schoenite thickening step is reacted with gypsum in a mixing tank to form syngenite.

$$CaSO_4 \cdot 2H_2O + 2K^+ + SO_4^{=} \rightarrow K_2SO_4 \cdot CaSO_4 \cdot H_2O + H_2O$$

(Gypsum) (Syngenite)

FIGURE 1.
KAINITE FLOTATION STEP

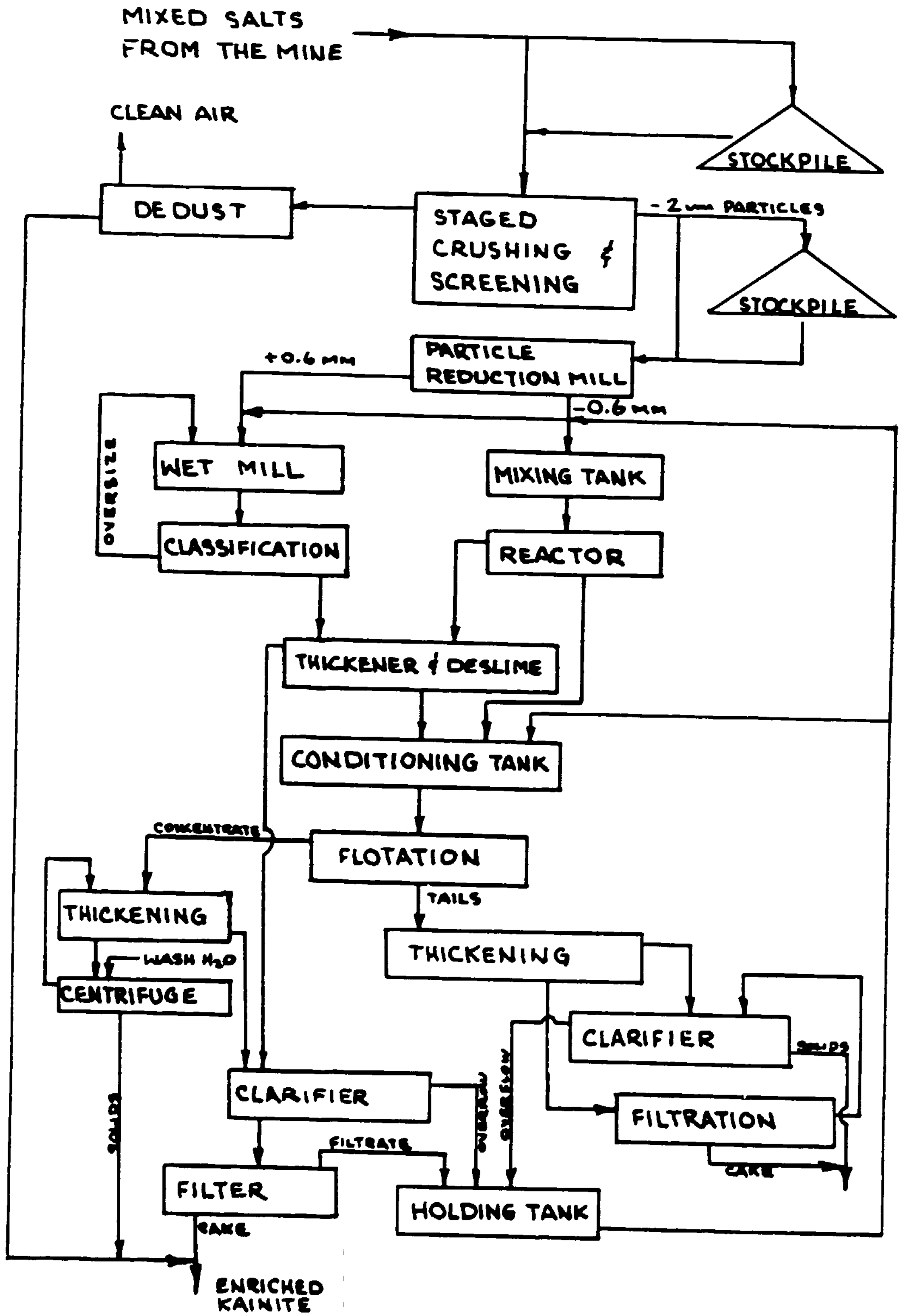
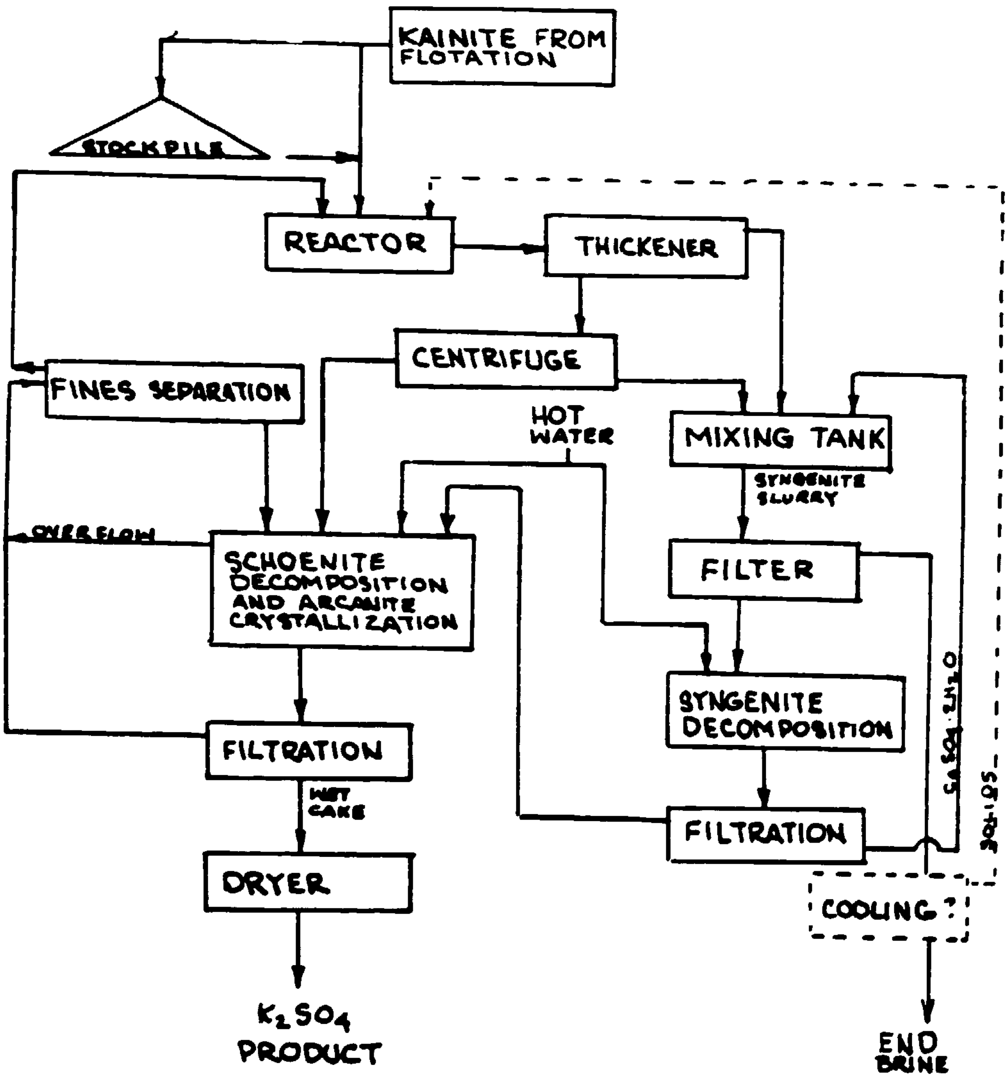


FIGURE 2.
KAINITE TO SCHOENITE CONVERSION
AND SCHOENITE DECOMPOSITION STEPS.



Syngenite is then filtered. The syngenite cake is then reacted with hot water where all of the K_4SO_4 is dissolved. $CaSO_4$ is not soluble in hot water and it is recycled back for reuse to make more syngenite in the mixing tank.

The leach water liquor pregnant in arcanite (K_2SO_4) is sent to a schoenite decomposition crystallizer where solid phase K_2SO_4 is formed. Magnesium sulfate is more soluble in hot water than potassium sulfate. Therefore, when a hot solution of K_2SO_4 is mixed with schoenite the following reaction will occur:

$$K_2SO_4 \cdot MgSO_4 \cdot 6H_2O + \text{Hot } H_2O \rightarrow \underset{\text{Product}}{K_2SO_4} + Mg^{++} + SO_4^{=}$$

This reaction is discussed in more detail in the next section.

2.1.4 Schoenite Decomposition

Schoenite decomposition is based on the different solubilities of K_2SO_4 and $MgSO_4$ in water as shown in Figure 3. Note that the solubility of $MgSO_4$ is higher than K_2SO_4. When water is reacted with schoenite, K_2SO_4 is left as a solid and becomes the final product after filtering and drying. Of course, some K_2SO_4 is also dissolved in the process but some is recovered later in the syngenite process.

It is seen that $MgSO_4$ is not used up in the process and the liquor is recycled back to the kainite schoenite reactor.

A few details of the process and operation follows:

Figure 3 shows the solubility of a K_2SO_4-$MySO_4$-H_2O system. All values are shown in grams per 100 grams of water. Figure 4 shows a development of mass balance equation to determine decomposition efficiency.

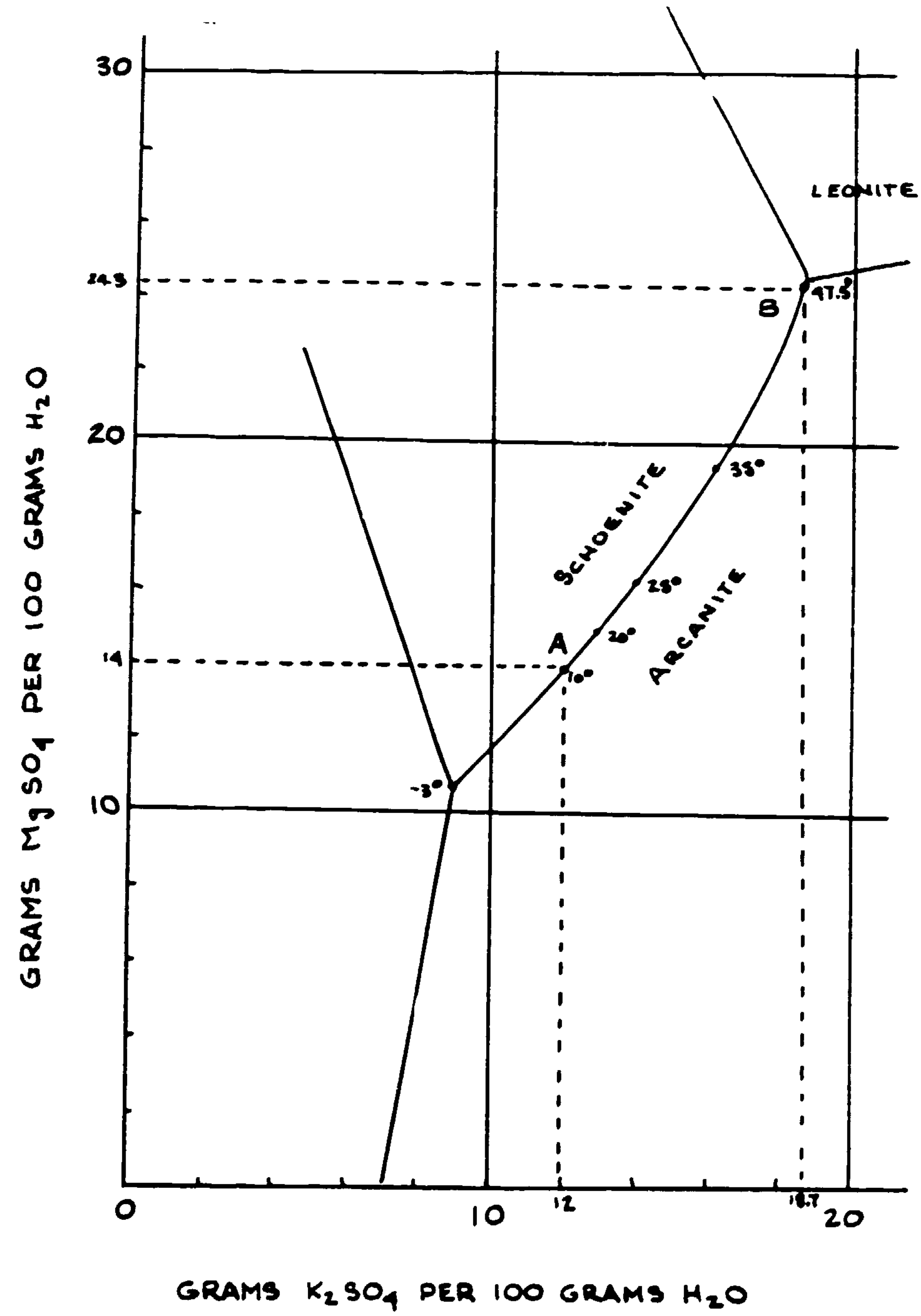
Point A on Figure 3 is the solubility of K_2SO_4 and $MgSO_4$ at 10°C. 12 grams of K_2SO_4 and 14 grams of $MgSO_4$ will dissolve in 100 grams of water. This is 9.5% K_2SO_4 and 11.1% $MgSO_4$. From this it is calculated that 269 ton of end liquor will be formed in the decomposition reaction. 187 ton of water must be added and 17.7 ton of solid K_2SO_4 will be formed. Potassium recovery from schoenite at 10° and pure water is therefore: 17.7/43.3 or 41%.

If the same reaction is carried out at 47.3°C, Point B on Figure 3, the solubility of K_2SO_4 is 18.7 and 24.3 for $MgSO_4$. Using these numbers:

176.0 tons liquor is formed
96.3 tons of H_2O is added
20.2 tons of K_2SO_4 solids are formed

FIGURE 3

SOLUBILITY IN THE SYSTEM K_2SO_4 - $MgSO_4$ - H_2O



Recovery is 20.2/43.3 or 47%. Note how much less water is used at the higher temperature. Cooling of this water will later yield schoenite for re-use in the crystallizer.

A gain in recovery is seen by increasing temperature. Decomposition of schoenite can be done at any temperature between -3°C and 47°C. Efficiency of conversion is highest at 47°C, but heat must also be added and economics must be studied to see if the added energy cost justifies the increase in efficiency.

Overall conversion efficiency of 40+50% is indeed low. Use of Syngenite will increase efficiency by creating a water solution already containing K_2SO_4. Any K_2SO_4 in the decomposition water means an equivalent amount K_2SO_4 will not be dissolved from schoenite and will consequently remain as solid SOP.

Crystallizer decomposition end liquor is relatively free of NaCl, and $MgCl_2$. This liquid is also saturated in schoenite and arcanite. It is therefore a valuable liquor to be recycled back and mixed with incoming kainite. Here the liquor dissolves soluble impurities and converts kainite to schoenite. It has been shown how this conversion forms $MgCl_2$. $MgCl_2$ is highly soluble and will actually depress the solubility of others salts.

Thus K_2SO_4 and $MgSO_4$ in the original liquor is forced out of the solution as it is mixed with kainite. $MgCl_2$ enters the solution. The salts forced out of solution form more schoenite which is fed back to the schoenite decomposition crystallization step. This increases the overall recovery of potassium in the combined steps to over 60%. The theoretical yield is as high as 67% but equilibrium of salts with brines are never reached and recovery is somewhat less.

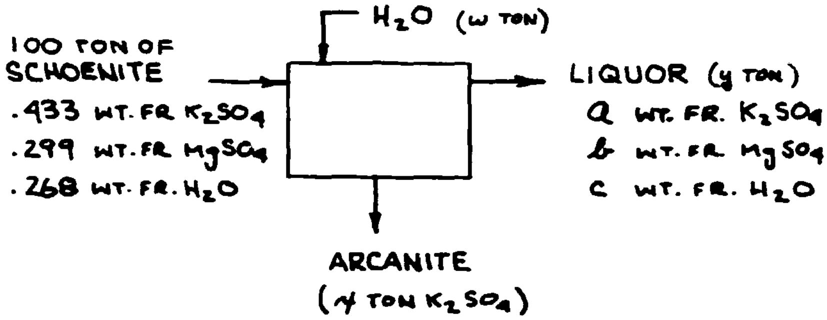
Recovery of even 60 to 65% is still low. Use of the syngenite step is reported to bring recoveries up to 70 to 75% and chilling or cooling of effluent streams has been reported to bring up conversion efficiency as high as 82%. Both potassium and sulfate are temperature sensitive. Cooling forces $MgSO_4$ and K_2SO_4 salts to crystallize. These salts can be filtered and returned to the reactor. From the information given, GSL is not sure where cooling is done in the streams, if done at all, but one possible location is indicated on the flow streams of Figure 2.

It is quite possible that even after the syngenite step and cooling, there is still an excess of SO_4 salts in the end liquor that can be used for the reaction:

$$2KCl + SO_4^{=} \rightarrow K_2SO_4 + 2Cl^-$$

FIGURE 4.

SCHOENITE DECOMPOSITION MATERIAL BALANCE



	IN		OUT
WATER BALANCE:	$(100)(.268) + w$	$=$	$(y)(c)$
$MgSO_4$ BALANCE:	$(100)(.299)$	$=$	$(y)(b)$
K_2SO_4 BALANCE:	$(100)(.433)$	$=$	$(y)(a) + r$

*AT 10°C: $a = .0952$, $b = .111$ & $c = .794$

FROM $MgSO_4$ BALANCE $\quad 29.9 = y(.111)$, $y = 269.4$ TON

FROM WATER BALANCE $\quad 26.8 + w = (269.4)(.794)$

$w = 187.1$ TON

FROM K_2SO_4 BALANCE $\quad 43.3 = (269.4)(.0952) + r$

$r = 17.65$

THEREFORE: WATER TO PRODUCT RATIO = 10.6

% POTASSIUM RECOVERY = 41 %

---

*AT 47.5°C: $a = .131$, $b = .1699$, $c = .70$

$MgSO_4$ BALANCE $\quad 29.9 = (y)(.1699)$, $y = 176$ TON

K_2SO_4 BALANCE $\quad 43.3 = (176)(.131) + r$, $r = 20.2$ TON

H_2O BALANCE $\quad 26.8 + w = (176)(.70)$, $w = 96.4$

THEREFORE: WATER TO PRODUCT RATIO = 4.77

% POTASSIUM RECOVERY = 47 %

* CALCULATED FROM DATA OF FIGURE .

Such a practice has been optimized at GSL. The viability of such a conversion depends on cost of KCl, sale price of K_2SO_4 and conversion efficiency.

2.1.5 Potassium Magnesium Sulfate (SOP/Mg)

Appendix 10/2 of reference (5) shows a cost table of SOP/Mg having 30-32% K_2O content. This product is apparently made by combining Schoenite with SOP. A section of Figure 2 is shown on the next page to indicate one way this could be done.

Appendix 10/2 also implies that .2925 ton of SOP is combined with schoenite to make one ton of product. The amount of schoenite is therefore 1-.2925 or .7075 ton.

It is also shown that 1.021 ton of kainite is needed. It is assumed that this is the amount of kainite needed to make .7075 ton of schoenite. 1.021 ton of kainite contains .1604 ton of potassium and .7075 ton of schoenite contains .1374 ton. Conversion efficiency is therefore .1374/.1604 or 85.7%.

The preceding calculation is based on pure substance. Pure SOP contains 54% K_2O, but SOP produced in Sicily has an average of 51%. SOP/Mg produced has an average of 31% K_2O. In order to produce a mixture having this concentration, a nearly pure schoenite must be combined with the 51% K_2O SOP. This balance is shown:

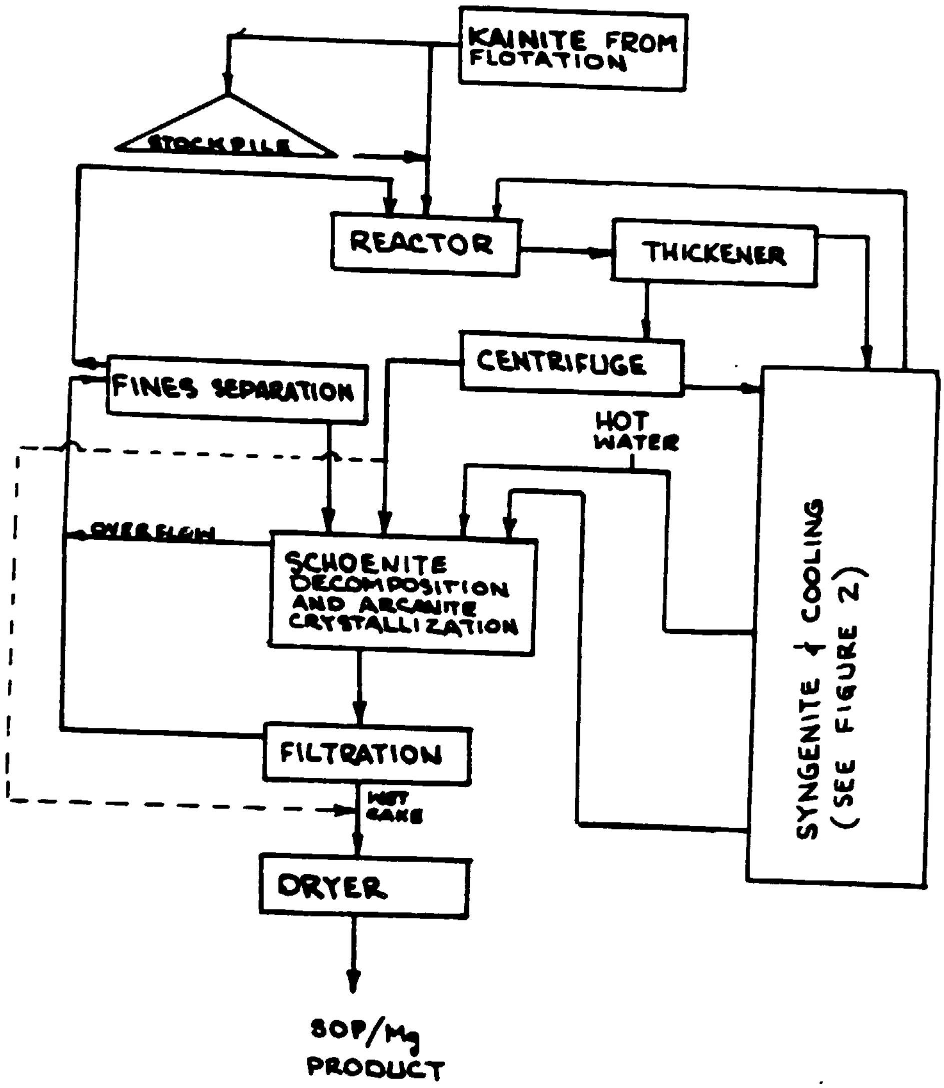
$$\frac{(.2925 \text{ TON SOP})(.51\, K_2O) + (.7075 \text{ TON SCHOENITE})(.234\, K_2O)}{1 \text{ TON SOP/Mg}} = .315 \text{ WT. FR } K_2O$$

Because SOP produced contains 51% K_2O, compared to 54% K_2O in pure SOP, the schoenite from which it is made must also be impure. If all impurities in schoenite become impurities in K_2SO_4, then schoenite produced for the crystallizer must contain 22% K_2O and not 23.4% in the pure substance. This means that .73 ton of impure schoenite is added to 51% K_2O SOP. When the mixture is dried .024 ton of hydrated water is driven off. This is about 10% of total hydrated water. The final result is to have one ton of dried SOP/Mg at 31% K_2O.

2.2 Relevant Competitive Process in Production of K_2SO_4

There are other salts that can be used to produce K_2SO_4. Even KCl is used as a base raw material to be reacted with H_2SO_4, Na_2SO_4 or gypsum. Since K_2SO_4 is more valuable than KCl, attempts are being made to convert KCl to the more valuable product. Price differences between the two varies with time and location.

PRODUCTION OF POTASSIUM-MAGNESIUM SULFATE, SOP/Mg, 31% K_2O.



If one ton of KCl is converted completely to K_2SO_4, the conversion efficiency ton to ton would be 118%. This means that even at a conversion efficiency of 85%, one ton of KCl will still make 1 ton of K_2SO_4.

2.1.1 Conversion From KCl with Sulfuric Acid

Reaction of H_2SO_4 with KCl is practiced by some companies. the reaction is shown:

$KCl + H_2SO_4 \rightarrow KHSO_4 + HCl$

More acid is then added to complete the reaction.

$KHSO_4 + H_2SO_4 \rightarrow K_2SO_4 + HCl$

The process is carried out in Mannheim furnaces. It has been reported that the same conversion can be carried out in a fluidized bed reactor. This type reactor is used by Climax Chemical Corporation but they have not reported any details concerning their reactor design. Raw material cost is obviously high because the basis relies on purchase of potassium chloride in addition to sulfuric acid. Economics is better if the producer has its own source of KCl. The competitive position of $KCl-H_2SO_4$ conversion against natural production depends on location, raw material cost and value of HCl.

Product K_2SO_4 is 90-95% K_2SO_4 with 1-2% chloride and 3-4% sulfuric acid. The acid is sometimes neutralized with calcium carbonate. Creation of HCl is usually a disadvantage unless a outlet for HCl can be found. Even if an outlet can be found, the Mannheim process does not appear to be a serious competition because of the high energy requirements (.15 ton fuel oil per ton K_2SO_4). Toxicity and corrosion problems of HCl and large capital investment for each production unit are other problems.

2.2.2 Glaserite Process

Another method of K_2SO_4 production is reaction of mirabilite with KCl. This is done in two steps:

$KCl + Na_2SO_4 \cdot 10H_2O \rightarrow 3K_2SO_4 \cdot Na_2SO_4 + NaCl + H_2O$
(mirabillite) (glaserite)

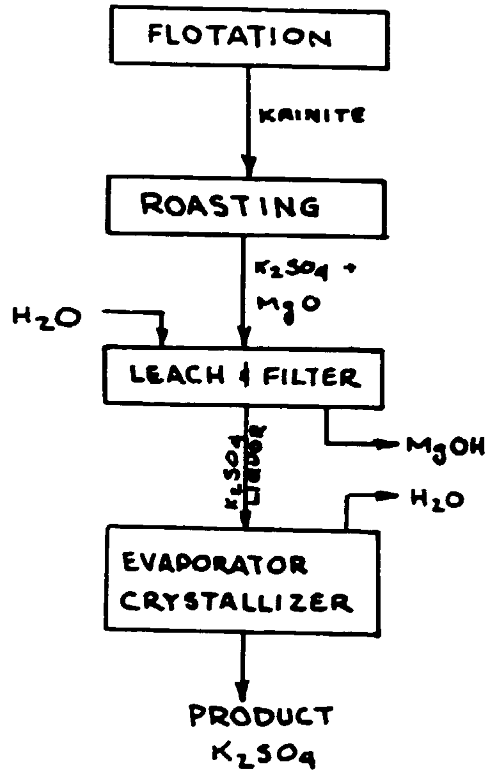
Glaserite is then dewatered and reacted with more KCl:

$3K_2SO_4 \cdot Na_2SO_4 + KCl \rightarrow K_2SO_4 + NaCl$

Work has been progressing on this project for over 20 years, but a viable process has not emerged. Most of the work has been done by the Potash Corporation of Saskatchewan. They have their own source of both KCl and Na_2SO_4. One can only estimate that they have not found an economical process. One reason may be the related inefficient recovery of only 60%.

2.2.3 Kainite Roasting

A process developed by N.L. Industries mixes KCl with Kainite followed by roasting and leaching. The process was never brought to the production stage, however. Since N.L., (now AMAX), had an abundance of kainite but still never used the process, it must not have been of enough economical value to try it. The process is patented, U.S. 3432250 by L.W. Ferris. The basic flow is shown:



The process is obviously energy intensive, high capital cost and generates HCl which must be handled and disposed.

2.2.4 Langbeinite Process

In Carlsbad, International Minerals and Chemicals Corporation (IMC) has produced K_2SO_4 from langbeinite. There are several methods of doing this but the one that seems to be the most economical is the reaction of KCl.

$K_2SO_4 \cdot 2MgSO_4 + 4KCl \rightarrow 3K_2SO_4 + 2MgCl_2$
(langbeinite)

If a smaller amount of KCl is used, potassium magnesium sulfate can be generated.

$2(K_2SO_4 \cdot 2MgSO_4) + 2KCl \rightarrow 3(K_2SO_4 \cdot MgSO_4) + MgCl_2$

Potassium magnesium sulfate (schoenite) is sold directly as a fertilizer. It has application in soils low in magnesium. Production has been limited to the volume of langbeinite and KCl dust generated in the respective production of SulpOmag and KCl.

2.2.5 Mixed Salts - Water Leach Process

Great Salt Lake Minerals & Chemicals Corporation uses a water leach process to produce K_2SO_4. The basic concept of the process is to convert a mixture of magnesium, potassium, and sodium salts into Schoenite ($K_2SO_4 \cdot MgSO_4 \cdot 6H_2O$). Schoenite is then decomposed into arcanite (K_2SO_4).

A variety of different minerals can be converted to schoenite. Some of the reactions are shown below:

$MgSO_4 \cdot 7H_2O + KCl \cdot MgSO_4 \cdot 2.75H_2O \rightarrow MgSO_4 \cdot K_2SO_4 \cdot 6H_2O + MgCl_2 +$ Water

$MgSO_4 \cdot 7H_2O$, epsomite, may occur as $MgSO_4 \cdot 6H_2O$, hexahydrate, or in lower hydrated forms. $KCl \cdot MgSO_4 \cdot 2.75H_2O$, kainite, is often shown with 3 waters of hydration.

$2MgSO_4 \cdot xH_2O + KCl \rightarrow MgSO_4 \cdot K_2SO_4 \cdot 6H_2O + Mg^{++} + Cl^-$

KCl may occur in the ponds as sylvinite (KCl + NaCl) or through decomposition of carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$) as shown below. However it can also be added from other sources in amounts needed to meet increased market demand. Adding KCl is controlled to use excess $MgSO_4$ in the system. No other chemicals are needed such as H_2SO_4, $CaSO_4$, or other sulfate salts. Neither is any additional equipment needed. The KCl need only be added at a strategic location to maximize recovery.

$2MgSO_4 \cdot xH_2O + KCl \cdot MgCl_2 \cdot 6H_2O \rightarrow MgSO_4 \cdot K_2SO_4 \cdot 6H_2O + Mg^{++} + Cl^- +$ Water

In this reaction carnallite is decomposed by water to form KCl and KCl reacts with epsomite. Feed salts almost always contain halite (NaCl) and sometimes mirabilite ($Na_2SO_4 \cdot 10H_2O$). Enough water is added to remove impurities such as sodium, magnesium and chloride.

$$Na_2SO_4 \cdot 10H_2O + KCl \cdot MgSO_4 \cdot 2.75H_2O \rightarrow KCl \cdot MgSO_4 \cdot 6H_2O + Na^+ + Cl^- + \text{water}$$

Schoenite is then converted to K_2SO_4 by the reaction with water. The basic process is a counter current flow of water with salts.

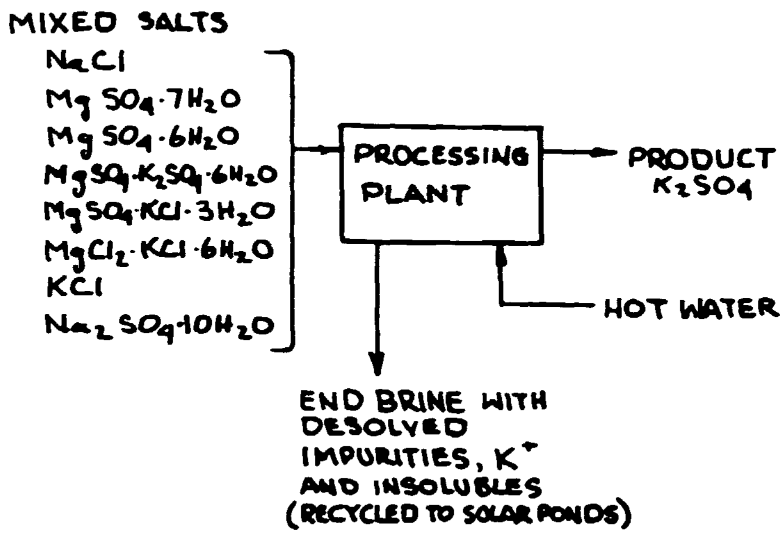


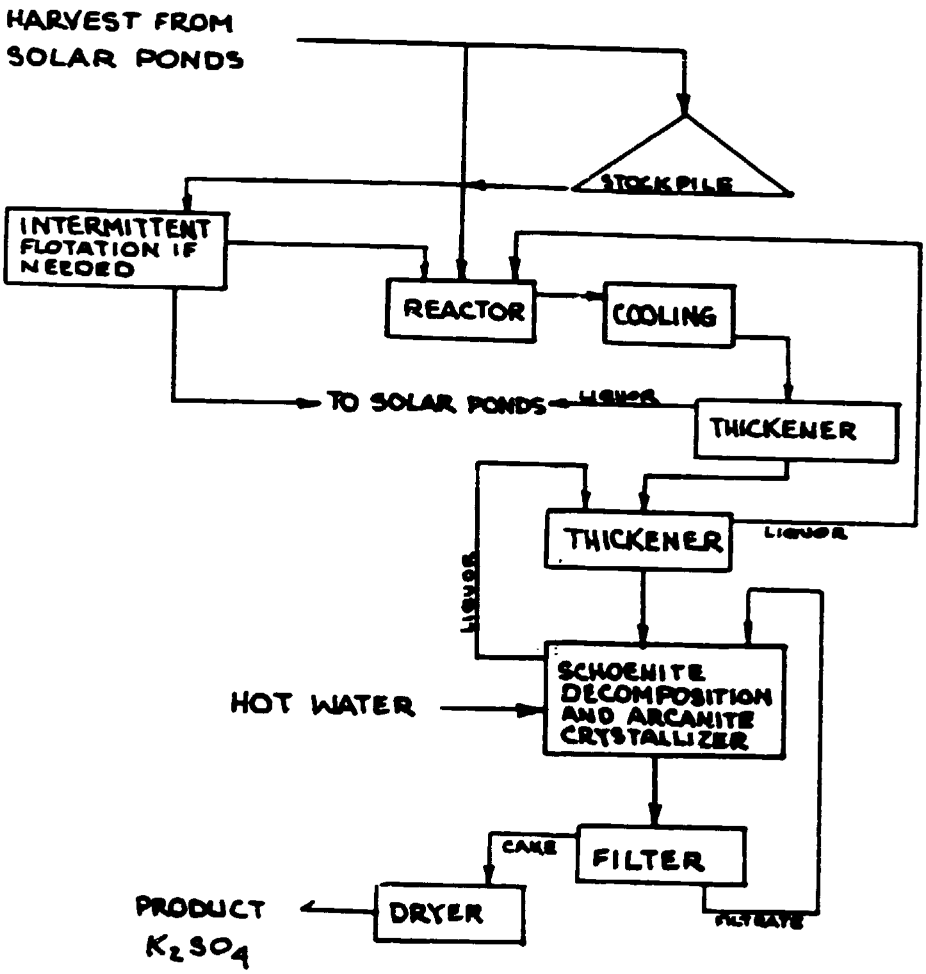
Figure 5 shows a flow chart of the process. The process is similar to the one at Pasquasia and Casteltermini in that salts are converted to schoenite and schoenite is decomposed into K_2SO_4.

This process has several advantages. One is that only water is added to the salt mixture. No other chemicals are used. This eliminates any ecology problems of toxic waste or expensive reagents.

It has one disadvantage in that the overall recovery is not high and this necessitates processing of the effluent brine to recover potassium. At GSL this is done with solar ponds. Effluent is flowed out into the ponds where water is evaporated and crystallized potassium salts are recovered, mixed with other harvested salts and process as already explained.

FIGURE 5

MIXED SALTS - WATER LEACH PROCESS



Occasionally salts are harvested having excess sodium chloride. The water leach process becomes less efficient with high sodium in feed salts. When this happens a side stream of salts is diverted into a flotation plant. These salts are converted to schoenite in reactor tanks and then schoenite and SO_4 salts are floated away from halite. These enriched salts are returned to the water leach plant and processed as normal.

The actual schoenite decomposition step in the crystallizer is the same as already explained and shown in Section 2.1.1.

At GSL up to 20,000 acres of solar ponds have been used to evaporate water from brines of the Great Salt Lake. Crystallized potassium salts from the solar ponds form feed stock to the plant. Plant effluent is also returned to solar ponds where all of the potassium is recovered and sent back to the plant the following year. Plant effluent is cooled before leaving the plant and some potassium is recovered in the form of schoenite.

2.2.6 Other Processes in the Mediterranean Area

GSL is familiar with operations in the Mediterranean area where research is underway to produce K_2SO_4. Tekel at the Camalti works in Turkey has already expanded its pond system and facilities to produce higher grade salt. They wish to produce K_2SO_4 as a by-product. In Egypt, at El Max Salines in Alexandria, evaluations of K_2SO_4 are underway, and in Tunisia, at Zarzis, a pilot plant has been operated.

Israel has been involved in research to produce K_2SO_4. The Arab Potash Company is also thinking of developing a chemical complex at their Dead Sea operation. Their plans include K_2SO_4 production.

Many have been interested in producing K_2SO_4 from ocean brines as a by-product from salt operations. This has been studied extensively, but to date no viable operation is now working. Several million of dollars were expended in research at Exportadora del Sal in Baja California to make K_2SO_4. The project was abandoned in 1976.

These studies and expenditures have not resulted in a single K_2SO_4 production facility and indicate that competition from these sources is not going to be a problem in the near future.

Possible future production of K_2SO_4 in Tunisia does not appear to be of serious consequence or a competitive threat in the Mediterranean. The plan for commercial operation has not been completed. If a plant is built, it would take five years from now to bring it to steady state production. The actual production is energy intensive and has several process steps that will make production costs high.

El Max Salines in Alexandria is quite serious about producing K_2SO_4. they have a unique operation but they are still in a pre-feasibility stage. GSL estimates that they will have high production costs if they decide to produce SOP. They also have a small reserve and at best they could not produce over 40,000 ton per year. Life of these reserves is only 10 years. Egypt will likely remain an importer of K_2SO_4 even if they do produce SOP because they are projecting uses of 100,000 ton per year in 1990. Presently all K_2SO_4 used by Egypt is imported.

The same is true for all Middle East and Mediterranean countries. Even if they produce their own K_2SO_4, they will likely consume more than they make and the projected consumption in the 1990's is increasing.

2.2.7 Salar de Atacama

The Salar de Atacama in Chili has a large reserve of potash. This reserve has not ben exploited except or lithium. Some attention is now being given to produce KCl, K_2SO_4, and boric acid. Amax Corporation has been investigating production of these salts.

The natural brines at the Salar are low in sulfate. Chloride is the controlling cation, but some K_2SO_4 can also be made. Costs will be high since the Salar is in a remote area without any infrastructure and 150 km from the sea. It will be many years before it will come on stream as a potash producer and when it does, it should not offer competition in the Mediterranean area.

2.2.8 China

China is scheduled to increase their production facility of KCl by an additional 200,000 ton in 1989. This production will come from the Qinghai Province. There are no sulfate in the brine at Qinghai. In 1995 they plan to increase production to one million ton and produce some K_2SO_4. this SOP must be produced with acid or gypsum. In any case, there will be little if any competition from the Chinese. Their source of potash is over 1,000 km from sea ports, production of sulfate of potash will be high and China will likely use all it makes.

APPENDIX TWO

LIST OF EVAPORITE MINERALS AND NOMENCLATURE

MARINE EVAPORITE MINERALS

COMMON NAME	FORMULA	MOLECULAR WEIGHT	% K	%Na	%Mg	%Ca	%Cl	$\%SO_4$	$\%H_2O$
Anhydrite	$CaSO_4$	136.14				29.44		70.56	
Arcanite (Sulfate of Potash)	K_2SO_4	174.25	44.88					55.12	
Astrakanite (Bloedite)	$Na_2SO_4 \cdot MgSO_4 \cdot 4H_2O$	334.46		13.75	7.27			57.44	21.54
Bischofite	$MgCl_2 \cdot 6H_2O$	203.30			11.95		34.88		53.17
Calcium Chloride	$CaCl_2$	110.99				36.11	63.89		
Carnallite	$KCl \cdot MgCl_2 \cdot 6H_2O$	277.85	14.07		8.75		38.28		38.90
Epsomite	$MgSO_4 \cdot 7H_2O$	246.47			9.86			38.97	51.17
Glaserite (Aphthitalite)	$3K_2SO_4 \cdot Na_2SO_4$	664.80	35.29	6.92				57.79	
Glauber's Salt	$Na_2SO_4 \cdot 10H_2O$	322.19		14.27				29.81	55.92
Halite	NaCl	58.44		39.34			60.66		
Hexahydrite	$MgSO_4 \cdot 6H_2O$	228.45			10.64			42.05	47.31
Kainite	$KCl \cdot MgSO_4 \cdot 3H_2O$	248.96	15.71		9.76		14.24	38.58	21.71
Kieserite	$MgSO_4 \cdot H_2O$	138.38			17.56			69.42	13.02
Langbeinite	$K_2SO_4 \cdot 2MgSO_4$	414.98	18.84		11.72			69.44	
Leonite	$K_2SO_4 \cdot MgSO_4 \cdot 4H_2O$	366.68	21.33		6.63			52.39	19.65
Loeweite	$Na_2SO_4 \cdot MgSO_4 \cdot 2.5H_2O$	307.44		14.95	7.91			62.49	14.65
Magnesium Chloride	$MgCl_2$	95.21			25.53		74.47		
Magnesium Sulfate	$MgSO_4$	120.35			20.19			79.81	
Polyhalite	$K_2SO_4 \cdot MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$	602.92	12.97		4.03	13.29		63.73	5.98
Salt Cake (Thenardite)	Na_2SO_4	142.04		32.37				67.63	
Schoenite (Picromerite)	$K_2SO_4 \cdot MgSO_4 \cdot 6H_2O$	402.71	19.42		6.04			47.70	26.84
Sylvite (Muriate of Potash)	KCl	74.55	52.44				47.56		
Syngenite	$K_2SO_4 \cdot CaSO_4 \cdot H_2O$	328.41	23.81			12.20		58.50	5.49
Vanthoffite	$3Na_2SO_4 \cdot MgSO_4$	546.47		25.24	4.45			70.31	

Atomic Weights*

K	39.0983
Na	22.98977
Mg	24.305
Ca	40.08
Cl	35.453
S	32.06
O	15.9994
H	1.0079

*Based on Sargent-Welch periodic chart - 1979

Molecular Weights

H_2O	18.0152
SO_4	96.0576

NOMENCLATURE

Activator — A chemical added to a flotation circuit that aids the collector in adhering to the mineral face.

Activity Coefficient — A factor used to convert concentration to activity to account for non-ideal solution behavior.

Ax bar — A bar with an ax head welded on the end of it for cleaning salt crystals off of weir logs. (See Figure A-1)

Backhoe — Heavy equipment with a bucket on an arm for digging (See Figure A-2)

Belly Dump Truck — A tractor trailer rig where the trailer is enclosed on all four sides and has gates on the bottom of the trailer for unloading (See Figure A-3)

Cleaner cells — Flotation cells to refloat froth concentrate from initial flotation cells. Generally used to enhance rejection of undesirable contaminents.

Collector — The primary reagent in a flotation circuit. Its usual function is to selectively coat the mineral to be floated with an organic film.

Common Ion Effect — Salt A and B are different salts with a common ion. If Salt A is added to a saturated solution of Salt B, Salt B will precipitate to maintain equilibrium.

Concentrate — The final product of a flotation circuit.

Conditioning of floors — The process of flooding a new pond with brine to displace all the subsurface waters in the pond with brine.

Conversion — The conversion of a salt, or a mixture of salts to a new mineralogy by reaction with a new brine. Often this entails temperature control to enhance the process.

Counter-current Decantation — A series of steps where a solid and liquid are mixed and then separated before the next mixing step. The solid and liquid move in opposite directions through the series of steps.

Cut-off Point — A term used in any operation to denote a point at which an operation is no longer viable.

Defrother — A chemical used to eliminate air bubbles from a process stream.

Depressent — A chemical added to a flotation circuit that suppresses the flotation of undesirable minerals.

Dike — A wall of earth that encloses a body of water or brine (See Figure A-4)

Dispersent — A chemical added to any circuit that causes fine particles to stay suspended in the liquor.

Dozer — A piece of heavy equipment that moves on tracks and has a vertical blade mounted on front for pushing material (See Figure A-5).

Dragline — A piece of equipment used to build dikes and canals. (See Figure A-9)

Dry Diagram — A phase diagram that does not show the water content on one of the axes.

Drying Up Point — The concentration of a brine at the point the pond dries up.

Efficiency — A measurement of the effectiveness of an operation. Different from recovery in that it measures variation from theoretcal recovery.

Encapsulation — The trapping of brine or impurities within a single salt crystal.

End Dump Truck (10 Wheeler) — A truck with the bed enclosed by four walls and the bed can be tipped to unload through a swing tail gate (See Figure A-6)

Entrainment — Brine trapped in the voids between salt crystals.

Entrainment Factor — The ratio of weight of brine to the weight of dry salt in a wet salt.

Equilibrium — A state where there is no further change in the system after time.

Equilibrium constant — (Solubility product) A salt has the chemical formula a_xb_y. The equilibrium constant for this salt in solution is the product a^xb^y.

Evaporation — The loss of water from a water or brine surface, usually measured in inches per day.

Evaporation Path — A plot of one brine component relative to another component to show how the concentration of the single component changes as the brine concentrates from evaporation.

Evaporite — A mineral produced by evaporation of a brine.

Extraneous Water — Water added to a process from unmetered or unmonitored sources such as pipe flushing.

Flocculent — A chemical added to any system that enhances settling of suspended solids.

Front end Loader — A piece of heavy equipment with a wide bucket on the front for scooping and loading material (Refer to Figure A-7)

Froth Paddles — Devices used in flotation to speed the flow of the froth from the flotation cells.

Froth Texture — The physical texture of a flotation froth.

Frother — A chemical added to a flotation circuit to aid recovery by helping to establish a good, workable froth.

Harvester — Heavy equipment that is used to recover a salt from solar ponds (See Figure A-8).

Harvest-to-product ratio(H/P) — The ratio of total feed tons to the product tons.

Heat of Crystallization The energy released when a salt crystallizes.

Insols Particles that are insoluble in water or the dissolving medium.

Interstitial Having to do with the voids between salt crystals in a deposit.

Inverse Lever Law When two solutions represented by two points on a phase diagram are mixed, the resulting solution lies on the line between the two points. The ratio of the lengths of the two segments is proportional to the ratio the amounts of each solution that were mixed.

Ion Exchange The exchange of ions in the brine with ions in subsurface brines and clays of the pond floor.

Ionic Concentration The total moles of ions in solution on a mono-valent basis per 1000 moles of water.

Janecke Phase Diagram A square shaped plot of equilibrium brine concentrations with reciprocal salt pairs at the ends of the diagonals.

Leakage Brine loss through porous pond floors and dikes, usually measured in inches per day.

Level Control A term used in a wide variety of operations to describe control of any vessel to exact levels to aid in controlling a process.

Mix Rule A line drawn between two points on a phase diagram represents the mixing of the two solutions represented by those points.

Mother Liquor The brine from which a particular salt was precipitated from.

Pan A metal evaporation pan used to measure evaporation rates (See Figure A-1).

Phase A part of a system that is uniform throughout in chemical compositon and physical properties.

Phase Rule (Gibbs) For systems in which pressure, temperature and concentration are the only variables, the number of degrees of freedom equals the number of components minus the number of phases plus two.

Pond A body of brine enclosed by dikes.

Quadruple Point The point on a phase diagram where four different salts are in equilibrium with a solution.

Reciprocal Salt Pair Two salts that have common anions (negative charged ions)

Recovery The percentage of the total amount of a desired material fed through a process that is recovered as product.

Regression A mathematical technique used to develop a relationship between experimental variables. Functions thus developed are called regression lines and are thought to represent the best fit of the experimental data.

Retention Time The time a process element will spend in a vessel or the volume of the vessel divided by the process stream flow rate.

Road Grader (Patrol, 16 Patrol) heavy equipment with a vertical blade between the front and rear wheels for leveling or piling up a windrow (See Figure A-10).

Rougher cells Primary flotation cells.

Salt 1. NaCl (Halite) or 2. Any evaporite mineral.

Saturated Solution A solution that has the maximum concentration of a specified component.

Scavanger cells Secondary flotation cells.

Scraper A self-loading piece of equipmnet used to transport material (See Figure A-11).

Settling Rate The rate at which solids will settle through a liquid.

Slimes Extremely fine insoluble material found in many processes, typically clays and shales.

Slurry The suspension of solids in liquid.

Soaking When ponds are flooded with brine, the surface and subsurface water will mix or exchange with the brine. A dry soil will soak up the brine until it is saturated.

Soils Index Number A measure of soil permeability.

Stacker An inclined conveyor belt on wheels used to stockpile salt (See Figure A-12).

Stoichiometric The conservation of atoms in a chemical reaction.

Tailings Material rejected by a flotation circuit.

Tipple A drive-over structure where belly dump trucks can unload (See Figure A-13).

Triangular Phase Diagram A triangular shaped plot of equilibrium brine concentrations for a 3 component system.

Triple Point The point on a phase diagram where three different salts are in equilibrium with a solution.

Tyler Mesh The number of openings per linear inch of screen.

Wear Any loss of metal or other materials to the combined effects of corrosion and abrasion.

Weir A wood structure that holds back brine or regulates the flow of brine over the structure. The structure is slotted so 4 inch by 4 inch wood logs can be added to or taken from the weir to raise or lower the pond level. (See Figure A-14).

Wet Diagram — A phase diagram that has water content indicated on one of the axes.

Windrow — A long, uniform pile of material.

APPENDIX THREE

HOW TO BRAINSTORM

BRAINSTORMING

Brainstorming is a method of group thinking that produces many ideas fast. Such ideas are needed in overall solar pond design because there are so many variables and alternatives in solar pond lagout, operation and design.

Brainstorming is ineffective if done improperly. Care should be taken when people get together for a "Brainstorming Session". Each brainstorming session should be organized with a Chairman, Recorder and participants. The session should brainstorm one subject at a time and each session must have the following rules.

1. No criticism. The session is open to ideas. Each idea is listed on a blackboard or written on a paper. Beware of killer phrases such as "It won't work"; "We don't have time"; "We've tried that"; "We've never done it that way before".

2. No judging. A permissive atmosphere must exist. All ideas are accepted without any judgement. This allows for complete thinking and allows for the bad ideas to be mentioned and recorded. Often, the bad ideas turn out to be the best ones.

3. Quantity. The more people, the better. The greater the number of ideas, the greater the the probability of good ones.

4. Evaluation. After all of the ideas are listed, they must be evaluated. Related ideas are combined. The validity of the ideas are then proven and the poor ideas are eliminated. Often the evaluation is done with all participants remaining, but many times it is done with only the key project engineer who may call in others later to help evaluate the ideas.

5. Processing. Once the better ideas are chosen, they must be developed or processed into a design.

The chairman see that the rules are followed. No criticism and no judging will be permitted until the evaluation and processing step is reached.

Brainstorming is an effective engineering tool, especially in various phases of solar pond design and problem solving.

APPENDIX FOUR

PAPER ON MAGNESIUM COMPOUNDS

MAGNESIUM NITRITE. **Magnesium nitrite,** $Mg(NO_2)_2$, is a white powder which crystallizes from saturated solutions in the form of the three hydrates: $Mg(NO_2)_2.9H_2O$ (−21.15 to 10.5°C), $Mg(NO_2)_2.6H_2O$ (10.5 to 29.5°C), and $Mg(NO_2)_2.3H_2O$ (above 29.5°C). Its solubility is 51.58 g $Mg(NO_2)_2$/100 g soln at 29.5°C, 38.6 g at 10.5°C, and 23.2 g at −21.15°C. The solutions as well as the crystallized hydrates decompose readily on heating, with evolution of nitrogen oxides. The hydrates can be prepared by dissolving magnesium amalgam in nitrous acid (obtained by absorption of nitrogen sesquioxide N_2O_3 in ice water) at a temperature below −5°C. The solution is evaporated under vacuum within the desired temperature range. An alcohol solution of $Mg(NO_2)_2$ can be prepared by adding alcohol to a stoichiometric mixture of finely pulverized $MgSO_4.7H_2O$ and sodium nitrite, and stirring and filtering. The hydrated salts are deliquescent and decompose even on standing in closed containers.

Magnesium nitrite is formed when nitrogen oxides are absorbed by solid $Mg(OH)_2$ at 25–35°C (1). Magnesium nitrate is formed at the same time and the salts are separated from $Mg(OH)_2$ by aqueous leaching. Although it has been tested as an additive to reduce the corrosion rate of porous concrete reinforcement (2), it has little industrial importance.

Bibliography for Magnesium Nitrite

1. E. N. Pesov, *Tr. Novocherk. Politekhn. Inst.* **121,** 57 (1961).
2. O. I. Dovalsk, S. G. Fusherbova, and V. B. Ratinov, *Sb. Tr. Gos. Vses. Nauchn. Issled. Inst. Zhelezobetonnykh Izdelii Stroit. i Nerudn. Materialov* 1962, 124; *Chem. Abstr.* **59,** 3646c (1963).

MAGNESIUM OXIDE AND HYDROXIDE. **Magnesium oxide** (magnesia), MgO, occurs infrequently in nature as the mineral periclase. Magnesium oxide is also the end product of the thermal decomposition of numerous magnesium compounds. Physical properties of purified magnesium oxide are listed in Table 1.

Table 1. Physical Properties of Magnesium Oxide

Property	Value
crystal form	fcc
lattice parameter, Å	a = 4.20
color	colorless
index of refraction	1.736
density, g/cm³ (x ray)	3.58
hardness, Mohs	5.5 to 6
melting point, °C	2800
boiling point, °C	est. 3600
thermal conductivity, cal/(sec)(cm²)(°C/cm),	
at 100°C	0.086
electrical resistivity, ohm-cm	
at 850°C	2 × 10^[illegible]
990°C	3 × 10^[illegible]
2100°C	4.5 × 10^[illegible]
heat of fusion, at 2642°C, cal/mole	18,500
heat capacity (T = °K), cal/(deg)(mole)	10.86 + 0.001197T − 208700 T^2 (temp range 273–2073°K)
solubility in water, g/100 ml	0.0086, 30°
	0.0062, 80°

The physical properties of commercial magnesium oxides vary greatly with the nature of the initial material, time and temperature of decomposition, and trace impurities. Many commercial oxides show surprisingly stable pseudostructures derived from the starting materials, although all primary particles have an fcc crystal structure. The specific gravity of magnesium oxides obtained by crystallization after fusion is in fair agreement with the value of 3.58 calculated from x-ray data. However, specific gravity determinations on MgO obtained by calcination of precipitated $Mg(OH)_2$ at different temperatures have yielded the following figures:

temperature, °C	600	710	850	1000	1200	1400	1700	1900
specific gravity	2.94	3.04	3.22	3.39	3.48	3.52	3.56	3.57

The chemical properties of magnesium oxide vary considerably with the temperature and time of calcination of the initial material. The increase in density resulting from increasing calcination temperature is paralleled by a decrease in reactivity. MgO prepared in the temperature range from 400 to 900°C (from magnesium hydroxide or basic magnesium carbonate) is readily soluble in dilute acids and hydrates rapidly even in cold water.

Fused magnesium oxides are virtually insoluble in concentrated acids and are indifferent to water unless very finely pulverized. The oxides prepared below 900°C, which are easily hydrated with water, are known as *caustic-burned magnesias*. The unreactive magnesias, prepared at higher temperatures, are called *dead-burned* or *sinter magnesias*. The hydration rate of various magnesium oxides is determined by the active surface area, and may vary from a few hours in the case of the reactive oxides obtained at low temperatures to months or even years for the dead-burned grades. The heat of formation of MgO is −143.84 kcal/mole at 25°C. The highly reflective power of magnesium oxide in the visible spectrum has led to its use as a white color standard. Magnesium oxide is a poor electric conductor at low temperature, but conductivity increases rapidly with rising temperatures (see Table 1).

The hydration of reactive grades of magnesium oxide leads to the formation of **magnesium hydroxide,** $Mg(OH)_2$. The physical properties of purified magnesium hydroxide are given in Table 2. Magnesium hydroxide crystallizes in the form of uniaxial hexagonal platelets. Even the apparent gelatinous magnesium hydroxide obtained by precipitation from magnesium salt solutions with alkalies show the same x-ray diffraction pattern as the coarse crystalline varieties.

Table 2. Physical Properties of Magnesium Hydroxide

Property	Value
crystal form	trigonal
lattice parameter, Å	a = 3.11
color	colorless
index of refraction	1.559, 1.580
density	2.38
hardness, Mohs	2.5
melting point, °C	decomp 350°C
solubility in water, g/100 ml H_2O	
at 18°C	0.0009
100°C	0.004

Thermal decomposition of magnesium hydroxide begins above 350°C, although much higher temperatures are required to remove the last traces of water. Both magnesium oxide and hydroxide absorb moisture and carbon dioxide from the air. Reactive grades of MgO and $Mg(OH)_2$ are gradually converted into the basic carbonate $5MgO.4CO_2.xH_2O$ on sufficiently long exposure to the atmosphere.

Magnesium hydroxide is found in nature as the mineral brucite, usually together with periclase (MgO) of which it is a hydration product, or in the form of occlusions in deposits of serpentine ($3MgO.2SiO_2.2H_2O$), magnesite ($MgCO_3$), or dolomite ($CaCO_3.MgCO_3$).

Manufacture

Magnesium oxide is produced by calcination of magnesium carbonates or magnesium hydroxide. It can also be produced economically by decomposition of magnesium chloride or magnesium sulfate. Magnesium oxide is produced in a number of different grades designed for various specific uses. Dead-burned magnesite or sinter-magnesia is a dense highly refractory product used almost exclusively in the manufacture of basic refractory bricks. Pure magnesium oxide has a sintering temperature of above 2800°C. The use of additives, such as alumina, silica, calcium oxide, or especially iron oxides, lowers the sintering temperature considerably (1–3). Most natural magnesites contain sufficient quantities of impurities to yield a dead-burned or fluxed product at calcining temperatures of about 1400°C. Relatively pure grades of magnesium hydroxide obtained by precipitation from seawater require the addition of ferric oxide (in amounts of from 2 to 7%) or of other additives in order to permit fluxing and recrystallization at the maximum temperatures of an oil- or gas-fired rotary kiln (1900°C).

The rotary kilns used in calcining magnesite and dolomite to produce refractory grade products are large kilns ranging in size of 6 to 11 ft in diam and up to 400 ft in length. The kilns are lined with magnesite or magnesite-chrome brick. The conditions of the calcination process can be closely controlled in these kilns by adjustments in the speed of rotation, inclination of the tube, and feed rate. Thermal efficiency can be increased by preheating the feed material with the exhaust gases. The kilns are countercurrent and the maximum temperature is reached near the discharge end. If the stack gases contain entrapped particles of feed material the gas is air-quenched to about 300°C, and the entrapped dust is removed by electrostatic precipitators (1). The recovered dust can be sold for soil conditioner or for various fillers.

Caustic-burned magnesias are produced by calcining magnesite, dolomite, or magnesium hydroxide at temperatures lower than 900°C. The caustic-burned materials are reactive and can be used for the preparation of magnesium chloride (by chlorination in the presence of carbon), oxychloride cements, decolorizing agents, and other processes requiring a reactive magnesia.

Temperatures required for rapid decomposition of magnesite are between 600 and 700°C. Dolomite decomposes rapidly at temperatures between 700 and 900°C. Some dolomites behave like mechanical mixtures of magnesite and calcite with a very sharp and extended break in the decomposition curve, while others behave like true double compounds, have a far less-pronounced break in the decomposition curve, and cover only a narrow range of temperature. Stepwise decomposition of dolomites, especially the first type, makes possible a "selective calcination" in which only the

magnesium carbonate is decomposed to oxide and the calcium carbonate is virtually untouched. Optimum conditions for selective calcination have to be determined for each type of dolomite. Generally, a maximum temperature of 800°C is adequate for decomposition of nearly all of the magnesium carbonate. (Pure calcium carbonate begins decomposition at 825°C and pure magnesium carbonate begins to decompose at 350°C.) In some cases, satisfactory separation of the two components of the partially or selectively calcined dolomites can be made by mechanical means, such as screening, air separation, or hydraulic classification. Internally fired rotary kilns are not satisfactory for closely controlled calcinations at low temperatures as the surface temperatures reached in the firing zone exceed 900°C, the temperature at which $CaCO_3$ begins to decompose. Externally heated rotary kilns or ore-roasting furnaces can be used.

Magnesium oxide can be produced from magnesium chloride or sulfate with simultaneous recovery of the acid components. Magnesium chloride can be completely decomposed in a temperature range between 1400 and 1700°C. Magnesium sulfate is generally decomposed in a reducing atmosphere such as S, H_2S, H_2, or CO. Magnesium sulfate decomposes at a temperature from 1100 to 1200°C. A process to recover MgO and HCl from potash waste brines was used from 1953 to 1961 by International Minerals & Chemical Corporation at their Carlsbad, New Mexico, plant (4,5). The products of the process were industrial refractory and electrical refractory grades of magnesia, and 30% hydrochloric acid. The use of potash waste brines to prepare $MgCl_2.6H_2O$ flake to be used in the decomposition step requires an initial step to remove the bulk of the K, Na, and SO_4 ions. The step used at Carlsbad was a precipitation of KCl, NaCl, and $KCl.MgSO_4.3H_2O$ (kainite) from the brine by a complex evaporation and recycling process. Another purification process, which was patented, but not used at Carlsbad, was the removal of sulfate ion by precipitation as gypsum by the addition of calcium chloride solution to the feed brine (6). The relatively pure $MgCl_2$ solution was concentrated to 30.5% $MgCl_2$ in boiling kettles (final temperature 182°C). The $MgCl_2$ was then flaked to $MgCl_2.6H_2O$ by cooling on rotary drum flakers. The $MgCl_2.6H_2O$ was partially dehydrated in a Roto-Louvre dryer at a final temperature of about 150°C. The product from this dryer contained 62–64% $MgCl_2$. Decomposition to MgO and HCl occurred in a standard 7 × 70 ft rotary kiln.

The final temperature in the decomposition kiln was about 540°C. The solids discharged from the decomposition kiln contained about 80% MgO, 12% $MgSO_4$, 2.5% NaCl, 2.5% KCl, and 0–2.5% residual $MgCl_2$. A peculiar characteristic of the magnesium oxide obtained in the decomposition step was the lack of chemical reactivity compared to products obtained by calcination of magnesium hydroxide or carbonate. This was true in spite of the low decomposition temperature (510–540°C). Physically, the product showed no significant change when heated in the temperature range between 540 and 1050°C. The residual impurities, NaCl, KCl, and $MgSO_4$, were removed and a synthetic periclase was formed by mixing the impure MgO from the decomposition kiln with carbonaceous material (carbon black or fuel oil) in pellet form and firing the mixture at a temperature of about 1650°C. Virtually no densification or sintering of the formed pellets occurred in the flame zone of the high-temperature periclase kiln unless fairly large quantities of other refractory oxides were added to the kiln feed. The impurities were removed in the high temperature kiln by volatilization of the chlorides and decomposition of the sulfate compounds (7).

The Aluminum Company of Canada has developed a process (8) in which magnesium oxide may be recovered from ground dolomite or brucite ores. The ground ore is leached with a mixture of carbon dioxide and sulfur dioxide.

The addition of CO_2 to the leaching step increases the leaching reaction rate, improves the recovery of MgO from 55% to more than 92%, and keeps the parallel solution of calcium to less than 3% in the magnesium solution. The resulting magnesium bisulfite solution can be treated by precipitation and calcining to recover magnesium oxide.

Highly reactive grades of magnesium oxide used in the rubber and pharmaceutical industries are prepared from basic magnesium carbonate or magnesium hydroxide in small, externally heated rotary kilns. The feed and temperature conditions are controlled to produce a magnesium oxide containing between 5 and 15% residual moisture and carbon dioxide.

Magnesium hydroxide can be produced by precipitation from solutions of magnesium salts or by slaking a reactive magnesium oxide. The most important commercial method is the precipitation of $Mg(OH)_2$ from seawater and brines (2). In the earlier attempts to produce $Mg(OH)_2$ directly from seawater, clarified limewater was used as a precipitant, but it was soon recognized that equally satisfactory products could be obtained by precipitating with much more concentrated lime slurries or even dry pulverized lime or calcined dolomite. Calcined dolomite reacts with the $MgCl_2$ in seawater as

$$CaO \cdot MgO + MgCl_2 + 2\,H_2O \rightarrow 2\,Mg(OH)_2 + CaCl_2$$

thus increasing the yield of magnesium hydroxide from a given volume of seawater or brine.

Seawater and most brines contain certain amounts of dissolved and suspended solid impurities. These impurities must be removed by a pretreatment (2). The removal of impurities is accomplished by precipitating a portion of the magnesium contained in the raw feed solution with calcium oxide or hydroxide. This pre-precipitate occludes calcium carbonate, silica, ferric oxide, and other impurities and is removed as a sludge after sedimentation in a thickener. The main precipitation is then accomplished by mixing the clarified brine or seawater with the calculated amount of calcium hydroxide and concentrating the precipitated magnesium hydroxide in large settling tanks or thickeners. The low concentration of magnesium in seawater (about 2.2 g MgO/liter) requires that very large volumes of liquid be processed; therefore, the thickening equipment is very large. Thickeners with diameters on the order of 250 ft are used in modern plants. The concentrated slurry underflow from the thickeners contains about 10–15% magnesium hydroxide. The removal of residual soluble impurities is accomplished by countercurrent washing with fresh water in thickeners as large as the original sedimentation tanks. The purified underflow from the wash step is filtered on large (14 ft diam × 18 ft long) rotary vacuum filters. The filter cake is from 25 to 50% $Mg(OH)_2$. Kaiser Refractories sells a small portion of the filter cake to the paper industry (2). The filter cake can be dried or calcined directly. A pharmaceutical grade of $Mg(OH)_2$ can be obtained by spray-drying the washed slurry.

The precipitation of $Mg(OH)_2$ from seawater using calcium carbide (CaC_2) has been studied (9). Acetylene is produced by this method according to the reaction

$$MgCl_2 + H_2O + CaC_2 \rightarrow CH{\equiv}CH + CaCl_2(aq) + Mg(OH)_2$$

One of the basic problems in the precipitation of magnesium hydroxide from seawater or brines on a larger scale has been the low settling and filtration rate of the product. Extensive development work has been done for the purpose of obtaining more rapidly settling and more readily filterable precipitates. A quicker settling and easier filtering precipitate reduces capital expenditure and operating costs. A reduction in the reactivity of the precipitant (lime or calcined dolomite) by control of the slaking conditions and burning temperatures, or by the addition of unslaked lime or dolomite to the cold brine, generally results in the formation of precipitates with better settling characteristics (10,11). Recirculation of a portion of the precipitated slurry into the precipitation zone (12) or the continuous addition of flocculating agents also improves settling rates of the magnesium hydroxide. The addition of small amounts of aldehydes to the brine has been found useful to give a better settling precipitate (13). In most cases the improvement in the settling characteristics takes place at the expense of purity of the final product, because of contamination with adsorbed flocculants or occlusion of residual unreactive lime.

A method to produce more readily filterable magnesium hydroxide by precipitating with an excess of $Ca(OH)_2$ present for at least 2 hr at a temperature of 40–80°C has been patented (14). In this process water washing of the filter cake produces a magnesium hydroxide of high bulk density and high purity.

Economic Aspects; Specifications; Analysis

The U.S. production figures for magnesias and magnesium hydroxide for 1959 through 1963 are given in Table 3 (15).

Table 3. U.S. Production of Magnesias and Magnesium Hydroxide for 1959–1963, short tons

	1959	1960	1961	1962	1963
magnesia					
caustic-burned	54,093	66,055	80,072	86,800	134,877
refractory	517,941	505,011	506,968	575,723	712,734
dead-burned dolomite	1,087,707	1,040,260	1,082,750	1,857,438	1,949,053
specified magnesias,					
100% MgO basis					
extra light and light	1,831	2,421	2,351	2,440	3,500
heavy	20,133	21,765	22,963	17,400	3,782
magnesium hydroxide					
USP and technical,					
100% $Mg(OH)_2$ basis	208,406	309,015	382,100	357,507	430,800

The prices quoted in February 1966 for various grades of magnesia were (16) calcined, technical, medium light bags, freight-equalized, 25.75 to 26.5¢/lb; technical, synthetic, rubber grade, light bags, carload lots, freight-equalized, 28.75 to 30¢/lb; calcined technical, synthetic, rubber grade, extra light bags, carload lots 28¢/lb; calcined, technical, heavy, fob Luning, Nevada, carload lots in bags, $53/short tons for 90%, $56/short tons for 93%, and $61/short tons for 95%; USP XVII light bags, 39.5¢/lb and USP XVII heavy bags, 40¢/lb. The price quoted for NF XII powdered magnesium hydroxide in drums, 300 lb or more, fob works, was 24.5 to 25.5¢/lb.

The analytical methods used for magnesium oxides are basically the same as those listed for magnesium carbonates. The specifications for USP grades of magnesium oxide call for a maximum of 1.5% calcium oxide, 10% loss on ignition, 2% alkali and soluble salts, 0.1% acid insoluble substances, 0.05% iron, 0.004% heavy metals, and 0.00025% arsenic. Specifications of refractory-grade magnesias made by different U.S. producers vary but a typical analysis is MgO, 98%; SiO_2, 0.4%; Al_2O_3, 0.15%; CaO, 1.0%; Fe_2O_3, 0.25%; and bulk density 100 lb/ft^3. The USP assay method is based on the solution of an ignited sample of magnesium oxide in 1N sulfuric acid and back titration with 1N sodium hydroxide. This value is corrected for CaO, which is determined separately by the oxalate method. When larger amounts of impurities are present, an accurate determination of SiO_2 (by evaporation with hydrochloric acid and volatilization with hydrofluoric acid), Fe_2O_3 and Al_2O_3 (as hydroxides with ammonia, double precipitation), and of SO_4^{2-} (as $BaSO_4$) is necessary, with precipitation of the magnesium as $MgNH_4PO_4$ and subsequent ignition.

Uses

The most important applications of magnesium oxide are in the manufacture of refractories, magnesium metal, and oxychloride cements. Impure grades are also used as components in mixed fertilizers, with magnesium as fifth in the series of elements required for plant nutrition and an essential ingredient for the formation of chlorophyll.

An electrically fused grade of pure magnesium oxide is used in the manufacture of high-temperature crucibles, and a fused pulverized oxide finds extensive application in the manufacture of heating elements for electric ranges. Purified magnesium oxide is the starting material in the preparation of numerous magnesium salts and other compounds. Considerable amounts are consumed by the drycleaning industry as decolorizing agents for solvents. The reactive grades of the oxide find use as neutralizing agents and vulcanization accelerators in the compounding of neoprene and other rubbers. Magnesium oxide is used as an absorbent and catalyst in the carbonate leach circuit for the recovery of uranium oxide from uranium ores. Numerous catalytic compositions used in the preparation of organic compounds contain magnesium oxide. It is also an ingredient of various pharmaceutical and cosmetic formulations, such as dentifrices and powders. Magnesium oxide, USP XVII, is used medicinally like the hydroxide and carbonate. The principal uses of magnesium hydroxide are in medicine, as an antacid and laxative, primarily in the form of the aqueous suspension known as milk of magnesia, USP XVII. Much of the latter is prepared by dilution of a 30% paste of magnesium hydroxide, which is obtained by vacuum filtration of a washed seawater precipitate. Milk of magnesia is also produced by precipitating $Mg(OH)_2$ from a solution of magnesium sulfate with caustic soda. A medicinal grade of dried magnesium hydroxide is used in tablet formulations for the same purpose.

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8. *Chem. Week* **90**, No. 26, 40 (June 30, 1962).
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16. *Oil, Paint Drug Rept.* **189** (Feb. 28, 1966).

MAGNESIUM PHOSPHATE. See Phosphoric acids and phosphates.

MAGNESIUM SULFATE. **Magnesium sulfate**, $MgSO_4$, cannot be obtained from solution, but only from dehydration of one of the hydrates. The best known hydrates of $MgSO_4$ are the monohydrate, $MgSO_4.H_2O$, which occurs in nature as the mineral kieserite, and the heptahydrate, $MgSO_4.7H_2O$ (epsom salt), which occurs in nature as the mineral epsomite. Physical properties of anhydrous magnesium sulfate and the mono and heptahydrates are listed in Table 1.

Table 1. Physical Properties of Magnesium Sulfate and the Mono- and Heptahydrates

Property	Anhydrous magnesium sulfate	Monohydrated magnesium sulfate	Heptahydrated magnesium sulfate
crystal form		monoclinic	rhombic (monoclinic)
color	colorless	colorless	colorless
index of refraction		1.523, 1.535, 1.586	1.433, 1.455, 1.461
density	2.66	2.517 (2.57)	1.636 (1.68)
melting point, °C	1124 decomp		$-6H_2O$ at 150° $-7H_2O$ at 200°
boiling point, °C	decomp		
hardness, Mohs		3.0–3.5	2.0–2.5
heat of fusion, cal/mole	3500 at 1127°C		
heat capacity, cal/(deg)(mole)	26.7 (296–372°K)	31 (282°K)	89 (291–310°K)
solubility in water, g/100 ml H_2O	26°, 73.8^{100}	68.4^{100}	71^0, 91^{40}

Magnesium sulfate heptahydrate exists in a stable rhombic (I), and in an unstable monoclinic (II) form. The rhombic form is the stable phase in aqueous solutions at normal temperatures. The unstable monoclinic form crystallizes below 21°C under certain conditions.

Solubility relations in the $MgSO_4$–H_2O system are very complex due to numerous metastable phases and slow equilibrium adjustments. Van't Hoff (1) and D'Ans (2) have compiled the most reliable data. The various hydrates of magnesium sulfate tend to form supercooled solutions and metastable solid phases and several hydrates may coexist in apparent equilibrium with the aqueous solution at various temperatures. Numerous old references are without value, particularly those that do not

APPENDIX FIVE

PRIMARY VENDORS IN THE U.S. POTASH INDUSTRY

TABLE I

Primary Vendors to the U.S. Potash Industry

Item	Vendor	Address	Telephone
Ball and Rod Mills	Allis-Chalmers	P.O. Box 2219 Appleton, Wisconsin 54913	414-734-9831
	Denver Equipment Div. Joy Manufacturing	P.O. Box 340 Denver, Colorado 80903	303-471-3443
Crushers	Allis-Chalmers	P.O. Box 2219 Appleton, Wisconsin 54913	414-734-3443
	Stedman Machine Company	500 Indiana Avenue Aurora, Indiana 47001	812-926-0038
	Pennsylvania Crusher	Box 100 Broomall, PA 19008	215-544-7200
Crystallization Equipment	Swenson	15700 Lathrop Avenue Harvey, Illinois 60426	312-331-5500
	HPD, Inc.	1717 North Naper Blvd. Naperville, Illinois 60540	312-357-7330
Dryers	Allis-Chalmers	P.O. Box 2219 Appleton, Wisconsin 54913	414-734-9831
	Louisville Drying	232 East Main Louisville, Kentucky 40202	502-583-7646
	Renneburg	2639 Boston Street Baltimore, Maryland 21224	301-732-1665

TABLE I (continued)

Item	Vendor	Address	Telephone
Filtration Equipment	EIMCO Process Equipment	P.O. Box 300 Salt Lake City, Utah 84110	801-526-2000
	Dorr-Oliver	77 Havemeyer Lane Stamford, Connecticut 06904	203-358-3200
	Denver Equipment	P.O. Box 340 Denver, Colorado 80903	303-471-3443
Flotation Equipment	Denver Equipment	P.O. Box 340 Denver, Colorado 80903	303-471-3443
	Wemco	P.O. Box 15619 Sacramento, California 95852	916-929-9363
Flotation Reagents	Sherex Chemical Co.	P.O. Box 646 Dublin, Ohio 43017	614-764-6659
	Armak	8401 West 47th Street McCook, Illinois 60525	312-442-7100
	American Cyanamid	Wayne, New Jersey 07470	201-831-3197
Pumps	Allis Chalmers	P.O. Box 512 Milwaukee, Wisconsin 53201	414-734-9831
	Gorman-Rupp	P.O. Box 1217 Mansfield, Ohio 44901	419-886-3001
	Denver Equipment	P.O. Box 15619 Denver, Colorado 80903	303-471-3443

TABLE I (continued)

Item	Vendor	Address	Telephone
Screens	C-E Tyler	8200 Tyler Blvd. Mentor, Ohio 44060	216-255-9131
	Rotex	1257 Knowlton Street Cincinnati, Ohio 45223	513-541-1236
	Sweco, Inc.	P.O. Box 4151 Los Angeles, California 90051	213-726-1177
Technical Consulting	Great Salt Lake Minerals & Chemicals Corporation	P.O. Box 1190 Ogden, Utah 84402	801-731-3100
Testing Facilities	International Fertilizer Development Center (IFDC)	Muscle Shoals, Alabama 35660	205-386-2593
	United States Bureau of Mines, Salt Lake Research Center	729 Arapeen Drive Salt Lake City, Utah 84113	801-524-5350

Final Report
Part Two
Optimization of El Mex Salines Solar Ponds and By-Product Investigation

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Volume in drive A has no label
Directory of  A:\

ELMEX    DAT       336   3-08-90   9:38a
BORGBASE DAT      1099   3-08-90  11:30a
ELMEXMOD EXE     32768  11-15-89  12:08p
ELMEXMOD BAK     54782  11-15-89  12:23p
TWO-POND DAT      1070   3-07-90   1:05p
TWO-POND         36229   3-07-90   1:10p
TWO-POND END       704   3-07-90   1:11p
BORGBASE         58807   3-08-90  11:35a
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NO-RCYL  END       627   3-08-90   9:27a
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ELMEX    END       625   3-08-90   9:40a
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ELMEXED  COM     61180   1-18-89   9:17a
ELMEXMOD PAS     54782  12-18-89   8:10a
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18752 (2 of 2)

Final Report
Part Two
Optimization of El Mex
Salines Solar Ponds and
By-Product Investigation
UNIDO Project DP/EGY/87/017
February 1990

By GSL Consulting Engineer
David Butts
Chad McCleary

ABSTRACT:

This report is Part Two of a final report authorized by the United Nations Industrial Development Organization (UNIDO). This report is a technical evaluation of El Mex Pond System. A computer program and operating disk is included.

REFERENCES

The following reports and books have been written as part of this study.

Name	No. of Pages
1. Report of First Mission to El Mex Salines. Fact Finding. Test Procedures and Complete Analytical Analysis Instruction. January 1988, David Butts and J.C. McLaughlin.	154
2. Work Book Problems for use with Hewlett Packard Advanced Scientific Calculator 28S. April 1988, Chad McCleary and David Butts.	50
3. Lecture and Training Series on Solar Ponding. Prepared for El Nasr Salines Company, Alexandria, Egypt. March, 1988, Chad McCleary and David Butts.	114
4. First test on the Concentration of El Mex Pond Brine. April 1988, David Butts, Chad McCleary.	40
5. Report on Second Mission to El Mex Salines, May 1 to May 20, 1988. Training and Establishing of Data Base. June, 1988, David Butts and Chad McCleary.	22
6. Concentration Path of El Mex Brine and Ocean Brine. September 1988, David Butts.	59
7. Brine Evaporation at El Mex Salines. November 1988, David Butts.	67
8. Draft Report, Optimization of El Mex Salines Solar Ponds and By-Product Investigation. December 1988, David Butts and Chad McCleary.	40
9. Final Report, Part One, Optimization of El Mex Salines Solar Ponds and By-Product Investigation. April 1989, David Butts and Chad McCleary.	57

SUMMARY

This final report includes a disk that can be used to run pond operations seminars for Port Said, El Mex Salines, and Borg El Arab. It will require someone familiar with personal computers, disk operating systems (DOS), and solar ponds. If special training is needed, GSL can supply training. Training time will take only two days.

GSL has already made many runs and conclusions are basically the same as reported earlier. These conclusions are summarized once again:

1. Stop recycle of bittern at El Mex Salines (this has already been done in 1989).

2. Establish better weather data and evaporation rates. Correlate this data with actual production rates and then use the data to optimize ponds at El Mex and Borg El Arab. (Again, this has been started in 1988, but correlation to production rates was never made.)

3. Establish a brine profile as a function of evaporation. (This was done at GSL, see report Reference 6.)

4. Plenty of bittern brine is produced at El Mex to supply magnesium for production of MgO. GSL is not an expert in MgO and therefore some name references were given. Since then, a company who has made MgO from sea bittern has been located. They have been contacted and said they would be willing to supply technology. They are:

Mr. M. Hariharaswamy, Senior Superintendent
Tata Chemicals
Mithapur-361 345
Jamnagar Dist.
Gujarat State, India

Telex: 116427 (Head office, Bombay)
Telephone: 204 9131 (Head office)

5. GSL does not recommend K_2SO_4 by-product production at the present time. There are two main reasons:

a. Evaporation of highly concentrated brine appears marginal and more study is needed in this area.

b. There are not very large reserves of potassium and production of K_2SO_4 could not be sustained for over ten years.

6. Proper sequencing of brine at all three salt works will increase quality of salt. This is especially true at El Mex Salines where production of 99.5 salt (dry basis) should be possible just as it is done at many similar salt works in the world. Recommendations for the brine sequence has been given in previous reports.

7. The computer program can be used to aid in long range planning and operation at El Mex and Borg El Arab. We suggest two or three engineers be

assigned to learn how to use it to better understand and operate their solar pond systems.

I. INTRODUCTION

In 1987, GSL consultant David Butts visited El Mex Salines in Alexandria, to observe their pond system and make comments concerning possible by-product production of K_2SO_4, $MgCl_2$, and MgO.

It was evident that changes could be made that would increase production of NaCl and also improve grade and quality. It was not possible to determine by-product production capabilities because data was lacking. GSL proposed that tests be made to obtain the data. Specifically, evaporative rates and brine chemistry as a function of evaporation in high concentration ranges was needed.

Approval for the tests was made and funded by the United Nations Development Program (UNDP) through the International Center in Vienna. The supervising agency would be UNIDO, Project DP/EGY/87/017. In January of 1988, work was begun.

Since then, nine reports have been written. Lectures and training of El Mex personnel have been conducted and extensive bench test work at Great Salt Lake Minerals & Chemicals Corporation (GSL) have been completed.

A final report is written in two parts. Part One was completed in April of 1989 and hand delivered to El Mex Salines, El Nasr Salines and Mining and Refractory Industrial Corporation personnel in Cairo and Alexandria. In this report, it was suggested that formation of K_2SO_4 mixed salts and other by-product salts did not look promising. Formation of MgO via lime addition (or dolomite) did have promise. The report also made suggestions how sodium chloride production could be increased. It was also reported that salt quality and quantity could be increased with a change of brine management.

Part Two of the final report is shown herein. GSL has requested that actual production rate of NaCl be supplied so that the data could be used as a base. Also, that all evaporation data up to date be submitted to GSL. As of now, this data has not been received and so the report is submitted without it.

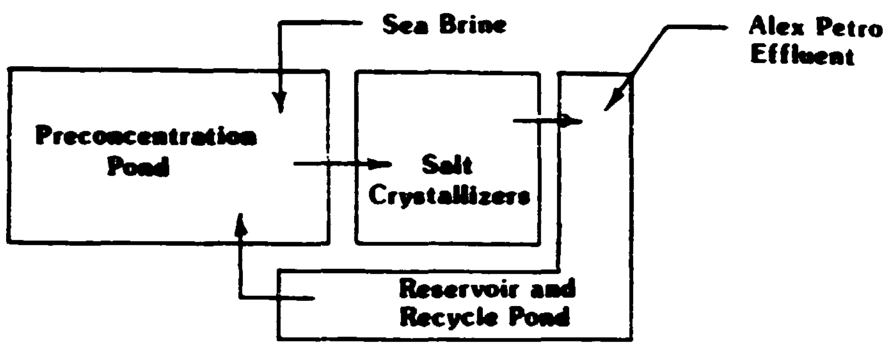
The main emphasis of this report is pond modeling, computer use to optimize ponds, and comments pertaining to both El Mex Salines and Borg el Arab solar pond system.

II. DISCUSSION

All of the following discussions and examples are based on a computer model as illustrated in the Appendix of this report. The actual program is also on a disk and can be executed on an IBM or compatible personal computer by entering the name ELMEXMOD. This program has been written especially for El-Mex Salines but can be used by Port Said and Borg el Arab. Some details of program execution and use are found in this report.

Base Case

For years, El Mex Salines has operated a closed pond system. This system is shown below:



In this system, none of the impurities or minerals other than NaCl are removed. The net result is brine now high in Magnesium concentration. This high magnesium results in suppressed evaporation rates and poor quality salt.

<u>Case One. Base Case</u>

A step-by-step procedure will show how to run this case on the computer. First, it is expected that the operator knows the basic operation of a PC.

1. Change the computer default drive to the "A" drive.

2. Type: ELMEXMOD and press the ENTER key.

3. The following screen will appear:

```
                              GGG                SSS            LLLL
                           GGGGGGGGG          SSSSSSSSS         LLLL
                          GGGG   GGGG      SSSS    SSSS         LLLL
                         GGGG     GGGG     SSSS                 LLLL
                         GGGG               SSSS                LLLL
                         GGGG                  SSSS             LLLL
                         GGGG                    SSSS           LLLL
                         GGGG    GGGGGG            SSSS         LLLL
                         GGGG     GGGG              SSSS        LLLL
                          GGGG   GGGG      SSSS     SSSS        LLLL
                           GGGGGGGGG        SSSS   SSSS         LLLLLLLLLLLLL
                             GGGGG            SSSSSSS           LLLLLLLLLLLLL

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                                     El Mex Model Version 1.01

Press <Enter> to continue.
```

4. Press ENTER and the next screen appears.

```
What INPUT data file do you want to read?
```

5. Type ELMEX.DAT or the name of any other data file you may want to use. Data may be in any ASCII file. See the Appendix for a description of data files. After typing ELMEX.DAT, press ENTER. The screen will now look like this:

```
What INPUT data file do you want to read? ELMEX.DAT
Read input file ELMEX.DAT OK?
```

6. Type Y (for yes) and the data screen will appear. ELMEX.DAT data screen, for example, will appear as shown below.

```
Data read from ELMEX.DAT:
Pond Pond Curnt Tar                          Ion Weight Percents            Pond    Pond  Salt
Name Area Depth Depth Inventory %K      %Na     %Mg     %Cl    %SO4 Max Flow Rec.  Dis.
     (Hect) (cm)  (cm)    (Tons)                                          m 3/d)         Fact
Lake    0      0      0           0 0.04   1.05    0.13    1.90    0.26   1000000 0.0 0.00
PND1 2500    100    100 30638767 0.41   7.07    1.75  15.35    2.57    500000 1.0 0.25
PND2  500     50     50  3109029 0.50   7.02    2.16  15.14    3.17    400000 0.0 0.01
HRV1  400     30     30  1522103 0.67   5.73    2.37  14.57    4.20    300000 0.0 0.00
Is all the data correct? <Y> or <N>
```

7. If the data is correct, type Y and the screen will ask the question:

```
What month do the calculations begin in?
```

8. Type the number or name of the months you wish to begin. For example, type 6 for June, and press ENTER. The next screen will appear.

```
What day in June do the calculations begin?
```

9. Type in the day and ENTER. 1 is used in this example. The next question then appears.

```
What is the evaporation factor for this run?
```

10. Now type in the evaporation factor. Evaporation is based on evaporation from pans at El Mex Weather Station as outlined in report Reference 7. If one wants to use this data directly, the factor would be 1. If weather for the year is 10% above normal then a 1.1 factor would be used. The example uses 1. Type 1 and ENTER.

```
What is the precipitation factor for this run?
```

11. The precipitation factor for normal rainfall is 1. Type 1 ENTER.

```
  Evaporation Factor = 1.000
Precipitation Factor = 1.000
Are these correct?
```

12. The screen (above) now asks for a verification of both the evaporation factor and the precipitation factor. If they are correct, type Y.

```
How many months do you want the calculations to run?
```

13. Now type in the number of months you want the computer to simulate the pond system. For example, say you are beginning in June 1990 and want to run to the end of December 1993. This is 42 months. Type 42 and press ENTER.

```
What file do you want the monthly totals written to?
```

14. Now the above question is asked. As the computer calculates what is happening in the pond system, it must store its calculation somewhere. This data can then be looked at later. You can name the file anything you want so long as it follows standard MS-DOS rules. In this example, let's call the file "BASECASE." Type BASECASE and press ENTER.

```
Do you want to keep a daily material balance file? <Y> or <N>
:
```

15. The screen now asks if you want to keep a daily material balance file. In most cases, the answer is no. A daily file will include complete details and trace all ions each day. It is a good analytical tool, but is time consuming, requires a lot of printout paper, and in most cases is not needed. Type N and press ENTER.

16. The computer now begins calculating and shows you its progress on the screen. When it is finished, the screen now looks like this:

```
     Calculating Year: 5
     Calculating Day:
     Calculating Pond:





  What file do you want the ending conditions written to?
```

17. A new file is asked for. This file will keep the pond status at the end of the fifth year. This is handy to compare to the starting condition (June 1, 1990) or to use later as the starting conditions of another computer run. Let's call the ending condition BASECASE.END. Type BASECASE.END and press ENTER.

```
Calculating Year: 5
Calculating Day:
Calculating Pond:




what file do you want the ending conditions written to? BASECASE.END
Write ending conditions to BASECASE.END. OK?
```

18. The computer now confirms that you want the file saved to BASECASE.END. Type Y and the run is complete.

```
A:\
```

The computer now returns to the DOS prompt. You may run again by executing ELMEXMOD or stop here and call up the data file just completed.

To continue, we will call up the three data files, ELMEX.DAT, BASECASE, AND BASECASE.END. Type PRINT ELMEX.DAT and then press ENTER. The following will be printed:

```
This is the set-up for the El Mex system as it is presently run.
The Lake is the concentration of the open ocean.
The line of asterisks may be moved to accomodate more comments.
Notice that ponds whose names begin with H are assumed to be harvestable.
The net deposit of the system is summed from these harvestable ponds.

                 Current Target                                           Salt
Pond  Area       Depth   Depth      Ion Weight Percents     Max. Flow Rec. Dsv.
Name  (Hect.)    (cm)    (cm)    K    Na   Mg    Cl    SO4   (Tons/d)       Fact.
***************************************************************************
Lake     0         0       0   0.04 1.05 0.13  1.90  0.26  1000000  0   0.00
PND1  2500       100     100   0.41 7.07 1.75 15.35  2.57   500000  1   0.05
PND2   500        50      50   0.50 7.02 2.16 15.14  3.17   400000  0   0.01
HRV1   400        30      30   0.67 5.73 2.87 14.57  4.20   300000  0   0.00
```

Next, type PRINT BASECASE and push ENTER. the data for each month over the time specified will be printed. These pages are shown in the Appendix. The summary of each year is shown below. SEE APPENDIX A

El Mex Model Summary File "BASECASE"
Evaporation factor is 1.000 Precipitation factor is 1.000

Summary of year 1
Months Calculated = June to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	0	0	0	-529	-288	-257	-223	-181	-121	-68	-1668
PND2	0	0	0	0	0	216	232	226	183	132	89	35	1112
HRV1	0	0	0	0	0	170	184	180	141	99	62	19	854
Total	0	0	0	0	0	-143	128	148	100	50	29	-14	298
Net	0	0	0	0	0	170	184	180	141	99	62	19	854

Summary of year 2
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-26	-23	-81	-153	-212	-232	-253	-250	-220	-178	-120	-67	-1816
PND2	22	46	124	185	211	225	228	220	181	128	86	33	1688
HRV1	8	25	90	140	166	179	185	179	141	99	61	19	1291
Total	4	48	133	172	165	172	160	148	101	49	28	-15	1164
Net	8	25	90	140	166	179	185	179	141	99	61	19	1291

Summary of year 3
Months Calculated = January to December
Deposit in thousands of tons.

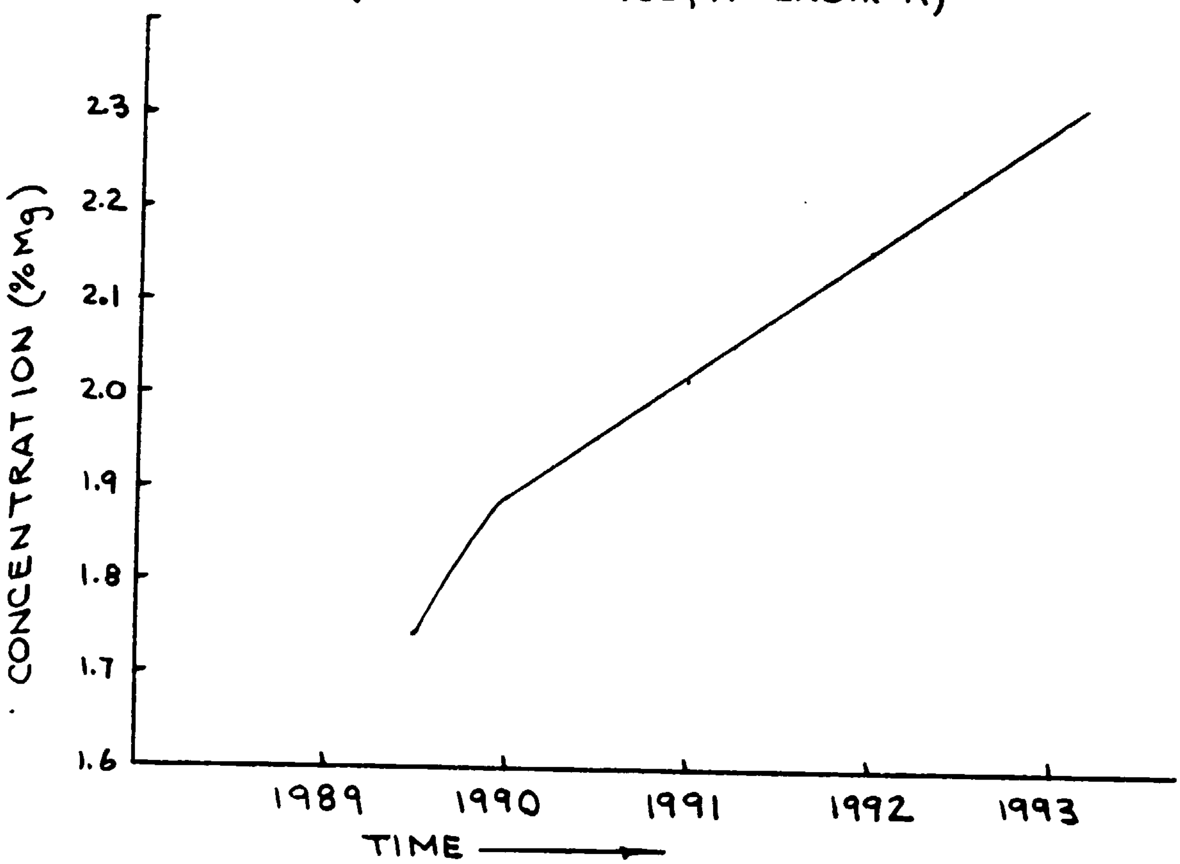
Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-24	-21	-80	-150	-208	-228	-248	-245	-216	-175	-118	-65	-1780
PND2	20	43	122	179	208	217	222	215	172	124	85	31	1637
HRV1	7	24	90	139	165	179	184	178	140	98	62	17	1283
Total	2	46	133	167	165	168	158	147	96	47	28	-17	1141
Net	7	24	90	139	165	179	184	178	140	98	62	17	1283

Summary of year 4
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-25	-24	-80	-148	-204	-223	-243	-240	-211	-172	-116	-65	-1750
PND2	19	42	120	173	203	209	215	210	165	122	82	29	1588
HRV1	9	26	90	138	165	178	183	178	139	98	61	18	1283
Total	3	44	130	164	164	164	155	148	94	48	27	-18	1121
Net	9	26	90	138	165	178	183	178	139	98	61	18	1283

The computer ran the 42-month period which began June 1, 1989 and ends December 31, 1992. A plot of magnesium concentrates for the period is shown on Graph 1. Note how concentrations continually increase.

GRAPH I
CONCENTRATION OF MAGNESIUM VERSUS TIME IN EL MEX 1ST POND WITH BITTERNS RECYCLE
(SEE BASE CASE, APPENDIX A)



Now print out the "BASECASE.END" data. This shows the pond status at the end of this 42-month period. All ionic concentrations are shown. Notice, for example, that the pond concentration has increased from 1.75 percent Mg in June of 1989 to 2.24 percent in December of 1992.

Ending Conditions File
Start Conditions From :ELMEX.DAT
Model run covered 5 years.
Model ran 42 months.
The first month run was June.
The last month run was December.
The evaporation factor was 1.000.
The precipitation factor was 1.000.
****

Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0.0	0.00
PND1	2500	100	100	0.56	6.87	2.24	15.93	3.54	500000	1.0	0.05
PND2	500	50	50	0.65	6.33	2.59	15.95	4.10	400000	0.0	0.01
HRV1	400	30	30	0.73	5.79	2.93	15.94	4.63	300000	0.0	0.00

Of course, all of this is based on an estimated evaporation rate, which, according to the yearly print out, should produce near 1,283,000 tons of NaCl per year. Suppose El Mex only produces 900,000 tons per year as a matter of record. This means that the evaporation rate is too high. If we multiply 1.283000 by a factor of .70 (900,000 ÷ 1283000) then the correct value of 900,000 tons would be obtained. This .70 factor can be placed in the computer when it asks for an evaporative factor. This is a type of calculation step that will correct calculations to duplicate actual conditions at El Mex.

Since GSL does not know actual conditions at El Mex, a factor of 1.0 will be used.

<u>Case 1. No Recycle</u>

Now an exact duplicate of the Base Case will be run, except recycle brine will be eliminated. This run is also shown in the Appendix. The starting data is shown on the next page. Note that the data is identical to the base case except for a "1" in the "Rec" column has been replaced by a "0" meaning that the pond is not receiving any recycled brine. A "1" means the pond is receiving recycled brine from the last salt crystallizer.

Note in the no recycle case, magnesium in the first concentration pond has decreased from 1.75% Mg down to 0.51 in just 42 months. This will be a tremendous boost to salt quality and will also result in much higher salt production in the future. (See Appendix B)

```
This is the set-up for the El Mex pond system without bitterns recycle.
The Lake is the concentration of the open ocean.
The line of asterisks may be moved to accomodate more comments.
Notice that ponds whose names begin with H are assumed to be harvestable.
The net deposit of the system is summed from these harvestable ponds.

                Current Target                                                    Salt
Pond  Area      Depth   Depth      Ion Weight Percents       Max. Flow  Rec.  Dsv.
Name  (Hect.)   (cm)    (cm)    K     Na    Mg    Cl     SO4   (Tons/d)          Fact.
*************************************************************************************
Lake     0        0       0    0.04  1.05  0.13   1.90   0.26   1000000    0    0.00
PND1  2500      100     100    0.41  7.07  1.75  15.35   2.57    500000    0    0.05
PND2   500       50      50    0.50  7.02  2.16  15.14   3.17    400000    0    0.01
HRV1   400       30      30    0.67  5.73  2.87  14.57   4.20    300000    0    0.00
```

<u>Case 2. Series Pond Operation</u>

It has already been suggested that salt crystallizer brine not be recycled. This will increase crystallized salt purity and will also increase the overall evaporative rates caused by lower magnesium concentration.

Crystallizer ponds placed in series will also increase both salt quality and quantity. The next case shows a computer run and an explanation how this is done.

ELMEX.DAT data file represents a starting point for the computer.

LAKE - sea brine. PND 1 - the large, 25 square kilometer preconcentration pond. PND 2 is the second preconcentration pond and HRV1 represents the salt crystallizer. The brine sequence is Sea → Preconcentration Pond #1 → Preconcentration Pond #2 → Salt Pond. To simulate a two salt pond system, the single salt pond of Base Case or Case 1 must be divided in two. This can be done as follows:

1. Start the program as done in Base Case by executing ELMEXMOD. When the computer asks for the data file, type in the name of the file desired or, if the desired file is non-existent, type ELMEX.DAT and push ENTER. The file will now appear on the screen and a question will be asked:

```
Data read from elmex.dat:
Pond Pond Curnt Tar                            Ion Weight Percents          Pond   Pond  Salt
Name Area Depth Depth Inventory %K     %Na    %Mg    %Cl   %SO4 Max Flow Rec.   Dis.
     (Hect) (cm)  (cm)    (Tons)                                     (T/d)               Fact
Lake    0             0            0 0.04  1.05   0.13   1.90   0.26  1000000 0.0 0.00
PND1 2500    100    100  [illegible] 0.41  7.07   1.75  15.35   2.57   500000 1.0 0.05
PND2  500     50     50  [illegible] 0.50  7.02   2.16  15.14   3.17   400000 0.0 0.01
HRV1  400     30     30  [illegible] 0.67  5.73   2.87  14.57   4.20   300000 0.0 0.00
Is all the data correct? (Y or N)
```

Press the N key and another question will be asked at the bottom of the screen:

```
**User specified error in input data.**
Do you want to read a different file? <Y> or <N>
```

Now you can push Y and enter a different file, or you can press N and change the ELMEX.DAT file. In this case we will change the existing file. Type N. The screen now changes to add two more lines.

```
**User specified error in input data.**
Do you want to read a different file? <Y> or <N> N
Program will exit to the editor with elmex.dat
Press <Enter> to continue.
```

Press ENTER and a new screen appears as shown next.

```
ELMEX.DAT                                   L:16     C:1    B:1              OVR AI
This is the set-up for the El Mex system as it is presently run.
The Lake is the concentration of the open ocean.
The line of asterisks may be moved to accomodate more comments.
Notice that ponds whose names begin with H are assumed to be harvestable.
The net deposit of the system is summed from these harvestable ponds.
```

Pond Name	Area (Hect.)	Current Depth (cm)	Target Depth (cm)	K	Na	Mg	Cl	SO4	Max. Flow (Tons/d)	Rec.	Salt Dsv. Fact.
Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0	0.00
PND1	2500	100	100	0.41	7.07	1.75	15.35	2.57	500000	1	0.05
PND2	500	50	50	0.50	7.02	2.16	15.14	3.17	400000	0	0.01
HRV1	400	30	30	0.67	5.73	2.87	14.57	4.20	300000	0	0.00

This screen is actually a text editor called EDWIN. Changes can now be made to this data and then stored for use in the program. We will change the HRV1 pond by dividing it in half. Move the cursor down to the area (Hect) space on the HRV1 line and overtype this 4 with a 2. This will change the salt area from 400 hectares (4 square kilometers) to 200 hectares. Now push ENTER and the cursor will move to the blank space just under HRV1. Type HRV2 and duplicate everything else as shown for HRV1. The screen should now look like this:

```
ELMEX.DAT                             L:12   C:67  B:773          OVR AI    SAVE
This is the set-up for the El Mex system as it is presently run.
The Lake is the concentration of the open ocean.
The line of asterisks may be moved to accomodate more comments.
Notice that ponds whose names begin with H are assumed to be harvestable.
The net deposit of the system is summed from these harvestable ponds.

                Current Target                                           Salt
Pond  Area      Depth  Depth       Ion weight Percents     Max. Flow Rec. Dsv.
Name (Hect.)   (cm)   (cm)    K     Na   Mg     Cl   SO4   (Tons/d)       Fact.
*************************************************************************************
Lake     0        0      0    0.04 1.05 0.13   1.90  0.26   1000000  0    0.00
PND1  2500      100    100    0.41 7.07 1.75  15.35  2.57    500000  0    0.05
PND2   500       50     50    0.50 7.02 2.16  15.14  3.17    400000  0    0.01
HRV1   200       30     30    0.67 5.73 2.87  14.57  4.20    300000  0    0.00
HRV2   200       30     30    0.67 5.73 2.87  14.57  4.20    300000  0    0.00
```

BOTTOM LINE IS ADDED

NOTE CHANGES

Now press CTRL K X or F1 and the data will be saved in the file ELMEX.DAT. <u>The old data in ELMEX.DAT will be lost</u>. The screen will now look like this:

```
Data read from elmex.dat:
Pond Pond Curnt Tar                      Ion Weight Percents          Pond    Pond  Salt
Name Area Depth Depth Inventory %K     %Na    %Mg    %Cl   %SO4 Max Flow Rec.  Dis.
   (Hect) (cm)  (cm)   (Tons)                                      (m^3/d)         Fact
Lake    0     0      0          0 0.04  1.05   0.13   1.90   0.26  1000000 0.0 0.00
PND1 2500   100    100  30638767 0.41  7.07   1.75  15.35   2.57   500000 0.0 0.05
PND2  500    50     50   3109028 0.50  7.02   2.16  15.14   3.17   400000 0.0 0.01
HRV1  200    30     30    761052 0.67  5.73   2.87  14.57   4.20   300000 0.0 0.00
HRV2  200    30     30    761052 0.67  5.73   2.87  14.57   4.20   300000 0.0 0.00
Is all the data correct? <Y> or <N>
```

If it is desired not to over-write the ELMEX.DAT file, this can also be done. Place the cursor at the beginning of the text and push CTRL K B. Then place the cursor at the end of the text file and push CTRL K K. This will mark the block. Then, push CTRL K W. The question at the top of the screen asks: What File Name? Type in the new name you want for the file such as ELMEX2.DAT. Now the data file will be stored without destroying the old file. To exit back to ELMEXMOD, push CTRL K Q and follow screen print instructions.

The question is asked:

Is all the data correct? <Y> or <N>

Press Y and the screen now advances to the question of normal routine. Enter in the same time, evaporation, and precipitation data as was done for the Base Case. Call the data file TWO-PNDS and the end file TWO-PNDS.END. Now print out the files. These files are shown in the Appendix of the report. A summary of the fourth year is shown below.

Summary of year 4
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-49	-44	-159	-246	-344	-349	-396	-379	-334	-280	-168	-99	-2847
PND2	47	74	157	224	255	273	279	274	228	168	121	64	2163
HRV1	13	23	58	87	102	109	114	110	90	65	44	20	839
HRV2	4	13	47	72	86	92	97	92	73	52	31	8	667
Total	15	66	102	138	100	124	93	98	58	5	29	-6	822
Net	18	36	105	159	188	201	211	203	164	117	76	29	1506

Note that the salt deposited is 1,506,000 tons in the salt ponds, compare this to the base case of 1,283,000. This increase of 223,000 tons is the result of simply placing salt crystallizer in series flow and not recycling concentrated brine.

With the computer program, a variety of cases can be made to optimize the ponds. GSL has run several cases and depending on the accuracy of the evaporation, much can be done to increase production.

Borg El Arab

The computer program can also be used for the Borg El Arab pond system. simply create a data file for Borg El Arab to start with and the computer will begin with that.

Borg El Arab is much different than El Mex Salines because it does not have a sodium chloride floor. All salt must rely on the sea.

As understood by GSL, Borg El Arab is 24 square kilometers in size or 2,400 hectares. This area is divided into one large 2,000 hectare concentration pond and 400 hectare crystallization ponds. The concentration pond is divided by a cement factory road. There is about 300 hectare of preconcentration pond on one side and 1,700 hectares on the other.

If we assume that the salt ponds will be run in series, then the pond system will be run as shown below:

This is the set-up for the Borg El Arab system of ponds.
The Lake is the concentration of the open ocean.
The line of asterisks may be moved to accommodate more comments.
Notice that ponds whose names begin with H are assumed to be harvestable.
The net deposit of the system is summed from these harvestable ponds.
In this starting state the ponds are filled with ocean brine and then
run in sequence for [illegible] years.

Pond Name	Area (Hect.)	Current Depth (cm)	Target Depth (cm)	Ion Weight Percents K	Na	Mg	Cl	SO4	Max. Flow (Tons)	Rec.	Salt Dis. Fact.
Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0	1.00
PND1	1700	50	50	0.04	1.05	0.13	1.90	0.26	500000	0	[illegible]
PND2	300	50	50	0.04	1.05	0.13	1.90	0.26	400000	0	[illegible]
HRV1	200	30	30	0.04	1.05	0.13	1.90	0.26	300000	0	[illegible]
HAR2	200	30	30	0.04	1.05	0.13	1.90	0.26	300000	0	[illegible]

The computer print out of Appendix E shows that steady state production is near 700,000 TPY if ponds are run in series. There also appears to be a mismatch in pond area ratios. If these ratios are adjusted even more salt could be produced. It is suggested, however, that no changes be made until several years running and evaporative and production rates can be sued to optimize the ponds as indicated by computer model runs.

Computer Model Details

The computer program enclosed is quite comprehensive. It has the program to dissolve salts from the bottom of the floor if salt is present. The amount of salt it dissolves is controlled by the computer operator. Evaporation, rain, pump flow rates, pond size, concentrates, depth, and bittern recycle, can also be specified by the computer operator.

The user can also follow a complete material balance through the pond day by day. This is time consuming but in time it may be very important to see what is really happening in a pond system.

GSL can provide specialized training in the detailed use of the model if needed.

The next page shows an example of the pond material balance from July 24 to July 25.

"Mass Balance = 0.000" means that TONS IN minus TONS OUT = 0.000, a perfect balance. Anything other than 0.000 is unsatisfactory. Notice that each pond is tested for Mass, Mg, and Na.

The disk included with this book is formatted 1.2 meg. This is done so that more storage space can be used on the disk. If the user runs out of space, then some files must be removed. One way to overcome this problem is to copy the disk to a hard disk and then execute the program from the hard disk. Another way is to simply place in another data storage floppy disk.

If a 1.2 meg formatted disk is not compatible with El Mex computer, GSL can supply a 360K or 720K formatted disk.

Max Material Balance File Balance

24

	Beginning Inventory	Flow In	Recycle In	=	Ending Inventory	Flow Out	Salt Deposit	Evaporation
01								
ss	9433544	159360	0	=	9426792	67996	0	98116
	39621	207	0	=	39542	286	0	0
	321684	1673	0	=	321038	2319	0	0

ss Balance = 0.000 Mg Balance = 0.000 Na Balance = 0.000

02								
ss	1723183	67996	0	=	1721958	52411	0	16810
	11890	286	0	=	11814	362	0	0
	95637	2319	0	=	95046	2909	0	0

ss Balance = 0.000 Mg Balance = 0.000 Na Balance = 0.000

V1								
ss	714184	52411	0	=	713252	39332	3378	10633
	8213	362	0	=	8122	452	0	0
	61777	2909	0	=	59955	3402	1329	0

ss Balance = 0.000 Mg Balance = 0.000 Na Balance = 0.000

R2								
ss	762865	39332	0	=	760959	30000	2874	8364
	22657	452	0	=	22218	891	0	0
	43712	3402	0	=	44265	1719	1131	0

ss Balance = 0.000 Mg Balance = 0.000 Na Balance = 0.000

ly 25

	Beginning Inventory	Flow In	Recycle In	=	Ending Inventory	Flow Out	Salt Deposit	Evaporation
01								
ss	9426792	161329	0	=	9425811	64189	0	98122
	39542	210	0	=	39483	269	0	0
	321038	1694	0	=	320546	2186	0	0

ss Balance = 0.000 Mg Balance = 0.000 Na Balance = 0.000

02								
ss	1721958	64189	0	=	1721429	47900	0	16817
	11814	269	0	=	11755	329	0	0
	95046	2186	0	=	94589	2644	0	0

ss Balance = 0.000 Mg Balance = 0.000 Na Balance = 0.000

V1								
ss	713252	47900	0	=	712714	37791	0	10647
	8122	329	0	=	8021	430	0	0
	59955	2644	0	=	59422	3177	0	0

ss Balance = 0.000 Mg Balance = 0.000 Na Balance = 0.000

R2								
ss	760959	37791	0	=	760202	27000	3122	8427
	22218	430	0	=	21860	788	0	0
	44265	3177	0	=	44643	1571	1228	0

ss Balance = 0.000 Mg Balance = 0.000 Na Balance = 0.000

APPENDIX A

BASE CASE RUN

File Names

Starting Conditions	ELMEX.DAT
Ending Conditions	BASECASE.END
Running File	BASECASE

This is the set-up for the El Mex system as it is presently run.
The Lake is the concentration of the open ocean.
The line of asterisks may be moved to accomodate more comments.
Notice that ponds whose names begin with H are assumed to be harvestable.
The net deposit of the system is summed from these harvestable ponds.

Pond Name	Area (Hect.)	Current Depth (cm)	Target Depth (cm)	K	Na	Mg	Cl	SO4	Max. Flow (Tons/d)	Rec.	Salt Dsv. Fact
				Ion Weight Percents							
************	************	************	************	********	********	********	********	********	************	******	********
Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0	0.00
PND1	2500	100	100	0.41	7.07	1.75	15.35	2.57	500000	1	0.05
PND2	500	50	50	0.50	7.02	2.16	15.14	3.17	400000	0	0.01
HRV1	400	30	30	0.67	5.73	2.87	14.57	4.20	300000	0	0.00

Ending Conditions File
Start Conditions From :ELMEX.DAT
Model run covered 5 years.
Model ran 42 months.
The first month run was June.
The last month run was December.
The evaporation factor was 1.000.
The precipitation factor was 1.000.
****

Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0.0	0
PND1	2500	100	100	0.56	6.87	2.24	15.93	3.54	500000	1.0	0
PND2	500	50	50	0.65	6.33	2.59	15.95	4.10	400000	0.0	0
HRV1	400	30	30	0.73	5.79	2.93	15.94	4.63	300000	0.0	0

El Mex Model Summary File "BASECASE"
Evaporation factor is 1.000 Precipitation factor is 1.000

Year = 1 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	104863	1.74	99.9	1.75	-529080
PND2	48.3	74100	2.26	50.0	2.29	216367
HRV1	28.5	51663	3.04	30.0	3.06	169778

Total Monthly Salt Deposit = -142934
Harvestable Salt Deposit = 169778

Year = 1 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	125981	1.76	99.9	1.77	-288402
PND2	47.9	95476	2.30	50.0	2.31	231588
HRV1	28.1	73020	3.04	30.0	3.02	184385

Total Monthly Salt Deposit = 127571
Harvestable Salt Deposit = 184385

Year = 1 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	125889	1.78	99.9	1.79	-257107
PND2	47.9	96350	2.31	50.0	2.32	225680
HRV1	28.1	74467	3.00	30.0	3.00	179550

Total Monthly Salt Deposit = 148124
Harvestable Salt Deposit = 179550

Year = 1 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	103677	1.80	99.9	1.80	-223320
PND2	48.3	79173	2.33	50.0	2.33	182550
HRV1	28.4	61395	3.00	30.0	3.00	141086

Total Monthly Salt Deposit = 100316
Harvestable Salt Deposit = 141086

Year = 1 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	71804	1.81	100.0	1.81	-180554
PND2	48.8	54922	2.34	50.0	2.35	132025
HRV1	28.9	42881	2.99	30.0	3.00	98855

Total Monthly Salt Deposit = 50326
Harvestable Salt Deposit = 98855

Year = 1 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	47747	1.82	100.0	1.82	-121429
PND2	49.2	36226	2.35	50.0	2.36	88637
HRV1	29.3	28458	2.99	30.0	3.00	61771

Total Monthly Salt Deposit = 28980
Harvestable Salt Deposit = 61771

Year = 1 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	18100	1.82	100.0	1.82	-67981
PND2	49.7	13704	2.36	50.0	2.37	35459
HRV1	29.7	11495	2.97	30.0	2.96	18531

Total Monthly Salt Deposit = -13991
Harvestable Salt Deposit = 18531

Summary of year 1
Months Calculated = June to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	0	0	0	-529	-288	-257	-223	-181	-121	-68	-1668
PND2	0	0	0	0	0	216	232	226	183	132	89	35	1112
HRV1	0	0	0	0	0	170	184	180	141	99	62	19	854
Total	0	0	0	0	0	-143	128	148	100	50	29	-14	298
Net	0	0	0	0	0	170	184	180	141	99	62	19	854

Year = 2 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	7973	1.82	100.0	1.82	-25817
PND2	49.9	5238	2.38	50.0	2.39	22033
HRV1	29.9	4282	2.96	30.0	2.96	7912

Total Monthly Salt Deposit = 4128
Harvestable Salt Deposit = 7912

Year = 2 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	17140	1.82	100.0	1.82	-23376
PND2	49.7	10842	2.41	50.0	2.43	45795
HRV1	29.8	7323	3.01	30.0	3.03	25382

Total Monthly Salt Deposit = 47801
Harvestable Salt Deposit = 25382

Year = 2 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	83574	1.83	100.0	1.85	-81414
PND2	48.6	68402	2.39	50.0	2.32	123884
HRV1	28.6	57625	2.99	30.0	2.85	90122

Total Monthly Salt Deposit = 132592
Harvestable Salt Deposit = 90122

Year = 2 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	100190	1.85	99.9	1.86	-152738
PND2	48.4	75846	2.37	50.0	2.36	184732
HRV1	28.5	58051	2.97	30.0	2.95	139928

Total Monthly Salt Deposit = 171921
Harvestable Salt Deposit = 139928

Year = 2 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	131583	1.86	99.9	1.89	-211873
PND2	47.9	104424	2.38	50.0	2.32	210918
HRV1	27.9	84253	2.99	30.0	2.85	165932

Total Monthly Salt Deposit = 164977
Harvestable Salt Deposit = 165932

Year = 2 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	131140	1.88	99.9	1.90	-232137
PND2	47.9	100785	2.39	50.0	2.37	224784
HRV1	28.0	78055	3.00	30.0	2.93	178854

Total Monthly Salt Deposit = 171501
Harvestable Salt Deposit = 178854

Year = 2 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	145567	1.90	99.9	1.92	-252730
PND2	47.6	115536	2.39	50.0	2.35	227863
HRV1	27.7	92956	2.99	30.0	2.88	184733

Total Monthly Salt Deposit = 159867
Harvestable Salt Deposit = 184733

Year = 2 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	135330	1.92	99.9	1.94	-250256
PND2	47.8	106209	2.41	50.0	2.38	219907
HRV1	27.9	84246	2.99	30.0	2.91	178719
					Total Monthly Salt Deposit =	148370
					Harvestable Salt Deposit =	178719

Year = 2 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	100434	1.94	99.9	1.93	-219958
PND2	48.4	76057	2.42	50.0	2.47	180731
HRV1	28.5	58055	2.99	30.0	3.09	140642
					Total Monthly Salt Deposit =	101416
					Harvestable Salt Deposit =	140642

Year = 2 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	84713	1.95	100.0	1.95	-178121
PND2	48.6	68214	2.42	50.0	2.46	128231
HRV1	28.6	56174	2.96	30.0	3.03	98968
					Total Monthly Salt Deposit =	49078
					Harvestable Salt Deposit =	98968

Year = 2 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	46392	1.96	100.0	1.95	-120443
PND2	49.2	35059	2.45	50.0	2.50	86478
HRV1	29.3	27210	2.99	30.0	3.10	61485
					Total Monthly Salt Deposit =	27520
					Harvestable Salt Deposit =	61485

Year = 2 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	24607	1.96	100.0	1.96	-670[illegible]
PND2	49.6	20546	2.44	50.0	2.47	32922
HRV1	29.6	18387	2.95	30.0	3.00	18677
					Total Monthly Salt Deposit =	-15463
					Harvestable Salt Deposit =	18677

Summary of year 2
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-26	-23	-81	-153	-212	-232	-253	-250	-220	-178	-120	-67	-1816
PND2	22	46	124	185	211	225	228	220	181	128	86	33	1688
HRV1	8	25	90	140	166	179	185	179	141	99	61	19	1291
Total	4	48	133	172	165	172	160	148	101	49	28	-15	1164
Net	8	25	90	140	166	179	185	179	141	99	61	19	1291

Year = 3 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	4320	1.96	100.0	1.95	-24232
PND2	49.9	1840	2.49	50.0	2.51	19595
HRV1	30.0	968	3.02	30.0	3.03	6829

Total Monthly Salt Deposit = 2191
Harvestable Salt Deposit = 6829

Year = 3 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	20072	1.95	100.0	1.95	-21318
PND2	49.7	14201	2.53	50.0	2.54	42913
HRV1	29.7	10875	3.07	30.0	3.08	24188

Total Monthly Salt Deposit = 45783
Harvestable Salt Deposit = 24188

Year = 3 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	83313	1.97	100.0	1.97	-80131
PND2	48.7	68210	2.47	50.0	2.48	122429
HRV1	28.6	57260	2.98	30.0	3.02	90233

Total Monthly Salt Deposit = 132531
Harvestable Salt Deposit = 90233

Year = 3 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	128148	1.99	99.9	2.00	-150226
PND2	47.9	104541	2.46	50.0	2.44	178539
HRV1	27.9	87056	2.99	30.0	2.94	139010

Total Monthly Salt Deposit = 167323
Harvestable Salt Deposit = 139010

Year = 3 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	128965	2.00	99.9	2.01	-208332
PND2	47.9	101905	2.47	50.0	2.49	208450
HRV1	28.0	81544	3.00	30.0	3.04	165223
					Total Monthly Salt Deposit =	165341
					Harvestable Salt Deposit =	165223

Year = 3 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	153856	2.02	99.9	2.02	-227616
PND2	47.5	124058	2.47	50.0	2.52	216658
HRV1	27.5	101341	2.98	30.0	3.09	178617
					Total Monthly Salt Deposit =	167658
					Harvestable Salt Deposit =	178617

Year = 3 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	159963	2.04	99.9	2.04	-248128
PND2	47.4	130349	2.49	50.0	2.53	222360
HRV1	27.4	107756	2.99	30.0	3.08	184048
					Total Monthly Salt Deposit =	158280
					Harvestable Salt Deposit =	184048

Year = 3 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	158215	2.06	99.9	2.06	-245388
PND2	47.4	129613	2.50	50.0	2.53	214546
HRV1	27.4	107757	2.99	30.0	3.06	178095
					Total Monthly Salt Deposit =	147252
					Harvestable Salt Deposit =	178095

Year = 3 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	144225	2.07	99.9	2.09	-215775
PND2	47.7	120823	2.51	50.0	2.48	172229
HRV1	27.6	103256	2.99	30.0	2.92	139907
					Total Monthly Salt Deposit =	96362
					Harvestable Salt Deposit =	139907

Year = 3 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	92252	2.09	100.0	2.10	-174848
PND2	48.5	76058	2.51	50.0	2.48	124143
HRV1	28.5	64033	2.98	30.0	2.91	98196

Total Monthly Salt Deposit = 47491
Harvestable Salt Deposit = 98196

Year = 3 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	48147	2.09	100.0	2.09	-118206
PND2	49.2	36989	2.52	50.0	2.54	84784
HRV1	29.3	29068	2.98	30.0	3.02	61614

Total Monthly Salt Deposit = 28192
Harvestable Salt Deposit = 61614

Year = 3 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	34323	2.09	100.0	2.11	-65326
PND2	49.4	30670	2.57	50.0	2.48	30798
HRV1	29.4	28774	3.04	30.0	2.86	17078

Total Monthly Salt Deposit = -17451
Harvestable Salt Deposit = 17078

Summary of year 3
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-24	-21	-80	-150	-208	-228	-248	-245	-216	-175	-118	-65	-1780
PND2	20	43	122	179	208	217	222	215	172	124	85	31	1637
HRV1	7	24	90	139	165	179	184	178	140	98	62	17	1283
Total	2	46	133	167	165	168	158	147	96	47	28	-17	1141
Net	7	24	90	139	165	179	184	178	140	98	62	17	1283

Year = 4 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	3647	2.11	100.0	2.10	-25443
PND2	49.9	1174	2.51	50.0	2.53	19334
HRV1	30.0	0	2.89	30.0	2.91	9069

Total Monthly Salt Deposit = 2960
Harvestable Salt Deposit = 9069

Year = 4 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	9742	2.10	100.0	2.09	-23635
PND2	49.8	3808	2.57	50.0	2.62	42036
HRV1	29.9	145	3.00	30.0	3.07	25517
					Total Monthly Salt Deposit =	43918
					Harvestable Salt Deposit =	25517

Year = 4 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	89899	2.11	100.0	2.11	-79642
PND2	48.6	75019	2.55	50.0	2.58	119722
HRV1	28.5	64056	2.99	30.0	3.06	89767
					Total Monthly Salt Deposit =	129847
					Harvestable Salt Deposit =	89767

Year = 4 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	151850	2.12	99.9	2.14	-147756
PND2	47.6	128741	2.55	50.0	2.51	173120
HRV1	27.4	111359	3.00	30.0	2.93	138435
					Total Monthly Salt Deposit =	163799
					Harvestable Salt Deposit =	138435

Year = 4 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	145315	2.14	99.9	2.14	-204378
PND2	47.7	118635	2.55	50.0	2.58	203202
HRV1	27.6	98269	3.01	30.0	3.05	164773
					Total Monthly Salt Deposit =	163597
					Harvestable Salt Deposit =	164773

Year = 4 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	186934	2.16	99.9	2.16	-222813
PND2	47.0	157776	2.55	50.0	2.57	208606
HRV1	26.9	135187	2.98	30.0	3.01	177949
					Total Monthly Salt Deposit =	163743
					Harvestable Salt Deposit =	177949

Year = 4 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	195253	2.17	99.9	2.19	-242716
PND2	46.9	166275	2.57	50.0	2.53	214869
HRV1	26.7	143850	3.00	30.0	2.90	183129
					Total Monthly Salt Deposit =	155282
					Harvestable Salt Deposit =	183129

Year = 4 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	165308	2.19	99.9	2.19	-239938
PND2	47.3	136859	2.57	50.0	2.62	209567
HRV1	27.3	114752	2.99	30.0	3.07	177971

Total Monthly Salt Deposit = 147600
Harvestable Salt Deposit = 177971

Year = 4 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	173602	2.21	99.9	2.22	-211019
PND2	47.2	150730	2.59	50.0	2.55	165085
HRV1	27.0	133213	2.99	30.0	2.90	139459

Total Monthly Salt Deposit = 93524
Harvestable Salt Deposit = 139459

Year = 4 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	99912	2.22	100.0	2.23	-171599
PND2	48.4	83930	2.60	50.0	2.57	121510
HRV1	28.3	71864	2.99	30.0	2.94	97905

Total Monthly Salt Deposit = 47816
Harvestable Salt Deposit = 97905

Year = 4 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	55967	2.23	100.0	2.22	-116382
PND2	49.1	45078	2.61	50.0	2.64	82114
HRV1	29.1	37181	2.99	30.0	3.04	61387

Total Monthly Salt Deposit = 27119
Harvestable Salt Deposit = 61387

Year = 4 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	33935	2.23	100.0	2.24	-64711
PND2	49.5	30382	2.62	50.0	2.59	29288
HRV1	29.4	28352	3.01	30.0	2.93	17665
				Total Monthly Salt Deposit =		-17758
				Harvestable Salt Deposit =		17665

Summary of year 4
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-25	-24	-80	-148	-204	-223	-24	-240	-211	-172	-116	-65	-1750
PND2	19	42	120	173	203	209	215	210	165	122	82	29	1588
HRV1	9	26	90	138	165	178	183	178	139	98	61	18	1283
Total	3	44	130	164	164	164	155	148	94	48	27	-18	1121
Net	9	26	90	138	165	178	183	178	139	98	61	18	1283

APPENDIX B

Pond Model Run identical to BASECASE (Appendix A)
but with no recycle of bittern to preconcentration pond.

This is the set-up for the El Mex pond system without bitterns recycle.
The Lake is the concentration of the open ocean.
The line of asterisks may be moved to accomodate more comments.
Notice that ponds whose names begin with H are assumed to be harvestable.
The net deposit of the system is summed from these harvestable ponds.

Pond Name	Area (Hect.)	Current Depth (cm)	Target Depth (cm)	K	Na	Mg	Cl	SO4	Max. Flow (Tons/d)	Rec.	Salt Dsv. Fact.
				Ion Weight Percents							
Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0	0.00
PND1	2500	100	100	0.41	7.07	1.75	15.35	2.57	500000	0	0.05
PND2	500	50	50	0.50	7.02	2.16	15.14	3.17	400000	0	0.01
HRV1	400	30	30	0.67	5.73	2.87	14.57	4.20	300000	0	0.00

Ending Conditions File
Start Conditions From :NO-RCYL.DAT
Model run covered 5 years.
Model ran 42 months.
The first month run was June.
The last month run was December.
The evaporation factor was 1.000.
The precipitation factor was 1.000.

Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0.0	0.00
PND1	2500	100	100	0.14	9.66	0.51	16.07	0.92	500000	0.0	0.05
PND2	500	50	50	0.31	8.72	1.12	16.05	1.99	400000	0.0	0.01
HRV1	400	30	30	0.80	5.72	2.98	15.84	5.14	300000	0.0	0.00

El Mex Model Summary File "NO-RCYL"
Evaporation factor is 1.000 Precipitation factor is 1.000

Year = 1 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	102531	1.69	99.9	1.62	-682059
PND2	48.3	72173	2.25	50.0	2.25	207040
HRV1	28.6	49733	3.04	30.0	3.06	169558
					Total Monthly Salt Deposit =	-305461
					Harvestable Salt Deposit =	169558

Year = 1 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	115867	1.54	99.9	1.47	-658686
PND2	48.1	86140	2.20	50.0	2.15	209769
HRV1	28.3	63706	3.03	30.0	3.00	184189
					Total Monthly Salt Deposit =	-264728
					Harvestable Salt Deposit =	184189

Year = 1 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	103120	1.41	99.9	1.36	-612504
PND2	48.3	73687	2.10	50.0	2.06	213406
HRV1	28.5	51774	3.00	30.0	3.00	179780
					Total Monthly Salt Deposit =	-219319
					Harvestable Salt Deposit =	179780

Year = 1 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	80494	1.32	99.9	1.28	-494001
PND2	48.7	55382	2.03	50.0	2.00	182023
HRV1	28.9	37588	3.00	30.0	3.00	141611
					Total Monthly Salt Deposit =	-170367
					Harvestable Salt Deposit =	141611

Year = 1 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	53715	1.25	100.0	1.23	-377782
PND2	49.1	36014	1.98	50.0	1.96	136973
HRV1	29.3	23952	2.99	30.0	2.99	99425
					Total Monthly Salt Deposit =	-141384
					Harvestable Salt Deposit =	99425

Year = 1 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	34739	1.21	100.0	1.20	-242854
PND2	49.4	22187	1.96	50.0	1.95	96567
HRV1	29.6	14399	2.99	30.0	3.00	62094

Total Monthly Salt Deposit = -84193
Harvestable Salt Deposit = 62094

Year = 1 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	13611	1.19	100.0	1.19	-138590
PND2	49.8	8161	1.95	50.0	1.96	44001
HRV1	29.8	5950	2.97	30.0	2.97	18621

Total Monthly Salt Deposit = -75968
Harvestable Salt Deposit = 18621

Summary of year 1
Months Calculated = June to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	0	0	0	-682	-659	-613	-494	-378	-243	-139	-3206
PND2	0	0	0	0	0	207	210	213	182	137	97	44	1090
HRV1	0	0	0	0	0	170	184	180	142	99	62	19	855
Total	0	0	0	0	0	-305	-265	-219	-170	-141	-84	-76	-1261
Net	0	0	0	0	0	170	184	180	142	99	62	19	855

Year = 2 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	6831	1.18	100.0	1.18	-53243
PND2	49.9	3043	1.96	50.0	1.97	30664
HRV1	29.9	2090	2.96	30.0	2.96	7911

Total Monthly Salt Deposit = -14667
Harvestable Salt Deposit = 7911

Year = 2 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	14344	1.18	100.0	1.17	-39322
PND2	49.8	6741	1.99	50.0	2.00	55870
HRV1	29.9	3216	3.00	30.0	3.03	25558

Total Monthly Salt Deposit = 42106
Harvestable Salt Deposit = 25558

Year = 2 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	45196	1.15	100.0	1.14	-153277
PND2	49.2	28572	1.99	50.0	1.96	135416
HRV1	29.4	17744	3.08	30.0	3.07	88784
					Total Monthly Salt Deposit =	70923
					Harvestable Salt Deposit =	88784

Year = 2 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	73309	1.11	99.9	1.08	-305947
PND2	48.8	47688	1.91	50.0	1.87	196336
HRV1	29.0	30336	3.07	30.0	3.04	138693
					Total Monthly Salt Deposit =	29081
					Harvestable Salt Deposit =	138693

Year = 2 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	81702	1.05	99.9	1.02	-416003
PND2	48.6	52685	1.81	50.0	1.77	225169
HRV1	28.9	32435	3.01	30.0	3.00	167365
					Total Monthly Salt Deposit =	-23470
					Harvestable Salt Deposit =	167365

Year = 2 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	86503	0.99	99.9	0.96	-431040
PND2	48.5	53939	1.73	50.0	1.70	243305
HRV1	28.9	31258	3.00	30.0	3.00	181097
					Total Monthly Salt Deposit =	-6638
					Harvestable Salt Deposit =	181097

Year = 2 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	84034	0.94	99.9	0.91	-450019
PND2	48.6	51134	1.67	50.0	1.64	254025
HRV1	29.0	28440	3.00	30.0	3.00	187307
					Total Monthly Salt Deposit =	-8687
					Harvestable Salt Deposit =	187307

Year = 2 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	79551	0.89	99.9	0.87	-432142
PND2	48.6	47401	1.61	50.0	1.58	249342
HRV1	29.0	25433	3.00	30.0	3.00	181431

Total Monthly Salt Deposit = -1370
Harvestable Salt Deposit = 181431

Year = 2 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	64778	0.85	100.0	0.83	-368156
PND2	48.9	37328	1.57	50.0	1.55	208027
HRV1	29.2	19504	3.00	30.0	3.00	142565

Total Monthly Salt Deposit = -17564
Harvestable Salt Deposit = 142565

Year = 2 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	44479	0.82	100.0	0.81	-293426
PND2	49.2	25169	1.54	50.0	1.53	153549
HRV1	29.5	13087	2.99	30.0	2.99	100014

Total Monthly Salt Deposit = -39863
Harvestable Salt Deposit = 100014

Year = 2 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	29581	0.80	100.0	0.80	-193163
PND2	49.5	15662	1.53	50.0	1.53	108587
HRV1	29.7	7858	2.99	30.0	3.00	62408

Total Monthly Salt Deposit = -22168
Harvestable Salt Deposit = 62408

Year = 2 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	12113	0.80	100.0	0.79	-111880
PND2	49.8	5514	1.53	50.0	1.54	53515
HRV1	29.9	3304	2.98	30.0	2.97	18587

Total Monthly Salt Deposit = -39777
Harvestable Salt Deposit = 18587

Summary of year 2
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-53	-39	-153	-306	-416	-431	-450	-432	-368	-293	-193	-112	-3248
PND2	31	56	135	196	225	243	254	249	208	154	109	54	1914
HRV1	8	26	89	139	167	181	187	181	143	100	62	19	1302
Total	-15	42	71	29	-23	-7	-9	-1	-18	-40	-22	-40	-32
Net	8	26	89	139	167	181	187	181	143	100	62	19	1302

Year = 3 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	6964	0.79	100.0	0.79	-46123
PND2	49.9	2099	1.55	50.0	1.56	39437
HRV1	30.0	1161	2.97	30.0	2.97	7812

Total Monthly Salt Deposit = 1127
Harvestable Salt Deposit = 7812

Year = 3 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	14228	0.79	100.0	0.79	-37437
PND2	49.8	5299	1.58	50.0	1.59	65813
HRV1	29.9	1786	3.00	30.0	3.02	25683

Total Monthly Salt Deposit = 54059
Harvestable Salt Deposit = 25683

Year = 3 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	38753	0.78	100.0	0.77	-127451
PND2	49.3	20727	1.58	50.0	1.56	147647
HRV1	29.6	9855	3.07	30.0	3.07	89404

Total Monthly Salt Deposit = 109600
Harvestable Salt Deposit = 89404

Year = 3 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	63066	0.76	100.0	0.75	-248265
PND2	48.9	35667	1.53	50.0	1.50	213329
HRV1	29.3	18292	3.07	30.0	3.04	139345

Total Monthly Salt Deposit = 104410
Harvestable Salt Deposit = 139345

Year = 3 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	71430	0.73	100.0	0.72	-346120
PND2	48.8	40785	1.46	50.0	1.43	242759
HRV1	29.2	20541	3.02	30.0	3.00	167946

Total Monthly Salt Deposit = 64586
Harvestable Salt Deposit = 167946

Year = 3 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	76888	0.70	100.0	0.69	-369240
PND2	48.7	42685	1.40	50.0	1.38	260281
HRV1	29.1	19974	3.00	30.0	3.00	181848

Total Monthly Salt Deposit = 72889
Harvestable Salt Deposit = 181848

Year = 3 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	75866	0.68	100.0	0.67	-392905
PND2	48.7	41429	1.35	50.0	1.33	270169
HRV1	29.1	18712	3.00	30.0	3.00	187995

Total Monthly Salt Deposit = 65259
Harvestable Salt Deposit = 187995

Year = 3 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	72632	0.65	100.0	0.64	-383454
PND2	48.7	39088	1.31	50.0	1.30	263560
HRV1	29.2	17102	3.00	30.0	3.00	181993

Total Monthly Salt Deposit = 62100
Harvestable Salt Deposit = 181993

Year = 3 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	59945	0.63	100.0	0.63	-331725
PND2	49.0	31213	1.28	50.0	1.28	219805
HRV1	29.3	13376	3.00	30.0	3.00	142938

Total Monthly Salt Deposit = 31018
Harvestable Salt Deposit = 142938

Year = 3 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	41429	0.62	100.0	0.62	-267268
PND2	49.3	21190	1.27	50.0	1.26	161888
HRV1	29.6	9105	2.99	30.0	2.99	100192

Total Monthly Salt Deposit = -5187
Harvestable Salt Deposit = 100192

Year = 3 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	28051	0.61	100.0	0.61	-178946
PND2	49.5	13316	1.27	50.0	1.27	115231
HRV1	29.7	5503	2.99	30.0	3.00	62577

Total Monthly Salt Deposit = -1138
Harvestable Salt Deposit = 62577

Year = 3 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	11704	0.61	100.0	0.61	-103816
PND2	49.8	4398	1.27	50.0	1.28	59234
HRV1	29.9	2191	2.98	30.0	2.98	18483

Total Monthly Salt Deposit = -26098
Harvestable Salt Deposit = 18483

Summary of year 3
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-46	-37	-127	-248	-346	-369	-393	-383	-332	-267	-179	-104	-2833
PND2	39	66	148	213	243	260	270	264	220	162	115	59	2059
HRV1	8	26	89	139	168	182	188	182	143	100	63	18	1306
Total	1	54	110	104	65	73	65	62	31	-5	-1	-26	533
Net	8	26	89	139	168	182	188	182	143	100	63	18	1306

Year = 4 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	7272	0.61	100.0	0.61	-45459
PND2	49.9	1739	1.29	50.0	1.30	44862
HRV1	30.0	816	2.98	30.0	2.98	7686

Total Monthly Salt Deposit = 7088
Harvestable Salt Deposit = 7686

Year = 4 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	14602	0.61	100.0	0.61	-39083
PND2	49.7	4849	1.32	50.0	1.32	71946
HRV1	29.9	1354	3.00	30.0	3.02	25712

Total Monthly Salt Deposit = 58575
Harvestable Salt Deposit = 25712

Year = 4 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	36898	0.60	100.0	0.60	-122426
PND2	49.4	18015	1.32	50.0	1.31	154708
HRV1	29.6	7113	3.05	30.0	3.06	89906

Total Monthly Salt Deposit = 122188
Harvestable Salt Deposit = 89906

Year = 4 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	58800	0.59	100.0	0.58	-228148
PND2	49.0	30283	1.29	50.0	1.27	222728
HRV1	29.4	12863	3.06	30.0	3.05	139724

Total Monthly Salt Deposit = 134304
Harvestable Salt Deposit = 139724

Year = 4 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	66562	0.58	100.0	0.57	-316305
PND2	48.8	34905	1.24	50.0	1.22	252304
HRV1	29.3	14700	3.04	30.0	3.03	167635

Total Monthly Salt Deposit = 103634
Harvestable Salt Deposit = 167635

Year = 4 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	73618	0.56	100.0	0.55	-346732
PND2	48.7	38479	1.20	50.0	1.18	268915
HRV1	29.2	15829	3.01	30.0	3.00	181906

Total Monthly Salt Deposit = 104089
Harvestable Salt Deposit = 181906

Year = 4 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	72428	0.55	100.0	0.54	-372010
PND2	48.7	37074	1.16	50.0	1.14	278686
HRV1	29.2	14347	3.00	30.0	3.00	188299
					Total Monthly Salt Deposit =	94975
					Harvestable Salt Deposit =	188299

Year = 4 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	69679	0.53	100.0	0.53	-364846
PND2	48.8	35301	1.13	50.0	1.12	271195
HRV1	29.3	13303	3.00	30.0	3.00	182277
					Total Monthly Salt Deposit =	88627
					Harvestable Salt Deposit =	182277

Year = 4 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	57853	0.52	100.0	0.52	-317555
PND2	49.0	28343	1.11	50.0	1.11	226379
HRV1	29.4	10496	3.00	30.0	3.00	143131
					Total Monthly Salt Deposit =	51955
					Harvestable Salt Deposit =	143131

Year = 4 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	39932	0.52	100.0	0.51	-256217
PND2	49.3	19121	1.10	50.0	1.10	166725
HRV1	29.6	7036	3.00	30.0	3.00	100178
					Total Monthly Salt Deposit =	10687
					Harvestable Salt Deposit =	100178

Year = 4 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	27548	0.51	100.0	0.51	-173318
PND2	49.5	12322	1.10	50.0	1.11	119152
HRV1	29.7	4525	3.00	30.0	3.00	62554
					Total Monthly Salt Deposit =	8388
					Harvestable Salt Deposit =	62554

Year = 4 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	11882	0.51	100.0	0.51	-103358
PND2	49.8	4147	1.11	50.0	1.12	62692
HRV1	29.9	1936	2.98	30.0	2.98	18576
					Total Monthly Salt Deposit =	-22090
					Harvestable Salt Deposit =	18576

Summary of year 4
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-45	-39	-122	-228	-316	-347	-372	-365	-318	-256	-173	-103	-2685
PND2	45	72	155	223	252	269	279	271	226	167	119	63	2140
HRV1	8	26	90	140	168	182	188	182	143	100	63	19	1308
Total	7	59	122	134	104	104	95	89	52	11	8	-22	762
Net	8	26	90	140	168	182	188	182	143	100	63	19	1308

APPENDIX C

The El Mex pond run with two salt crystallizers in series
and no bitterns recycle

This is the set-up for the El Mex pond system with two salt ponds in series and no bitterns recycle to pre-concentration ponds.
The Lake is the concentration of the open ocean.
The line of asterisks may be moved to accomodate more comments.
Notice that ponds whose names begin with H are assumed to be harvestable.
The net deposit of the system is summed from these harvestable ponds.

Pond Name	Area (Hect.)	Current Depth (cm)	Target Depth (cm)	K	Ion Weight Percents Na	Mg	Cl	SO4	Max. Flow (Tons/d)	Salt Rec.	Dsv. Fact.
**********											
Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0	0.00
PND1	2500	100	100	0.41	7.07	1.75	15.35	2.57	500000	0	0.05
PND2	500	50	50	0.50	7.02	2.16	15.14	3.17	400000	0	0.01
HRV1	200	30	30	0.67	5.73	2.87	14.57	4.20	300000	0	0.00
HRV2	200	30	30	0.67	5.73	2.87	14.57	4.20	300000	0	0.00

Ending Conditions File
Start Conditions From :elmex2.dat
Model run covered 5 years.
Model ran 42 months.
The first month run was June.
The last month run was December.
The evaporation factor was 1.000.
The precipitation factor was 1.000.
****

Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0.0	0.00
PND1	2500	100	100	0.14	9.69	0.49	16.07	0.89	500000	0.0	0.05
PND2	500	50	50	0.29	8.84	1.05	16.06	1.87	400000	0.0	0.01
HRV1	200	30	30	0.48	7.70	1.74	15.93	3.09	300000	0.0	0.00
HRV2	200	30	30	0.84	5.57	3.08	15.79	5.39	300000	0.0	0.00

El Mex Model Summary File "two-ponds"
Evaporation factor is 1.000 Precipitation factor is 1.000

Year = 1 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	126186	1.67	99.8	1.58	-765047
PND2	47.9	96352	2.19	50.0	2.15	196552
HRV1	26.1	84855	2.61	30.0	2.44	89717
HRV2	26.6	73671	2.98	30.0	2.86	85343

Total Monthly Salt Deposit = -393435
Harvestable Salt Deposit = 175060

Year = 1 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	108935	1.52	99.9	1.45	-674753
PND2	48.2	78782	2.15	50.0	2.10	211874
HRV1	26.8	66638	2.51	30.0	2.47	98548
HRV2	27.3	55208	2.97	30.0	2.94	93195

Total Monthly Salt Deposit = -271136
Harvestable Salt Deposit = 191743

Year = 1 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	107426	1.39	99.9	1.33	-612509
PND2	48.2	77924	2.06	50.0	1.99	215117
HRV1	26.9	66179	2.45	30.0	2.34	96721
HRV2	27.3	55214	2.96	30.0	2.85	90301

Total Monthly Salt Deposit = -210370
Harvestable Salt Deposit = 187022

Year = 1 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	82149	1.30	100.0	1.25	-504677
PND2	48.6	56858	1.98	50.0	1.92	184228
HRV1	27.7	47020	2.40	30.0	2.30	78506
HRV2	28.1	38051	2.94	30.0	2.83	71285

Total Monthly Salt Deposit = -170657
Harvestable Salt Deposit = 149792

Year = 1 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	50313	1.23	100.0	1.21	-369234
PND2	49.2	32334	1.95	50.0	1.91	140363
HRV1	28.7	25518	2.39	30.0	2.32	56222
HRV2	29.0	19428	2.98	30.0	2.92	49497
			Total Monthly Salt Deposit =			-123152
			Harvestable Salt Deposit =			105719

Year = 1 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	31521	1.19	100.0	1.18	-249432
PND2	49.5	18733	1.92	50.0	1.92	98365
HRV1	29.2	14042	2.37	30.0	2.40	37118
HRV2	29.4	10086	2.99	30.0	3.03	30880
			Total Monthly Salt Deposit =			-83068
			Harvestable Salt Deposit =			67999

Year = 1 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	9565	1.18	100.0	1.17	-110570
PND2	49.8	3961	1.94	50.0	1.95	44924
HRV1	29.8	2229	2.45	30.0	2.48	13833
HRV2	29.9	1172	3.07	30.0	3.10	8314
			Total Monthly Salt Deposit =			-43499
			Harvestable Salt Deposit =			22147

Summary of year 1
Months Calculated = June to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	0	0	0	-765	-675	-613	-505	-369	-249	-111	-3286
PND2	0	0	0	0	0	197	212	215	184	140	98	45	1091
HRV1	0	0	0	0	0	90	99	97	79	56	37	14	471
HRV2	0	0	0	0	0	85	93	90	71	49	31	8	429
Total	0	0	0	0	0	-393	-271	-210	-171	-123	-83	-43	-1295
Net	0	0	0	0	0	175	192	187	150	106	68	22	899

Year = 2 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	8882	1.17	100.0	1.17	-53260
PND2	49.9	5136	1.96	50.0	1.96	30764
HRV1	29.8	4173	2.48	30.0	2.47	8039
HRV2	29.8	3832	3.07	30.0	3.04	3071

Total Monthly Salt Deposit = -11386
Harvestable Salt Deposit = 11110

Year = 2 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	18540	1.16	100.0	1.15	-60070
PND2	49.7	10957	1.96	50.0	1.96	56265
HRV1	29.6	8565	2.48	30.0	2.48	17846
HRV2	29.7	6899	3.05	30.0	3.05	12310

Total Monthly Salt Deposit = 26351
Harvestable Salt Deposit = 30156

Year = 2 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	49379	1.13	100.0	1.11	-201603
PND2	49.2	32599	1.91	50.0	1.89	136387
HRV1	28.7	26375	2.39	30.0	2.40	51973
HRV2	28.9	20884	3.00	30.0	3.06	44998

Total Monthly Salt Deposit = 31756
Harvestable Salt Deposit = 96972

Year = 2 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	74744	1.08	100.0	1.06	-320324
PND2	48.7	48761	1.83	50.0	1.81	198982
HRV1	28.0	38871	2.31	30.0	2.32	79694
HRV2	28.4	30065	2.98	30.0	3.03	70094

Total Monthly Salt Deposit = 28446
Harvestable Salt Deposit = 149788

Year = 2 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	79987	1.03	99.9	1.00	-407970
PND2	48.6	50612	1.76	50.0	1.74	228812
HRV1	27.9	39284	2.26	30.0	2.27	94036
HRV2	28.4	29106	2.99	30.0	3.05	83508

Total Monthly Salt Deposit = -1613
Harvestable Salt Deposit = 177545

Year = 2 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	86913	0.97	99.9	0.95	-432184
PND2	48.5	54112	1.68	50.0	1.67	245574
HRV1	27.8	41424	2.19	30.0	2.22	101953
HRV2	28.3	30055	2.98	30.0	3.05	90445

Total Monthly Salt Deposit = 5788
Harvestable Salt Deposit = 192398

Year = 2 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	86270	0.92	99.9	0.89	-456269
PND2	48.5	53218	1.62	50.0	1.59	255480
HRV1	27.8	40452	2.13	30.0	2.13	106226
HRV2	28.4	29087	2.96	30.0	2.99	93767

Total Monthly Salt Deposit = -797
Harvestable Salt Deposit = 199993

Year = 2 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	84597	0.87	100.0	0.85	-439022
PND2	48.6	52418	1.56	50.0	1.51	249848
HRV1	27.8	40036	2.08	30.0	1.99	103541
HRV2	28.4	29085	2.95	30.0	2.83	90982

Total Monthly Salt Deposit = 5349
Harvestable Salt Deposit = 194523

Year = 2 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	67058	0.83	100.0	0.81	-374445
PND2	48.8	39450	1.51	50.0	1.47	209615
HRV1	28.4	29013	2.05	30.0	1.94	84116
HRV2	28.8	20059	2.95	30.0	2.79	71540

Total Monthly Salt Deposit = -9175
Harvestable Salt Deposit = 155656

Year = 2 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	42864	0.80	100.0	0.79	-310251
PND2	49.3	23270	1.48	50.0	1.47	155471
HRV1	29.0	15921	2.01	30.0	2.00	60561
HRV2	29.4	9718	2.91	30.0	2.90	50504

Total Monthly Salt Deposit = -43715
Harvestable Salt Deposit = 111065

Year = 2 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	33001	0.79	100.0	0.78	-203695
PND2	49.4	19010	1.47	50.0	1.45	109643
HRV1	29.2	14001	2.02	30.0	1.95	40575
HRV2	29.4	10088	2.93	30.0	2.83	31573

Total Monthly Salt Deposit = -21904
Harvestable Salt Deposit = 72148

Year = 2 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	10365	0.78	100.0	0.77	-118938
PND2	49.8	3495	1.46	50.0	1.47	55221
HRV1	29.9	1274	2.01	30.0	2.05	17747
HRV2	29.9	0	2.88	30.0	2.93	9984

Total Monthly Salt Deposit = -35986
Harvestable Salt Deposit = 27731

Summary of year 2
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-53	-60	-202	-320	-408	-432	-456	-439	-374	-310	-204	-119	-3378
PND2	31	56	136	199	229	246	255	250	210	155	110	55	1932
HRV1	8	18	52	80	94	102	106	104	84	61	41	18	766
HRV2	3	12	45	70	84	90	94	91	72	51	32	10	653
Total	-11	26	32	28	-2	6	-1	5	-9	-44	-22	-36	-27
Net	11	30	97	150	178	192	200	195	156	111	72	28	1419

Year = 3 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	6980	0.77	100.0	0.77	-44478
PND2	49.9	1937	1.49	50.0	1.50	40810
HRV1	29.9	516	2.09	30.0	2.12	11328
HRV2	30.0	0	2.95	30.0	2.97	4031

Total Monthly Salt Deposit = 11691
Harvestable Salt Deposit = 15359

Year = 3 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	14150	0.77	100.0	0.77	-38196
PND2	49.8	4996	1.51	50.0	1.53	67302
HRV1	29.8	2138	2.18	30.0	2.23	20777
HRV2	29.9	377	3.03	30.0	3.09	12452

Total Monthly Salt Deposit = 62335

Harvestable Salt Deposit = 33229

Year = 3 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	49403	0.76	100.0	0.75	-175663
PND2	49.1	31399	1.47	50.0	1.44	148593
HRV1	28.7	24894	2.04	30.0	1.96	55814
HRV2	29.0	19445	2.91	30.0	2.84	46177

Total Monthly Salt Deposit = 74920

Harvestable Salt Deposit = 101991

Year = 3 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	66837	0.74	99.9	0.72	-259530
PND2	48.8	39138	1.43	49.9	1.37	217507
HRV1	28.4	28807	2.00	30.0	1.84	84102
HRV2	28.8	20051	2.95	29.9	2.74	70601

Total Monthly Salt Deposit = 112680

Harvestable Salt Deposit = 154703

Year = 3 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	63846	0.71	100.0	0.70	-354568
PND2	48.9	32380	1.37	50.0	1.38	245669
HRV1	28.7	20302	1.94	30.0	2.02	98754
HRV2	29.2	9727	2.93	30.0	3.11	84906

Total Monthly Salt Deposit = 74762

Harvestable Salt Deposit = 183660

Year = 3 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	79276	0.68	100.0	0.67	-380658
PND2	48.6	44763	1.32	50.0	1.32	262302
HRV1	28.1	31533	1.87	30.0	1.96	106657
HRV2	28.7	20036	2.90	30.0	3.08	91886
					Total Monthly Salt Deposit =	80187
					Harvestable Salt Deposit =	198542

Year = 3 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	78882	0.66	100.0	0.65	-408204
PND2	48.6	44192	1.28	50.0	1.27	271626
HRV1	28.2	30889	1.83	30.0	1.89	110867
HRV2	28.7	19385	2.89	30.0	3.03	95198
					Total Monthly Salt Deposit =	69487
					Harvestable Salt Deposit =	206065

Year = 3 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	77110	0.63	100.0	0.62	-400242
PND2	48.6	43403	1.24	50.0	1.22	264381
HRV1	28.2	30500	1.79	30.0	1.79	107843
HRV2	28.8	19399	2.88	30.0	2.90	92323
					Total Monthly Salt Deposit =	64306
					Harvestable Salt Deposit =	200166

Year = 3 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.4	59301	0.61	100.0	0.61	-341665
PND2	49.0	30188	1.21	50.0	1.22	222143
HRV1	28.7	19194	1.78	30.0	1.85	87885
HRV2	29.2	10045	2.91	30.0	3.05	72279
					Total Monthly Salt Deposit =	40642
					Harvestable Salt Deposit =	160164

Year = 3 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	43910	0.60	100.0	0.60	-282288
PND2	49.2	23493	1.19	50.0	1.20	163000
HRV1	29.0	15888	1.75	30.0	1.82	63388
HRV2	29.4	9707	2.86	30.0	3.00	51275
				Total Monthly Salt Deposit =		-4626
				Harvestable Salt Deposit =		114663

Year = 3 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	34076	0.59	100.0	0.59	-200564
PND2	49.4	19317	1.18	50.0	1.17	116051
HRV1	29.2	14044	1.75	30.0	1.72	43211
HRV2	29.4	10118	2.86	30.0	2.80	32498
				Total Monthly Salt Deposit =		-8803
				Harvestable Salt Deposit =		75709

Year = 3 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	11362	0.59	100.0	0.59	-110039
PND2	49.8	3781	1.18	50.0	1.19	61170
HRV1	29.8	1310	1.76	30.0	1.81	19876
HRV2	29.9	0	2.84	30.0	2.88	10335
				Total Monthly Salt Deposit =		-18658
				Harvestable Salt Deposit =		30211

Summary of year 3
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-44	-38	-176	-260	-355	-381	-408	-400	-342	-282	-201	-110	-2996
PND2	41	67	149	218	246	262	272	264	222	163	116	61	2081
HRV1	11	21	56	84	99	107	111	108	88	63	43	20	811
HRV2	4	12	46	71	85	92	95	92	72	51	32	10	664
Total	12	62	75	113	75	80	69	64	41	-5	-9	-19	559
Net	15	33	102	155	184	199	206	200	160	115	76	30	1474

Year = 4 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.9	7989	0.59	100.0	0.59	-49045
PND2	49.9	2238	1.20	50.0	1.21	46659
HRV1	29.9	559	1.84	30.0	1.87	13462
HRV2	30.0	0	2.91	30.0	2.92	4402
			Total Monthly Salt Deposit =			15478
			Harvestable Salt Deposit =			17864

Year = 4 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	15154	0.58	100.0	0.58	-44086
PND2	49.7	5103	1.23	50.0	1.24	73987
HRV1	29.8	1914	1.92	30.0	1.96	23285
HRV2	29.9	94	2.99	30.0	3.04	12933
			Total Monthly Salt Deposit =			66119
			Harvestable Salt Deposit =			36218

Year = 4 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.6	41439	0.58	100.0	0.57	-159141
PND2	49.3	22305	1.20	50.0	1.21	156692
HRV1	29.1	15382	1.82	30.0	1.87	58250
HRV2	29.4	9762	2.89	30.0	3.01	46520
			Total Monthly Salt Deposit =			102321
			Harvestable Salt Deposit =			104770

Year = 4 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	68089	0.57	100.0	0.56	-245670
PND2	48.8	39406	1.17	50.0	1.13	224316
HRV1	28.3	28806	1.77	30.0	1.62	87201
HRV2	28.8	20067	2.91	30.0	2.67	71654
			Total Monthly Salt Deposit =			137501
			Harvestable Salt Deposit =			158855

Year = 4 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	64899	0.55	100.0	0.55	-343593
PND2	48.9	32619	1.13	50.0	1.12	255287
HRV1	28.6	20260	1.69	30.0	1.69	102080
HRV2	29.2	9702	2.84	30.0	2.87	86111
				Total Monthly Salt Deposit =		99885
				Harvestable Salt Deposit =		188190

Year = 4 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	71115	0.54	100.0	0.53	-349381
PND2	48.7	35361	1.11	50.0	1.11	272752
HRV1	28.5	21682	1.69	30.0	1.76	109403
HRV2	29.1	10051	2.92	30.0	3.10	91726
				Total Monthly Salt Deposit =		124499
				Harvestable Salt Deposit =		201129

Year = 4 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	79912	0.53	100.0	0.52	-396031
PND2	48.6	44432	1.07	50.0	1.05	278893
HRV1	28.1	30864	1.61	30.0	1.59	114002
HRV2	28.7	19380	2.82	30.0	2.80	96587
				Total Monthly Salt Deposit =		93451
				Harvestable Salt Deposit =		210589

Year = 4 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.2	69196	0.51	100.0	0.51	-378660
PND2	48.8	34372	1.05	50.0	1.05	273669
HRV1	28.5	21014	1.61	30.0	1.64	110486
HRV2	29.1	9710	2.87	30.0	2.97	92480
				Total Monthly Salt Deposit =		97976
				Harvestable Salt Deposit =		202966

Year = 4 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.3	60253	0.50	100.0	0.50	-334003
PND2	48.9	30445	1.03	50.0	1.03	227960
HRV1	28.7	19192	1.59	30.0	1.64	90473
HRV2	29.2	10042	2.86	30.0	2.98	73138
				Total Monthly Salt Deposit =		57568
				Harvestable Salt Deposit =		163611

Year = 4 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.5	44632	0.50	100.0	0.49	-280139
PND2	49.2	23700	1.01	50.0	1.01	167509
HRV1	29.0	15911	1.56	30.0	1.57	65333
HRV2	29.3	9738	2.81	30.0	2.82	51907
				Total Monthly Salt Deposit =		4610
				Harvestable Salt Deposit =		117240

Year = 4 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.7	25393	0.49	100.0	0.49	-167869
PND2	49.5	9793	1.02	50.0	1.04	121458
HRV1	29.6	4156	1.64	30.0	1.70	44327
HRV2	29.8	63	2.95	30.0	3.07	31392
				Total Monthly Salt Deposit =		29308
				Harvestable Salt Deposit =		75719

Year = 4 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	99.8	12468	0.49	100.0	0.49	-99175
PND2	49.8	4553	1.04	50.0	1.05	64226
HRV1	29.8	2074	1.72	30.0	1.74	20241
HRV2	29.9	1056	3.08	30.0	3.08	8343
				Total Monthly Salt Deposit =		-6365
				Harvestable Salt Deposit =		28584

Summary of year 4
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	-49	-44	-159	-246	-344	-349	-396	-379	-334	-280	-168	-99	-2847
PND2	47	74	157	224	255	273	279	274	228	168	121	64	2163
HRV1	13	23	58	87	102	109	114	110	90	65	44	20	839
HRV2	4	13	47	72	86	92	97	92	73	52	31	8	667
Total	15	66	102	138	100	124	93	98	58	5	29	-6	822
Net	18	36	105	159	188	201	211	203	164	117	76	29	1506

APPENDIX D

Pond Model

<u>ELMEXMOD</u>

Source Code

```
program ElMexModel;
{ Version 1.01, October 31, 1989. The program ElMexMod is a model which
  simulates salt production in solar ponds given the weather conditions
  at the El Nasr Salines Co. El Mex site. The evaporation data and the
  control point for the system are internally set in the program and can't
  be changed without recompiling the program. The only input to the program
  is the input data file and user supplied information.
  Version 1.01 update allows the user to use any editor desired by renaming
  the editor ELMEXED with the same extension as the original program had.

  The basic operation of the program follows:
  1. A GSL header is displayed with the version of the program.
  2. The program requests the name of a data file for system setup. This
     file sets up the pond system. Certain conventions are used in the set
     up. These are explained later. After the data is read it is displayed
     and the user has the option of changing the data.
  3. Next the program requests information for the specific run.
  4. The program calculates the current run. The program calculates each pond
     each day. The calculational procedure for each day is to begin with the
     last pond. The evaporation is determined for the pond through the
     evaporation data. The flow from the last pond is determined by looking
     at a control point. The recycle flow is set to the brine flowing from
     the last pond. Once the outflow is known a material balance is done by
     assuming no inflow. The balance is iterative on the amount of salt
     deposited. Once the resulting Na material balance matches what the
     equilibrium Na value should be within the tolerance the balance is
     completed. New weight percents are calculated for all ions from the
     material by a material balance on each ion. Next a flow required to
     keep the pond at a target level is calculated. This flow is mixed
     with the brine that was remaining in the pond. The daily statistics
     are for the pond are recorded and the calculation proceeds to the next
     pond. This is done each day of each month of each year for the duration
     of the run.
  5. At the end of each day the program will print a material balance file
     if the user has requested it. Otherwise, the records are kept to be
     printed at the end of each month and year.
  6. At the completion of the loops through the ponds, days, month and
     years the statistics files are closed and the program requests a file
     name for the ending conditions file. This file is kept so an additional
     run can be made to continue the current simulation. After this file is
     written the program terminates.

   Notes for Turbo Pascal programmers: This program has been compilied in
     Turbo Pascal Version 5.5. The program was written to be compatable
     with any type of display unit and any type of PC based hardware. The
     program doesn't require the use of a numeric coprocessor but it will
     use it if available. This is accomplished through the use of the
     complier directives $E and $N. The $M directive allows the program to
     to open an external editing program while running.

     There are three units used by the program; the two standard units dos
     and crt and a unit called StrUnit. StrUnit manipulates and generates
     string variables. For the program to compile the compilier must locate
     the StrUnit.TPU file as well as the .TPU files for both dos and crt.

     The program is straight forward in the method of programing. Simple
     procedures used throughout the program are the first procedures to be
     listed. The procedure BalancePond does the bulk of the calculational
     portional of the program. BalancePond has the sub procedures which take
     care of determining the flow from the last pond (LastPondFlowOut), main-
     taining the target level in each pond (AdjustLevel) and determining the
     ion weight percents (Chem). All calculations are done in metric tons and
     weight percents. Record variables are used liberaly to facilitate
     programing.
```

```
    This program was written by Dave Butts and Chad McCleary of
    GSL Solar Consultants and Advisors
    P.O.Box 1190
    Ogden, Utah
    84402

    Tel. 801-731-3100 }

{$M 8192,0,0}                                   { Leave memory for child process. }
{$E+}                                               { Emulation processor switch. }
{$N+}                                                  { Numeric processor switch. }
uses dos, crt, StrUnit;

const
  MaxPonds = 15;
  MaxMonths = 100;
  Editor = 'ELMEXED ';
  delayvalue = 100;
  bell = #7;
  ProgramVersion = 1.01;

  { The evaporation data is the monthly evaporation expressed as tons per
    hectare per month. Likewise, the rain is expressed as tons per hectare
    per month. The evapdat array contains the constants to make functional
    (linear) evaporation calculations based on the weight percent magnesium. }

  evapdat: ARRAY[1..13, 1..4] OF REAL =
       {  Inter.  Slope   Rain   Days  }
      ((  805.0,  115.0,  410.0,  31),  { January }
       (  956.0,  129.5,  390.0,  28),  { February }
       ( 1167.0,  144.0,  110.0,  31),  { March }
       ( 1533.0,  181.0,   20.0,  30),  { April }
       ( 1700.0,  181.0,    0.0,  31),  { May }
       ( 1810.0,  187.0,    0.0,  30),  { June }
       ( 1810.0,  187.0,    0.0,  30),  { July }
       ( 1810.0,  187.0,    0.0,  31),  { August }
       ( 1533.0,  181.0,   10.0,  30),  { September }
       ( 1167.0,  144.0,   50.0,  31),  { October }
       (  956.0,  129.5,  140.0,  30),  { November }
       (  805.0,  115.0,  340.0,  30),  { December }
       (15730.0, 1777.0, 1470.0, 365)); { Year }

  MonthNames : array[1..12] of string[9] =          { Names of the months. }
             ('January','February','March','April',
              'May','June','July','August',
              'September','October','November','December');

  MonthDays : array[1..12, 1..3] of integer = { Ordinal days of the months. }
         { FirstDay LastDay Counter }
          ((  1,       31,       1),
           ( 32,       59,       2),
           ( 60,       90,       3),
           ( 91,      120,       4),
           (121,      151,       5),
           (152,      181,       6),
           (182,      212,       7),
           (213,      243,       8),
           (244,      273,       9),
           (274,      304,      10),
           (305,      334,      11),
           (335,      365,      12));
```

```
{ Molecular Weights of the Ions }
  MW: array[1..6] of real =
      ( 39.0938*2,  { K2 }
        22.98977*2, { Na2 }
        24.305,     { Mg }
        35.453*2,   { Cl2 }
        96.0596,    { SO4 }
        18.0152 );  { H2O }

{ These values control the convergence for pond balancing. }
  MaxIterations  = 100;
  Tol = 0.0000000001;

type
  PondRecord = RECORD
    Name        : STRING[4];
    Area        : REAL;
    Depth       : REAL;
    TargetDepth : REAL;
    Inventory   : REAL;
    K           : REAL;
    Na          : REAL;
    Mg          : REAL;
    Cl          : REAL;
    SO4         : REAL;
    MaxFlow     : REAL;
    Recycle     : REAL;
    OutFlow     : REAL;
    SDFact      : REAL;
  end;
  PondData    = array[0.. MaxPonds] of PondRecord;

  MonthRecord = RECORD
    Name      : STRING;
    FirstDay  : INTEGER;
    LastDay   : INTEGER;
    Counter   : INTEGER;
  end;
  MonthInfo   = array[1..12] of MonthRecord;

  DayStatRecord = RECORD
    BeginningInventory  : REAL;
    Mg0                 : REAL;
    Na0                 : REAL;
    InFlow              : REAL;
    Mg1                 : REAL;
    Na1                 : REAL;
    Recycle             : REAL;
    Mg2                 : REAL;
    Na2                 : REAL;
    EndingInventory     : REAL;
    Mg3                 : REAL;
    Na3                 : REAL;
    OutFlow             : REAL;
    Evaporation         : REAL;
    SaltDeposit         : REAL;
  end;
  DayStats    = array[0.. MaxPonds] of DayStatRecord;
```

```
  MonthStatRecord = RECORD
    DailyDepthSum         : REAL;
    DailyOutFlowSum       : REAL;
    DailyMgSum            : REAL;
    EndingDepth           : REAL;
    EndingMg              : REAL;
    DailySaltDepositSum   : REAL;
  end;
  MonthStats = array[0..MaxPonds] of MonthStatRecord;

var
  Command: STRING[127];                 { String for executing dos commands. }


  { RECORD Variables }
  MonthData    : MonthStats;                           { The monthly statistics. }
  DayData      : DayStats;            { The daily material balance statistics. }
  Months       : MonthInfo;                         { The record of month data. }
  Ponds        : PondData;                     { The array of pond information. }
  { The Yearly Statistics }
  YearData : array[1..12, 1..MaxPonds] of REAL;

  { File Name Variables }
  InFileName,                     { Pond system initial condition file name. }
  BalOutFileName,                        { Daily material balance file name. }
  OutFileName,                       { Monthly and yearly summary file name. }
  EndingFileName : STRING;                     { Ending conditions file name. }

  { File Variables for OutPut }
  BalOutFile,                                 { Daily material balance file. }
  OutFile     : TEXT;                     { Monthly and yearly summary file. }

  { Various Input and Output Variables }
  InChar : CHAR;
  DisplayDay,
  InString: STRING;

  { Counter Variables }
  i, j, InVal, CodeVar,
  Pond, LastPond,
  Day, BeginDay, BeginningDay, DaysRun, FirstMonth, LastMonth,
  Month, BeginMonth, EndMonth, MonthsRun, NumberOfMonths,
  Year, NumberOfYears: INTEGER;
  PreviousOutFlow, PreviousMg : REAL;

  { Balance Variables }
  Tr, Kr, Mgr, Nar, Clr, SO4r: REAL;        { The recycle flow and weight %. }
  Tin, Kin, Nain, Mgin, Clin, SO4in: REAL;          { The flow into the pond. }
  Tout, Tb, Kb, Nab, Mgb, Clb, SO4b: REAL;         { The beginning inventory. }
  Tf, Kf, Naf, Mgf, Clf, SO4f, H2O: REAL;  { The values calculated in Chem. }
  W, EvapFact, PrecipFact : REAL;           { The evaporation for the pond. }
  Cp, CpRange : REAL;                              { Last pond flow controls. }
  iotest : INTEGER;  { Input Output checking flag. }

  { Flags for controling Calculations, Printing and Reading }
  FirstDay, MonthPrn, BalancePrint, ReadFile, EvapChanged,
  ControlChanged: BOOLEAN;

procedure WaitForEnter;

    { The procedure WaitForEnter displays a prompt
      on the screen, and waits for the user to press
      the Enter key }

begin                                                          { WaitForEnter }
  writeln;
  write ('Press <Enter> to continue. ');
  readln;
  writeln;
end;                                                           { WaitForEnter }
```

```
function Density( x : REAL) : REAL;

        { The Density function calculates the density of a
          brine given the weight percent Mg++ in the brine.
          The value returned is tons per cubic meter. }

begin;                                                                  { Density }
  if x <= 0.0 then
    begin
      gotoxy ( 10, 15);
      writeln ('The value of x in density function is  ',x:6:2);
      write ('What is a valid value for x in pond ',Ponds[Pond].Name,' ?');
      readln (x);
    end;
  Density := 1.1788 * EXP( LN (x) * 0.0695);
end;                                                                    { Density }

procedure GSLHeader;
    { The GSLHeader program clears the screen and displays the GSL
      Solar Consultants and Advisors logo.
      The program uses the following procedures from the CRT unit:
      CLRSCR
      gotoxy }

begin;                                                                { GSLHeader }
  clrscr;
  TextColor (15);
  gotoxy (18, 3);
  write ('     GGG              SSS           LLLL');
  gotoxy (18, 4);
  write ('  GGGGGGGGG       SSSSSSSSS         LLLL');
  gotoxy (18, 5);
  write (' GGGG    GGGG    SSSS    SSSS       LLLL');
  gotoxy (18, 6);
  write ('GGGG      GGGG   SSSS               LLLL');
  gotoxy (18, 7);
  write ('GGGG              SSSS              LLLL');
  gotoxy (18, 8);
  write ('GGGG                 SSSS           LLLL');
  gotoxy (18, 9);
  write ('GGGG                   SSSS         LLLL');
  gotoxy (18, 10);
  write ('GGGG    GGGGGG           SSSS       LLLL');
  gotoxy (18, 11);
  write ('GGGG      GGGG            SSSS      LLLL');
  gotoxy (18, 12);
  write (' GGGG    GGGG    SSSS     SSSS      LLLL');
  gotoxy (18, 13);
  write ('  GGGGGGGGG       SSSS   SSSS       LLLLLLLLLLLLL');
  gotoxy (18, 14);
  write ('    GGGGG            SSSSSSS        LLLLLLLLLLLLL');
  gotoxy (18, 16);
  write ('        SOLAR CONSULTANTS and ADVISORS');
  gotoxy (18, 17);
  write ('          El Mex Model Version ',ProgramVersion:4:2);
  writeln;
  WaitForEnter;
end;                                                                  { GSLheader }
```

```
procedure Input;

{ Procedure Input begins by loading the Months record with the names, first
  days, last days and month number of each month. The procedure then goes on
  to reading a data file which contains the initial conditions for the pond
  system. If the boolean variable is set to TRUE the procedure requests a
  file name for reading. Otherwise it reads the current file. The procedure
  returns the number of ponds in the system and the name of the file read.
  The read section skips over all lines up to and including a line of 40
  asterisks, (*). This line signals the beginning of the data section. }


var
  FileStart      : STRING[30];    { String flag in the to signal read start. }
  tempStart      : STRING[6];
  InFile         : TEXT;                                    { Data file name. }
  j              : INTEGER;

procedure ChangeEvapControl;
{ This procedure allows the user to change the evaporation and/or the
  control point data of the system. There are two sub procedures, ChangeEvap
  and ChangeControl. }
type
  charsettype = SET OF CHAR;
var
  MenuChars : charsettype;

procedure ChangeEvap;
begin                                                          { ChangeEvap }
  clrscr;
  gotoxy (10, 10);
  write ('You''ve selected change the evaporation data.');
  gotoxy (10, 11);
  write ('Do you want to continue? ');
  InChar := upcase(readkey);
  write (InChar);
  delay (delayvalue);
  while InChar = 'Y' do
    begin
      EvapChanged := True;
      gotoxy (10, 11);
      clreol;
      write ('What month to change the data for? Numbers only. ');
      readln (Month);
      gotoxy (10, 11);
      clreol;
      write ('Changing evaporation data for ',Months[Month].Name);
      gotoxy (10, 12);
      clreol;
      write ('What is the intercept for ',Months[Month].Name,'? ');
      readln (EvapDat [Month, 1]);
      gotoxy (10, 13);
      clreol;
      write ('What is the slope for ',Months[Month].Name,'? ');
      readln (EvapDat [Month, 2]);
      gotoxy (10, 14);
      clreol;
      write ('What is the rain for ',Months[Month].Name,'? ');
      readln (EvapDat [Month, 3]);
      gotoxy (10, 15);
      clreol;
      write ('Do you want to change another? ');
      InChar := upcase(readkey);
      write (InChar);
      delay (delayvalue);
    end;
end;                                                           { ChangeEvap }
```

```
procedure ChangeControl;
begin                                                          { ChangeControl }
  ControlChanged := True;
  clrscr;
  gotoxy (10, 10);
  write ('You''ve selected change the control point.');
  gotoxy (10, 11);
  write ('The current control point is ',Cp:4:2,'.');
  gotoxy (10, 12);
  write ('The current control range is ',CpRange:4:2,'.');
  repeat
    begin
      gotoxy (10, 15);
      clreol;
      gotoxy (10, 13);
      clreol;
      write ('What is the new control point? ');
      readln (Cp);
      gotoxy (10, 14);
      clreol;
      write ('What is the new control range? ');
      readln (CpRange);
      gotoxy (10, 15);
      write ('Are these values correct? ');
      InChar := upcase(readkey);
      write (InChar);
      delay (delayvalue);
    end;
  until InChar = 'Y';

end;                                                           { ChangeControl }

begin                                                      { ChangeEvapControl }
  MenuChars := ['E','C','B','N'];
  clrscr;
  gotoxy (10, 10);
  write ('The change flag was detected while reading ',InFileName,'.');
  gotoxy (10, 11);
  write ('Do you want to change <E>vaporation data');
  gotoxy (10, 12);
  write ('                      <C>ontrol point data');
  gotoxy (10, 13);
  write ('                      <B>oth');
  gotoxy (10, 14);
  write ('                      <N>othing');
  repeat
    begin
      gotoxy (10, 15);
      clreol;
      write ('Enter the first letter of your choice ');
      InChar := upcase(readkey);
      write (InChar);
      delay (delayvalue);
    end;
  until InChar in MenuChars;
  if InChar = 'E' then ChangeEvap;
  if InChar = 'C' then ChangeControl;
  if InChar = 'B' then
    begin
      ChangeControl;
      ChangeEvap;
    end;
  InChar := 'N';
end;                                                       { ChangeEvapControl }
```

```
begin
                                                                    { Input }
  for i := 1 to 12 do                          { First load the months record. }
    begin
      with Months[i] do
        begin
          Name := MonthNames[i];
          FirstDay := MonthDays[i, 1];
          LastDay  := MonthDays[i, 2];
          Counter  := MonthDays[i, 3];
        end;
    end;
  repeat
    begin
      if ReadFile then
        begin
          repeat
            begin
              clrscr;
              gotoxy (5, 10);
              write ('What INPUT data file do you want to read? ');
              readln (InFileName);
              gotoxy(5, 11);
              write ('Read input file ',InFileName,' OK? ');
              InChar := upcase(readkey);
              writeln (InChar);
              delay (delayvalue);
            end;
          until InChar = 'Y';
        end;
        assign (InFile, InFileName);      { Open the input file for reading. }
{$I-}
        reset (InFile);
{$I+}
        iotest := ioresult;
        if iotest <> 0 then
          begin
            writeln (InFileName,' wasn''t found. Try again.');
            WaitForEnter;
          end;
    end;
  until iotest = 0;
  repeat                       { Skip the comment section of the input file. }
  readln (InFile, tempStart, FileStart);
  until FileStart = '********************************';
  if tempStart = 'CHANGE' then ChangeEvapControl;
  i := 0;

  while not eof (InFile) do                       { Begin reading the data. }
    begin
      with Ponds[ i ] DO
        begin
          readln (InFile, Name,
                          Area,
                          Depth,
                          TargetDepth,
                          K,
                          Na,
                          Mg,
                          Cl,
                          SO4,
                          MaxFlow,
                          Recycle,
                          SDFact);
        end;
      inc(i);
    end;
  close (InFile);
  LastPond := i - 1;
```

```
    if LastPond > MaxPonds then
      begin
        gotoxy (10, 20);
        writeln ('Maximum number of ponds is limited to ',MaxPonds:3,'.');
        writeln (InFileName,' has ',LastPond:3,' ponds.');
        writeln ('Please check your input data.');
        WaitForEnter;
        Input;
      end;
    Ponds[0].Inventory := 0.0;        { Calculate the inventory for each pond. }
    for i := 0 TO LastPond DO
      begin
        with Ponds[i] DO
          begin
            Inventory := Area * Depth * 100.0 * Density(Mg);
          end;
      end;
  end;                                                              { Input }

  procedure WriteEndingConditionsFile;
  { This procedure writes the ending conditions to a file that can be used as
    the starting file for another run. }

  var
    EndingFile : text;

  begin                                         { WriteEndingConditionsFile }
    repeat
      begin
        write (bell);
        gotoxy (10, 20);
        clreol;
        write ('What file do you want the ending conditions written to? ');
        readln (EndingFileName);
        gotoxy (10, 21);
        clreol;
        write ('Write ending conditions to ',EndingFileName,'. OK? ');
        InChar := upcase(readkey);
        write (InChar);
        delay (delayvalue);
      end;
    until InChar = 'Y';
    assign (EndingFile, EndingFileName);
    rewrite (EndingFile);
    writeln (EndingFile,'Ending Conditions File');
    writeln (EndingFile,'Start Conditions From :',InFileName);
    writeln (EndingFile,'Model run covered ',NumberOfYears:2,' years.');
    writeln (EndingFile,'Model ran ',NumberOfMonths,' months.');
    writeln (EndingFile,'The first month run was ',Months[FirstMonth].Name,
                        '.');
    writeln (EndingFile,'The last month run was ',Months[LastMonth].Name,'.');
    writeln (EndingFile,'The evaporation factor was ',EvapFact:5:3,'.');
    writeln (EndingFile,'The precipitation factor was ',PrecipFact:5:3,'.');
    writeln (EndingFile,'**********************************************',
                        '*****************');
    for Pond := 0 to LastPond do
      begin
        with Ponds[Pond] do
          begin
            writeln (EndingFile,Name,'  ',round(Area):5,'  ',round(Depth):4,'   ',
                     round(TargetDepth):4,'  ',K:6:2,Na:6:2,Mg:6:2,Cl:6:2,
                     SO4:6:2,MaxFlow:9:0,'  ',Recycle:3:1,'  ',SDFact:4:2);
          end;
      end;
    close (EndingFile);
  end;                                          { WriteEndingConditionsFile }
```

```
function Evap : REAL;

        { The Evap function calculates the evaporation
          at the El Mex site for a given Mg weight percent and a
          given month. The evaporation is expressed in tons per
          hectare per day. This evaporation function can be
          modified by changing the constant array, evapdat}

var
  x, a, b, rain, days: REAL;

begin                                                          { Evap }
  x := Ponds[Pond].Mg;
  a := evapdat[month, 1];
  b := evapdat[month, 2];
  rain := evapdat[month, 3];
  days := evapdat[month, 4];
  Evap := ((a - b * x) * EvapFact - rain * PrecipFact) / days;

end;                                                           { Evap }

procedure ShowData;

{ Procedure ShowData displays the pond data that has been read and asks the
  user to confirm that the data is correct. If the user signals an error in
  the pond data ShowData asks if a new file should be read or if editing of
  the current file should be done.
  If editing is requested the procedure exits to the text editor EDWIN with
  the file that was just read. Upon completion of EDWIN the file is re-read
  and displayed again.
  If a new file is requested the procedure simply informs procedure Input of
  the request.
  The procedure ShowData ends when the user signals the data to be correct. }


begin                                                      { ShowData }
  repeat                           { Show the data until the user OK's it. }
    begin                                              { Echo what was read. }
      clrscr;
      writeln ('Data read from ',InFileName,':');
      writeln ('Pond Pond Curnt Tar                   Ion Weight Percents',
               '          Pond   Pond  Salt');
      writeln ('Name Area Depth Depth Inventory %K    %Na    %Mg    %Cl   ',
               '%SO4 Max Flow Rec.  Dis.');
      writeln ('     (Hect) (cm)  (cm)   (Tons)                          ',
               '         (m^3/d)       Fact');
      for i := 0 to LastPond do
        begin
          with Ponds[i] do
            begin
              writeln (Name,' ',
                       Area:4:0,'   ',
                       Depth:3:0,'    ',
                       TargetDepth:3:0,' ',
                       Inventory:8:0,' ',
                       K:4:2,' ',
                       Na:5:2,' ',
                       Mg:5:2,' ',
                       Cl:5:2,' ',
                       SO4:5:2,' ',
                       MaxFlow:8:0,' ',
                       Recycle:1:1,' ',
                       SDFact:4:2);
            end;
        end;
```

```
      write ('Is all the data correct? <Y> or <N> ');
      InChar := UPCASE(READKEY);
      write (InChar);
      delay (delayvalue);

      if InChar = 'N' then              { User saw an error in the data read. }
        begin
          gotoxy (1, 22);
          write ('**User specified error in input data.**');
          gotoxy (1, 23);
          write ('Do you want to read a different file? <Y> or <N> ');
          InChar := UPCASE (READKEY);
          write (InChar);
          delay (delayvalue);

          if InChar = 'Y' then              { Read a new file if desired... }
            begin
              InChar := 'N';
              ReadFile := TRUE;
            end
          else
            begin
              gotoxy (1, 24);
              write ('Program will exit to the editor with '+InFileName);
              WaitForEnter;
              Command := Editor + InFileName;
              SwapVectors;
              Exec(GetEnv('COMSPEC'), '/C ' + Command);
              SwapVectors;
              if DosError <> 0 then
              WriteLn('Could not execute COMMAND.COM');
              WriteLn;
              ReadFile := FALSE;
            end;
          Input;
        end;
    end;
  until InChar = 'Y';
end;                                                          { ShowData }


procedure MaterialBalancePrint;
{ This procedure prints the material balance to the Balout file. The material
  balance is printed at the end of each days calculation. The DayData array
  contains the material balance information for each pond, each day. }

begin                                              { MaterialBalancePrint }
  writeln (BalOutFile);
  writeln (BalOutFile, Months[Month].Name + ' ' + DisplayDay);
  writeln (BalOutFile,'      Beginning  Flow   Recycle   Ending     ',
                     'Flow  Salt ');
  writeln (BalOutFile,'      Inventory  In     In      = Inventory  Out   ',
                     'Deposit  Evaporation');
  for Pond := 1 to LastPond do
    begin
{ First print the mass balance. }
      write (BalOutFile, Ponds[Pond].Name);
      writeln (BalOutFile,' ------------------------------------------',
                         '-----------------');
```

```
    with DayData[Pond] do
      begin
        writeln (BalOutFile,'Mass ',
                 round(BeginningInventory):9,' ',
                 round(InFlow):6,'    ',
                 round(Recycle):6,'  =',
                 round(EndingInventory):9,' ',
                 round(OutFlow):6,'    ',
                 round(SaltDeposit):5,'          ',
                 round(Evaporation):5);
        writeln (BalOutFile,'Mg    ',
                 round(BeginningInventory*Mg0/100.0):8,'  ',
                 round(InFlow*Mg1/100.0):5,'     ',
                 round(Recycle*Mg2/100.0):5,'  = ',
                 round(EndingInventory*Mg3/100.0):8,'  ',
                 round(OutFlow*Mg0/100.0):5,'     ',
                 0:4,'        ',
                 0:7);
        writeln (BalOutFile,'Na    ',
                 round(BeginningInventory*Na0/100.0):8,'  ',
                 round(InFlow*Na1/100.0):5,'     ',
                 round(Recycle*Na2/100.0):5,'  = ',
                 round(EndingInventory*Na3/100.0):8,'  ',
                 round(OutFlow*Na0/100.0):5,'  ',
                 round(SaltDeposit*0.3934):6,'       ',
                 0:7);
        writeln (BaloutFile,'      -------------------------------------',
                           '------ -----------------');
        writeln (BaloutFile,'Mass Balance = ',abs(BeginningInventory+
                                              InFlow+
                                              Recycle-
                                              EndingInventory-
                                              OutFlow-
                                              SaltDeposit-
                                              Evaporation):7:3,'    ',
                         'Mg Balance = ',abs((BeginningInventory*Mg0/100.0)+
                                          (InFlow*Mg1/100.0)+
                                          (Recycle*Mg2/100.0)-
                                          (EndingInventory*Mg3/100.0)-
                                          (OutFlow*Mg0/100.0)):7:3,'    ',
                         'Na Balance = ',abs((BeginningInventory*Na0/100.0)+
                                          (InFlow*Na1/100.0)+
                                          (Recycle*Na2/100.0)-
                                          (EndingInventory*Na3/100.0)-
                                          (OutFlow*Na0/100.0)-
                                          (SaltDeposit*0.3934)):7:3);
        writeln(BaloutFile);
   end;                                                  { with DayData }
   end;                                                  { for Pond loop }
end;                                               { MaterialBalancePrint }
```

```
procedure GetStartConditions;
                 { Request the begining month, begining day, output file etc. }
var
  InString, InChar  : STRING;
  i, InVal, CodeVar : INTEGER;

begin                                                  { GetStartConditions }
  repeat
    begin                                              { The beginning month.}
      Month := 0;
      clrscr;
      gotoxy (5, 10);
      write ('What month do the calculations begin in? ');
      readln (InString);
      InString := InitialCap (Instring);
      val ( InString, InVal, CodeVar );
      i := 0;
      repeat
        begin
          inc(i);
          if Months[i].Counter = InVal then
            begin
              Month := i;
            end
          else if copy(Months[i].Name, 1, 4) = copy(InString, 1, 4) then
            begin
              Month := i;
            end;
        end;
      until (Month = i) or (i = 12);
      if Month <> i then
        begin
          gotoxy (10, 20);
          clreol;
          writeln (InString,' isn''t recognized as a month.');
          writeln ('Please enter either the complete name or the number.');
          WaitForEnter;
        end;
    end;
  until (Month > 0) and (Month < 12);
  FirstMonth := Month;
  repeat                                               { The beginning day. }
    gotoxy (5, 10);
    clreol;
    write ('What day in ',Months[Month].Name,' do the calculations begin? ');
    readln (Day);
    Day := Months[Month].FirstDay + Day - 1;
  until (Day <= Months[Month].LastDay) and
        (Day >= Months[Month].FirstDay);
  repeat
    begin
      gotoxy (5, 10);
      clreol;
      write ('What is the evaporation factor for this run? ');
      readln (EvapFact);
      gotoxy (5, 10);
      clreol;
      write ('What is the precipitation factor for this run? ');
      readln (PrecipFact);
      gotoxy (5, 10);
      clreol;
      write ('  Evaporation Factor = ',EvapFact:5:3);
      gotoxy (5, 11);
      clreol;
      write ('Precipitation Factor = ',PrecipFact:5:3);
      gotoxy (5, 12);
      clreol;
      write ('Are these correct? ');
      InChar := upcase(readkey);
      write (InChar);
      delay (delayvalue);
    end;
```

```
  until InChar = 'Y';
  clrscr;
  repeat                                  { The number of months to run... }
    begin
      clrscr;
      gotoxy (5, 10);
      clreol;
      write ('How many months do you want the calculations to run? ');
      readln (NumberOfMonths);
      if NumberOfMonths > MaxMonths then
        begin
          gotoxy (5,11);
          write ('Must be less than ',MaxMonths:3);
          WaitForEnter;
        end;
    end;
  until NumberOfMonths <= MaxMonths;

  if (trunc(NumberOfMonths / 12) = (NumberOfMonths / 12)) and
      (Month = 1) then                    { ...and the number of years. }
    begin
      NumberOfYears := trunc(NumberOfMonths / 12);
    end
  else
    begin
      NumberOfYears := trunc((NumberOfMonths + Month) / 12 + 1);
    end;

  gotoxy (5, 10);                                       { The output file. }
  clreol;
  write ('What file do you want the monthly totals written to? ');
  readln (OutFileName);

  gotoxy (5, 10);                       { A material balance output file? }
  BalancePrint := false;
  clreol;
  write ('Do you want to keep a daily material balance file? <Y> or <N> ');
  InChar := upcase(readkey);
  write (InChar);
  delay (delayvalue);
  if InChar = 'Y' then
    begin
      gotoxy (5, 10);
      clreol;
      write ('What file name for the balance file? ');
      readln (BalOutFileName);
      BalancePrint := true;
    end;
end;                                              { GetStartConditions }

procedure ZeroDayData;

                           { Procedure to zero out the daily data record. }

begin                                                    { ZeroDayData }
  for i := 1 to LastPond do
    begin
      with DayData[i] do
        begin
          BeginningInventory  := 0.0;
          InFlow              := 0.0;
          Recycle             := 0.0;
          EndingInventory     := 0.0;
          OutFlow             := 0.0;
          Evaporation         := 0.0;
          SaltDeposit         := 0.0;
        end;
    end;
end;                                                     { ZeroDayData }
```

```
procedure ZeroMonthData;

                          { Procedure to zero out the monthly data record. }

begin                                                     { ZeroMonthData }
  for i := 1 to LastPond do
    begin
      with MonthData[i] do
        begin
          DailyDepthSum          := 0.0;
          DailyOutFlowSum        := 0.0;
          DailyMgSum             := 0.0;
          EndingDepth            := 0.0;
          EndingMg               := 0.0;
          DailySaltDepositSum    := 0.0;
        end;
    end;
end;                                                      { ZeroMonthData }

procedure ZeroYearData;

                           { Procedure to zero out the yearly data record. }

begin                                                      { ZeroYearData }
  for i := 1 to 12 do
    begin
      for j := 1 to LastPond do
        begin
          YearData [i, j] := 0.0;
        end;
    end;
end;                                                       { ZeroYearData }

procedure BalancePond;
{ This procedure uses Wegstien convergence acceleration to close on the
  amount of salt deposited. A first guess of the salt deposit is made
  by removing the evaporation water then calculating the new sodium weight
  percent. The new magnesium value is calculated also, both by material
  balance. }
const
  tol2 = 0.00000001;

var
  Mgc, Nac, Saltc, Salte : REAL;                   { The estimated values. }
  CalculateAllIons: BOOLEAN;    { Flag to calculate ion wt. % after balance. }
  Iterations : INTEGER;
  Saltc1, Saltc2, Delta1, Delta2,
  Intercept, Slope : REAL;           { Wegstien convergence variables. }


procedure Chem(x : REAL);                                        { Chem }

    { The Chem Procedure calculates the weight percent of
      the ions in El Mex brine given the weight percent Mg++.
      The procedure assumes only five ions in solution.
      The K+, Cl- and the SO4-- ions are calculated by material
      balance. The Mg++ and Na+ ions are calculateed in the procedure
      BalancePond. The Na+ ion calculation done in this procedure
      is the equilibrium value. }
```

```
var
  H2O    : REAL;

begin                                                          { Chem }
  if CalculateAllIons then
    begin
      Naf := ((Tb - Tout) * Nab + Tr * Nar - Saltc * 39.34) / Tf;
      Clf := ((Tb - Tout) * Clb + Tr * Clr - Saltc * 60.66) / Tf;
      Kf := ((Tb - Tout) * Kb + Tr * Kr) / Tf;
      SO4f := ((Tb - Tout) * SO4b + Tr * SO4r) / Tf;
    end
  else
    begin
      Naf := 10.5397 - 1.5951*x - 0.0359*x*x + 0.0095*x*x*x;
    end;
end;                                                           { Chem }


procedure LastPondFlowOut;

   { Procedure LastPondFlowOut determines the flow from the last pond.
     If it is the first day of calculations the flow is set to 1/2
     the maximum flow from the pond. Otherwise, the flow from the last
     pond is determined by comparing the Mg concentration in the last
     pond, x, with what is was the day before, xp. The procedure also
     uses an upper and lower limit on the desired Mg concentration to
     determine whether to flow maxium or not at all. The procedure returns
     the flow from the last pond as Tr, the recycle flow, and Mgr, Nar as
     the recycle concentrations of Mg and Na respectively. }

var
  x, K1, K2 : REAL;
  ControlValue : REAL;

begin                                                { LastPondFlowOut }
  K1 := Cp + CpRange;
  K2 := Cp - CpRange;
  x := Ponds[Pond].Mg;
  if PreviousOutFlow = 0.0 then ControlValue := 150.0;
  if PreviousOutFlow <> 0.0 then ControlValue := 0.0;
  if x >= K1 then                          { Beginning of the decision tree. }
    begin
      DayData[Pond].OutFlow := Ponds[Pond].MaxFlow;
    end
  else if x <= K2 then
    begin
      DayData[Pond].OutFlow := 0.0;
    end
  else if FirstDay then
    begin
      DayData[Pond].OutFlow := Ponds[Pond].MaxFlow * 0.10;
      FirstDay := FALSE;
      ControlValue := 0.0
    end
  else
    begin
      if PreviousMg > x then
        begin                          { Decreasing Mg weight percent }
          if x < Cp then
            begin
              DayData[Pond].OutFlow := (PreviousOutFlow+ControlValue) * 0.9;
            end
          else if x > Cp then
            begin
              DayData[Pond].OutFlow := PreviousOutFlow;
            end;
```

```
      end
    else if PreviousMg < x then    { Increasing Mg weight percent }
      begin
        if x > Cp then
          begin
            DayData[Pond].OutFlow := (PreviousOutFlow+ControlValue) * 1.1;
          end
        else if x < Cp then
          begin
            DayData[Pond].OutFlow := PreviousOutFlow;
          end;
      end;
   end;                                    { End of the decision tree. }
  if DayData[Pond].OutFlow > Ponds[Pond].MaxFlow then
    begin
      DayData[Pond].OutFlow := Ponds[Pond].MaxFlow;
    end
  else if DayData[Pond].OutFlow < 0.0 then
    begin
      DayData[Pond].OutFlow := 0.0;
    end;
  PreviousMg := x;
  PreviousOutFlow := DayData[Pond].OutFlow;
end;                                              { LastPondFlowOut }


procedure AdjustLevel;
   { Procedure AdjustLevel determines the flow from the pond feeding the
     current pond to come closest to the target depth. It cannot exceed
     the maximum flow from the pond feeding the current pond. After the
     procedure determines the required flow it calculates the new concen-
     trations and depth. These values are set for the current pond and
     the flow is set for the pond feeding the current pond. Note that the
     local variables for procedure Balance are global for AdjustLevel and
     the program ElMexModel global variables are known in AdjustLevel. }

var
  depth : REAL;

begin                                                 { AdjustLevel }
     Ponds[Pond].Depth := Tf / (Density(Mgf) *
                          Ponds[Pond].Area * 100.0);   { Current depth in cm. }
     if Ponds[Pond].Depth <= Ponds[Pond].TargetDepth then
         Tin := (Ponds[Pond].TargetDepth - Ponds[Pond].Depth) *
                Ponds[Pond].Area * 100.0 * Density(Mgin);
     if Tin > Ponds[Pond-1].MaxFlow then
         Tin := Ponds[Pond-1].MaxFlow;
     Kf := (Kf* Tf + Kin * Tin) / (Tf + Tin); { Mix the Flows. }
     Naf := (Naf*Tf + Nain*Tin) / (Tf + Tin);
     Mgf := (Mgf*Tf + Mgin*Tin) / (Tf + Tin);
     Clf := (Clf*Tf + Clin*Tin) / (Tf + Tin);
     SO4f := (SO4f*Tf + SO4in*Tin) / (Tf + Tin);
     Tf := Tf + Tin;
     if Ponds[Pond].Depth < 0.5 then
       begin
         gotoxy (10, 20);
         writeln ('The depth of pond ',Ponds[Pond].Name,' is ',
                   Ponds[Pond].Depth:5:2,' cm.');
         gotoxy (10, 21);
         writeln ('This may indicate ',Ponds[Pond].Name,' is drying up.');
         gotoxy (10, 22);
         writeln ('Pond ',Ponds[Pond].Name,' may not be getting enough ',
                  'brine from ',Ponds[Pond - 1].Name,'.');
         gotoxy (10, 23);
         writeln ('Please check the Maximum Outflow parameter of pond ',
                   Ponds[Pond - 1].Name,' in ',InFileName);
         WaitForEnter;
         for i := 0 to 3 do
           begin
             gotoxy (10, 20+i);
             clreol;
           end;
       end;
end;                                                  { AdjustLevel }
```

```
begin                                                          { BalancePond }

  if Pond = LastPond then        { First get the flow out of the last pond. }
    begin
      LastPondFlowOut;
      Kr   := Ponds[LastPond].K;
      Nar  := Ponds[LastPond].Na;
      Mgr  := Ponds[LastPond].Mg;
      Clr  := Ponds[LastPond].Cl;
      SO4r := Ponds[LastPond].SO4;
    end;

  Tin   := 0.0;          { Initialize the pond flows to balance nomenclature. }
  Kin   := Ponds[Pond-1].K;
  Nain  := Ponds[Pond-1].Na;
  Mgin  := Ponds[Pond-1].Mg;
  Clin  := Ponds[Pond-1].Cl;
  SO4in:= Ponds[Pond-1].SO4;
  Tout  := DayData[Pond].OutFlow;
  Tb    := Ponds[Pond].Inventory;
  Kb    := Ponds[Pond].K;
  Nab   := Ponds[Pond].Na;
  Mgb   := Ponds[Pond].Mg;
  Clb   := Ponds[Pond].Cl;
  SO4b  := Ponds[Pond].SO4;
  Tr    := DayData[LastPond].OutFlow * Ponds[Pond].Recycle;
  W     := Ponds[Pond].Area * Evap;

  CalculateAllIons := false;
  { Generates the first guess for the salt deposit. }
  Tf := Tb + Tr - W - Tout;                                    { Mass Balance }
  Nac := ((Tb - Tout) * Nab + Tr * Nar) / Tf;                    { Na Balance }
  Mgf := ((Tb - Tout) * Mgb + Tr * Mgr) / Tf;                    { Mg Balance }
  Chem (Mgf);                                { Chem calculates Naf from Mgf }
  Delta1 := Nac - Naf;
  Saltc1 := Tf * Delta1 / 39.34;         { A first estimate of the deposit. }
  Tf := Tb + Tr - W - Tout - Saltc1;
  Nac := ((Tb - Tout) * Nab + Tr * Nar - Saltc1 * 39.34) / Tf;
  Mgf := ((Tb - Tout) * Mgb + Tr * Mgr) / Tf;
  Chem (Mgf);
  Delta1 := Nac - Naf;
  Saltc2 := Saltc1 * 1.1;   { The initial second estimate is a 10% increase.}
  i := 0;
  repeat
    begin
      Tf := Tb + Tr - W - Tout - Saltc2;
      Nac := ((Tb - Tout) * Nab + Tr * Nar - Saltc2 * 39.34) / Tf;
      Mgf := ((Tb - Tout) * Mgb + Tr * Mgr) / Tf;
      Chem (Mgf);
      Delta2 := Nac - Naf;
      if abs(Delta2) > tol then       { Beginning of Wegstien acceleration. }
        begin
          Slope := (Delta1 - Delta2) / (Saltc1 - Saltc2);
          Intercept := Delta2 - Slope * Saltc2;
          Saltc1 := Saltc2; { Update the estimate and value. }
          Delta1 := Delta2;
          if abs(slope) < tol2 then
            begin
              Saltc2 := abs(Saltc2) * 1.5;
            end
          else
            begin
              Saltc2 := -Intercept / Slope;
            end;
        end;
      inc(i);
    end;
  until (abs(Nac - Naf) <= tol) or (i > maxiterations);
```

```
    if i > maxiterations then
      begin
       gotoxy (10, 20);
       writeln ('Maximum iterations exceeded. ');
       WaitForEnter;
      end;
    Saltc := Saltc2;
    if Saltc < 0.0 then              { Control how much salt can be dissolved. }
      begin
        Saltc := Saltc * Ponds[Pond].SDFact;
        Tf := Tb + Tr - W - Tout - Saltc;
        Mgf := ((Tb - Tout) * Mgb + Tr * Mgr) / Tf;
        CalculateAllIons := true;
        Chem (Mgf);
      end
    else
      begin
        CalculateAllIons := true;
        Chem (Mgf);
      end;
    AdjustLevel;
    with DayData[Pond] do                          { Keep the daily flow record. }
      begin
        BeginningInventory := Tb;
        Mg0 := Mgb;
        Na0 := Nab;
        EndingInventory := Tf;
        Mg3 := Mgf;
        Na3 := Naf;
        InFlow := Tin;
        Mg1 := Mgin;
        Na1 := Nain;
        Recycle := Tr;
        Mg2 := Mgr;
        Na2 := Nar;
        OutFlow := Tout;
        Evaporation := W;
        SaltDeposit := Saltc;
      end;
    DayData[Pond-1].OutFlow := Tin;
    with MonthData[Pond] do
      begin
        DailyDepthSum := DailyDepthSum + Ponds[Pond].Depth;
        DailyOutFlowSum := DailyOutFlowSum + Tout;
        DailyMgSum := DailyMgSum + Mgf;
        DailySaltDepositSum := DailySaltDepositSum + Saltc;
      end;
    with Ponds[Pond] do     { Reset the Ponds array to the calculated values. }
      begin
        Inventory := Tf;
        K := Kf;
        Na := Naf;
        Mg := Mgf;
        Cl := Clf;
        SO4 := SO4f;
        Depth := Inventory / (Density(Mg) * Area * 100.0);
      end;
  end;                                                          { BalancePond }

  procedure MonthlySummaryPrint;
  { This procedure writes the monthly summary to the Out file. The procedure
    uses the MonthData array to print the output. The MonthData array is
    zeroed at the end of each month. }
```

```
var
  SaltDepositTotal, NetDeposit : REAL;

  begin                                                  { MonthlySummaryPrint }
    writeln (OutFile);
    if Month = 1 then
      begin
        writeln (OutFile,'Year = ',Year:2,'  Month = ',MonthNames[Month],
                       ' Beginning Day = ',BeginningDay,
                       ' Days Run This Month = ',DaysRun:2);
      end
    else
      begin
        writeln (OutFile,'Year = ',Year:2,'  Month = ',MonthNames[Month],
                       ' Beginning Day = ',BeginningDay-MonthDays[Month-1, 2],
                       ' Days Run This Month = ',DaysRun:2);
      end;
     writeln (OutFile,
     '      Average  Average  Average');
     writeln (OutFile,
     '      Daily    Daily    Daily         Ending   Ending    Salt');
     writeln (OutFile,
     'Pond  Depth    Flow     Mg %          Depth    Mg %      Deposit');
     writeln (OutFile,
     '---------------------------           --------------    -------');
     SaltDepositTotal := 0.0;
     NetDeposit := 0.0;
     for Pond := 1 to Lastpond do
       begin
         with MonthData[Pond] do
           begin
             writeln (OutFile,
             Ponds[Pond].Name,'  ',(DailyDepthSum / DaysRun):5:1,'    ',
             round(DailyOutFlowSum / DaysRun):6,'    ',
             (DailyMgSum / DaysRun):5:2,'          ',
             Ponds[Pond].Depth:5:1,'    ',
             Ponds[Pond].Mg:5:2,'    ',round(DailySaltDepositSum):7);
             SaltDepositTotal := SaltDepositTotal + DailySaltDepositSum;
             if upcase(Ponds[Pond].Name[1]) = 'H' then
               begin
                 NetDeposit := NetDeposit + DailySaltDepositSum;
               end;
           end;                                         { with MonthData loop }
      end;                                                   { for Pond loop }
      writeln (OutFile,'                           Total Monthly Salt Deposit = '
,
                     round(SaltDepositTotal):8);
      writeln (OutFile,'                            Harvestable Salt Deposit = '
,
                     round(NetDeposit):8);
      writeln (OutFile,
      '-------------------------------------------------------------');
  end;                                                   { MonthlySummaryPrint }

procedure YearlySummaryPrint;
{ This procedure writes the yearly deposit statistics to the Outfile.
  The procedure uses the YearData record array. }
var
  PondTotal, MonthTotal, MonthTotalNet, MonthsTotalSum, MonthsTotalSumNet
  : REAL;
begin                                                     { YearlySummaryPrint }
  writeln (OutFile);
  writeln (OutFile,'Summary of year ',Year);
  writeln (OutFile,'Months Calculated = ',MonthNames[BeginMonth],' to ',
               MonthNames[EndMonth]);
  writeln (OutFile,' Deposit in thousands of tons.');
  writeln (OutFile,'       Jan  Feb  Mar  Apr  May  Jun  Jly  Aug  Sep  ',
                   'Oct  Nov  Dec   Tot');
  writeln (OutFile,'Pond ---------------------------------------------',
               '-----------------');
```

```
for Pond := 1 to LastPond do
  begin
    write (OutFile, Ponds[Pond].Name,' ');
    PondTotal := 0.0;
    for Month := 1 to 12 do
      begin
        write (OutFile, (YearData[ Month, Pond]/1000.0):5:0);
        PondTotal := PondTotal + (YearData[ Month, Pond]/1000.0);
      end;                                        { end of the month loop }
    writeln (OutFile, PondTotal:7:0);
  end;                                             { end of the Pond loop }
writeln (OutFile,'------------------------------------------------------',
                 '------------------');
write (OutFile,'Total');
MonthsTotalSum := 0.0;
for Month := 1 to 12 do
  begin
    MonthTotal := 0.0;
    MonthTotalNet := 0.0;
    for Pond := 1 to LastPond do
      begin
        MonthTotal := MonthTotal + (YearData[ Month, Pond]/1000.0);
        if upcase(Ponds[Pond].Name[1]) = 'H' then
          begin
            MonthTotalNet := MonthTotalNet + (YearData[ Month, Pond]/1000.0);
          end;
      end; { end of the pond loop }
    write (OutFile, MonthTotal:5:0);
    MonthsTotalSum := MonthsTotalSum + MonthTotal;
    MonthsTotalSumNet := MonthsTotalSumNet + MonthTotalNet;
  end; { end of the months loop }
writeln (OutFile, MonthsTotalSum:7:0);
write (OutFile,'Net  ');
MonthsTotalSumNet := 0.0;
for Month := 1 to 12 do
  begin
    MonthTotalNet := 0.0;
    for Pond := 1 to LastPond do
      begin
        if upcase(Ponds[Pond].Name[1]) = 'H' then
          begin
            MonthTotalNet := MonthTotalNet + (YearData[ Month, Pond]/1000.0);
          end;
      end; { end of the pond loop }
    write (OutFile, MonthTotalNet:5:0);
    MonthsTotalSumNet := MonthsTotalSumNet + MonthTotalNet;
  end; { end of the months loop }
writeln (OutFile, MonthsTotalSumNet:7:0);
end;                                                  { YearlySummaryPrint }

begin                                                          { ElMexModel }
  GSLHeader;                 { Clear the screen and display the GSL Header. }
  Cp := 3.0;                               { Set the starting control point. }
  CpRange := 0.1;
  EvapChanged := FALSE;
  ControlChanged := FALSE;
  ReadFile := true;          { Now get all the information to run the model. }
  Input;                                          { First the pond system. }
  ShowData ;                                { Echo/confirm the pond system. }
  GetStartConditions;                          { Get the starting conditions. }
  assign (OutFile, OutFileName);               { Open the file(s) for output. }
  rewrite (OutFile);
  writeln (OutFile,'El Mex Model Summary File "' + OutFileName +'"');
      if EvapChanged then
        writeln (OutFile,'Evaporation data was changed for this run.');
      if ControlChanged then
        writeln (OutFile,'Control data was changed for this run.');
  writeln (OutFile,'Evaporation factor is ',EvapFact:5:3,
                   ' Precipitation factor is ',PrecipFact:5:3);
```

```
  if BalancePrint then
    begin
      assign (BalOutFile, BalOutFileName);
      rewrite (BalOutFile);
      writeln (BalOutFile,'El Mex Material Balance File "' + BalOutFileName +'"'
);
    end;
  MonthsRun := 0;        { The calculational part ofthe program begins here. }
  FirstDay := true;
  Year := 1;
  while Year <= NumberOfYears do               { Loop through the years. }
    begin
      ZeroYearData;
      clrscr;    { This sets up a display to show where the calculations are. }
      gotoxy (12, 6);
      write (' Calculating Year: ',Year);
      gotoxy (12, 7);
      write ('  Calculating Day:   ');
      gotoxy (12, 8);
      write (' Calculating Pond:   ');
      if ((NumberOfMonths + Month - MonthsRun) >= 12) then
        begin                          { The last month for the current year. }
          EndMonth := 12;
        end
      else
        begin
          EndMonth := NumberOfMonths + Month - MonthsRun - 1;
        end;
      BeginMonth := Month;
      while Month <= EndMonth do                  { Loop through the months. }
        begin
          ZeroMonthData;
          beginningDay := Day;
          DaysRun := 0;

          while Day <= Months[Month].LastDay do      { Loop through the days. }
            begin
              ZeroDayData;
              str (Day - Months[Month].FirstDay + 1, DisplayDay);
              gotoxy (30, 7);
              write (' ' + Months[Month].Name + ' ' + DisplayDay);
              clreol;

              for Pond := LastPond downto 1 do      { Loop through the ponds. }
                begin
                  gotoxy (30, 8);
                  write (' ' + Ponds[Pond].Name);
                  BalancePond;

                end;                                { End of the pond loop. }
              if BalancePrint then MaterialBalancePrint;
              inc(Day);
              inc(DaysRun);
            end;                                  { End of the days loop. }
          MonthlySummaryPrint;
          for Pond := 1 to LastPond do
            begin
              YearData[Month, Pond] := MonthData[Pond].DailySaltDepositSum;
            end;
          Day := Months[Month + 1].FirstDay;
          LastMonth := Month;
          inc(MonthsRun, 1);
          inc(Month, 1);
        end;                                     { End of the months loop. }

                      { At the end of each year display the pond statistics
                              then write the statistics to a file. }
        EndMonth := Month - 1;
        if Year <= NumberOfYears then YearlySummaryPrint;

            Month := 1;
            Day := 1;
            inc(Year, 1);

    END;                                          { End of the years loop. }
    close(outFile);
    if balancePrint then close (BaloutFile);
    WriteEndingConditionsFile;
    clrscr;

  END.;                                                        { ElMexModel }
```

APPENDIX E

Borg el Arab Run

6 Years Starting with Sea Brine

This is the set-up for the Borg El Arab system of ponds.
The Lake is the concentration of the open ocean.
The line of asterisks may be moved to accomodate more comments.
Notice that ponds whose names begin with H are assumed to be harvestable.
The net deposit of the system is summed from these harvestable ponds.
In this starting state the ponds are filled with ocean brine and then
run in sequence for [illegible] years.

Pond Name	Area (Hect.)	Current Depth (cm)	Target Depth (cm)	K	Na	Mg	Cl	SO4	Max. Flow (Tons/d)	Rec.	Salt Ds. Fact.
				Ion Weight Percents							
******	******	******	******	******	******	******	******	******	******	******	******
Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0	0.00
PND1	1700	50	50	0.04	1.05	0.13	1.90	0.26	500000	0	0.00
PND2	300	50	50	0.04	1.05	0.13	1.90	0.26	400000	0	0.00
HRV1	200	30	30	0.04	1.05	0.13	1.90	0.26	300000	0	0.00
HAR2	200	30	30	0.04	1.05	0.13	1.90	0.26	300000	0	0.00

Ending Conditions File
Start Conditions From :BORGBASE.DAT
Model run covered 6 years.
Model ran 72 months.
The first month run was January.
The last month run was December.
The evaporation factor was 1.000.
The precipitation factor was 1.000.

****

Lake	0	0	0	0.04	1.05	0.13	1.90	0.26	1000000	0.0	0.00
PND1	1700	50	50	0.13	3.41	0.42	6.17	0.84	500000	0.0	0.00
PND2	300	50	50	0.21	5.55	0.69	10.05	1.38	400000	0.0	0.00
HRV1	200	30	30	0.35	8.65	1.15	15.82	2.30	300000	0.0	0.00
HAR2	200	30	30	0.91	5.73	2.97	15.26	5.95	300000	0.0	0.00

El Mex Model Summary File BORGBASE

Evaporation factor is 1.000 Precipitation factor is 1.000

Year = 1 Month = January Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.8	9150	0.13	[illegible]	0.14	0
PND2	49.7	5223	0.14	50.0	0.14	0
HRV1	29.7	2615	0.14	30.0	0.15	0
HAR2	29.[illegible]	0	0.14	30.0	0.15	[illegible]
			Total Monthly Salt Deposit =			0
			Harvestable Salt Deposit =			0

Year = 1 Month = February Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.7	14547	0.15	50.0	0.15	0
PND2	49.5	8290	0.15	50.0	0.16	0
HRV1	29.5	4151	0.16	30.0	0.17	0
HAR2	29.8	0	0.16	30.0	0.17	0
			Total Monthly Salt Deposit =			0
			Harvestable Salt Deposit =			0

Year = 1 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	24672	0.16	50.0	0.18	0
PND2	49.2	14049	0.17	50.0	0.19	0
HRV1	29.3	7063	0.19	30.0	0.22	0
HAR2	29.7	0	0.21	30.0	0.24	0
			Total Monthly Salt Deposit =			0
			Harvestable Salt Deposit =			0

Year = 1 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.3	36090	0.19	50.0	0.20	0
PND2	48.9	20533	0.21	50.0	0.23	0
HRV1	[illegible].0	10321	0.25	30.0	0.[illegible]9	0
HAR2	[illegible].5	[illegible]	0.29	30.0	0.[illegible]5	0
			Total Monthly Salt Deposit =			0
			Harvestable Salt Deposit =			0

Year = 1 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	[illegible]	0.22	50.0	0.23	0
PND2	48.8	[illegible]	0.26	50.0	0.28	0
HRV1	[illegible]	[illegible]	0.33	30.0	0.38	0
HAR2	29.5	0	0.43	30.0	0.51	[illegible]

Total Monthly Salt Deposit = 0
Harvestable Salt Deposit = [illegible]

Year = 1 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	41894	0.25	50.0	0.26	0
PND2	48.7	23737	0.31	50.0	0.33	0
HRV1	28.9	11830	0.43	30.0	0.47	0
HAR2	29.5	0	0.61	30.0	0.71	0

Total Monthly Salt Deposit = 0
Harvestable Salt Deposit = 0

Year = 1 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	41144	0.27	50.0	0.28	0
PND2	48.7	23202	0.36	50.0	0.38	0
HRV1	28.9	11497	0.52	30.0	0.57	0
HAR2	29.5	0	0.84	30.0	0.96	0

Total Monthly Salt Deposit = 0
Harvestable Salt Deposit = 0

Year = 1 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	40128	0.29	50.0	0.30	0
PND2	48.8	22953	0.41	50.0	0.43	0
HRV1	29.0	11806	0.62	30.0	0.66	0
HAR2	29.5	0	1.11	30.0	1.26	31796

Total Monthly Salt Deposit = 31796
Harvestable Salt Deposit = 31796

Year = 1 Month = September Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.7	[illegible]	0.31	50.0	0.32	0
PND2	48.9	17751	0.44	50.0	0.46	0
HRV1	[illegible]	10438	0.59	30.0	0.72	0
HAR2	29.5	0	1.40	30.0	1.54	30144

Total Monthly Salt Deposit = 30144
Harvestable Salt Deposit = 30144

Year = 1 Month = October Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	24090	0.32	50.0	0.33	0
PND2	49.3	13752	0.47	50.0	0.48	0
HRV1	29.4	7137	0.75	30.0	0.77	0
HAR2	29.7	0	1.65	30.0	1.75	38486

Total Monthly Salt Deposit = 38486
Harvestable Salt Deposit = 38486

Year = 1 Month = November Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.6	17414	0.33	50.0	0.33	0
PND2	49.5	9754	0.49	50.0	0.50	0
HRV1	29.6	4917	0.79	30.0	0.80	0
HAR2	29.8	0	1.82	30.0	1.89	27254

Total Monthly Salt Deposit = 27254
Harvestable Salt Deposit = 27254

Year = 1 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.8	8758	0.33	50.0	0.34	0
PND2	49.7	4601	0.50	50.0	0.51	0
HRV1	29.3	2078	0.82	30.0	0.83	0
HAR2	29.9	0	1.93	30.0	1.96	12267

Total Monthly Salt Deposit = 12267
Harvestable Salt Deposit = 12267

Summary of Year [illegible]
Months Calculated : January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jl	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	[illegible]	0	0	0	[illegible]	0	[illegible]	0	0	0	0
PND2	0	0	0	0	0	[illegible]	0	0	[illegible]	0	[illegible]	[illegible]	0
HRV1	0	0	0	0	0	0	0	0	0	[illegible]	0	[illegible]	0
HAR2	0	0	0	0	0	0	0	32	50	[illegible]	27	12	[illegible]
Total	0	0	0	0	0	0	0	32	[illegible]	[illegible]	27	12	[illegible]
Net	0	0	0	0	0	0	0	32	50	[illegible]	27	12	[illegible]

Year = 2 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.8	5684	0.34	50.0	0.34	0
PND2	49.8	3360	0.51	50.0	0.52	0
HRV1	29.9	1042	0.24	30.0	0.35	0
HAR2	29.9	0	1.98	30.0	2.01	8569

Total Monthly Salt Deposit = 8569
Harvestable Salt Deposit = 8569

Year = 2 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.7	11539	0.34	50.0	0.35	0
PND2	49.6	6103	0.52	50.0	0.53	0
HRV1	29.7	2305	0.37	30.0	0.38	0
HAR2	29.9	0	2.05	30.0	2.09	16246

Total Monthly Salt Deposit = 16246
Harvestable Salt Deposit = 16246

Year = 2 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.6	21952	0.35	50.0	0.35	0
PND2	49.3	12347	0.54	50.0	0.55	0
HRV1	29.5	6295	0.90	30.0	0.92	0
HAR2	29.7	0	2.21	30.0	[illegible]	41976

Total Monthly Salt Deposit = [illegible]
Harvestable Salt Deposit = 41976

Year = 2 Month = April Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PND2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HRV1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HAR2	[illegible]	0	2.49	[illegible]	[illegible]	[illegible]

Total Monthly Salt Deposit = [illegible]
Harvestable Salt Deposit = [illegible]

Year = 2 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.0	36733	0.37	50.0	0.37	0
PND2	48.9	21165	0.58	50.0	0.59	0
HRV1	29.1	11295	1.00	30.0	1.02	0
HAR2	29.5	968	2.80	30.0	2.97	76005

Total Monthly Salt Deposit = 76005
Harvestable Salt Deposit = 76005

Year = 2 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	48761	0.37	50.0	0.38	0
PND2	48.5	31795	0.58	50.0	0.58	0
HRV1	23.6	21047	0.94	30.0	0.95	0
HAR2	29.1	10052	2.65	30.0	2.58	74906

Total Monthly Salt Deposit = 74906
Harvestable Salt Deposit = 74906

Year = 2 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	39693	0.38	50.0	0.38	0
PND2	48.8	22532	0.60	50.0	0.61	0
HRV1	29.0	11538	0.98	30.0	1.02	0
HAR2	29.5	0	2.80	30.0	3.01	83213

Total Monthly Salt Deposit 83213
Harvestable Salt Deposit = 83213

Year = 2 Month = August Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.[illegible]	4[illegible]	0.38	50.0	0.[illegible]	[illegible]
PND2	48.[illegible]	[illegible]	0.[illegible]	50.0	[illegible]	[illegible]
HRV1	29.5	20452	0.91	30.0	0.95	[illegible]
HAR2	29.1	[illegible]28	2.5[illegible]	30.[illegible]	2.50	[illegible]

Total Monthly Salt Deposit = [illegible]
Harvestable Salt Deposit = [illegible]

Year = 2 Month = September Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	72537	0.39	50.0	0.39	0
PND2	49.0	1321[illegible]	0.61	50.0	0.62	0
HRV1	29.2	9132	1.00	30.0	1.04	0
HAR2	29.6	0	2.20	30.0	2.97	65437

Total Monthly Salt Deposit = 65437
Harvestable Salt Deposit = 65437

Year = 2 Month = October Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	31483	0.39	50.0	0.39	0
PND2	49.1	21663	0.62	50.0	0.61	0
HRV1	29.[illegible]	15558	1.00	30.0	0.93	168
HAR2	29.3	9826	2.[illegible]	30.0	2.42	45602

Total Monthly Salt Deposit = 45770
Harvestable Salt Deposit = 45770

Year = 2 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.7	16568	0.39	50.0	0.39	0
PND2	49.5	9104	0.61	50.0	0.62	0
HRV1	29.6	4397	0.96	30.0	0.99	0
HAR2	29.8	0	2.50	30.0	2.58	29983

Total Monthly Salt Deposit = 29983
Harvestable Salt Deposit = 29983

[illegible] 2 [illegible] = December Beginning [illegible] = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	[illegible].3	[illegible]	0.40	50.[illegible]	0.40	[illegible]
PND2	49.8	[illegible]	0.62	[illegible]	0.63	[illegible]
HRV1	29.8	[illegible]	1.00	30.[illegible]	1.02	[illegible]
HAR2	29.[illegible]	0	2.61	30.0	2.63	[illegible]

Total Monthly Salt Deposit = [illegible]
Harvestable Salt Deposit = [illegible]

Summary of year [illegible]
Months calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	0	0	0	0	0	0	0	0	0	0	0
PND2	0	0	0	0	0	0	0	0	0	0	0	0	0
HRV1	0	0	0	0	0	0	0	0	0	0	0	0	0
HAR2	9	16	42	64	76	75	83	76	65	46	30	11	[illegible]
Total	9	16	42	64	76	75	83	76	65	46	30	11	[illegible]
Net	9	15	42	64	76	75	83	76	65	46	30	11	[illegible]

Year = 3 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.9	5811	0.40	50.0	0.40	0
PND2	49.8	2632	0.64	50.0	0.64	0
HRV1	29.9	303	1.04	30.0	1.06	0
HAR2	30.0	0	2.65	30.0	2.67	6160

Total Monthly Salt Deposit = 6160
Harvestable Salt Deposit = 6160

Year = 3 Month = February Beginning Day = 1 Days Run This Month = 29

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.8	10612	0.40	50.0	0.40	0
PND2	49.7	5372	0.65	50.0	0.66	0
HRV1	29.8	2147	1.08	30.0	1.10	3049
HAR2	29.[illegible]	0	2.71	30.0	2.75	15446

Total Monthly Salt Deposit = 18495
Harvestable Salt Deposit = 18495

Year = 3 Month = March Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	[illegible]	[illegible]	[illegible]	50.0	[illegible]	[illegible]
PND2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HRV1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HAR2	[illegible]	[illegible]	[illegible]	[illegible]	3.06	[illegible]

Total Monthly Salt Deposit : [illegible]
Harvestable Salt Deposit : [illegible]

Year = 3 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	[illegible]1568	0.40	50.0	0.40	0
PND2	48.7	27746	0.65	50.0	0.65	0
HRV1	28.8	13336	1.05	30.0	1.04	2904
HAR2	29.1	10060	2.6	30.0	2.62	65408

Total Monthly Salt Deposit : 70312
Harvestable Salt Deposit : 70312

Year = 3 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.3	55882	0.41	50.0	0.41	0
PND2	48.9	20461	0.65	50.0	0.67	0
HRV1	29.[illegible]	10344	1.09	30.0	1.12	2940
HAR2	29.6	25	2.89	30.0	3.05	80602

Total Monthly Salt Deposit : 83541
Harvestable Salt Deposit : 83541

Year = 3 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	49014	0.41	50.0	0.41	0
PND2	48.5	32211	0.64	50.0	0.65	0
HRV1	28.6	21338	1.02	30.0	1.05	4268
HAR2	29.1	10027	2.[illegible]1	30.0	2.75	82415

Total Monthly Salt Deposit : 86683
Harvestable Salt Deposit : 86683

Year = 3 Month = July Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.[illegible]	[illegible]	0.41	[illegible]	[illegible]	
PND2	48.5	[illegible]	[illegible]	[illegible]	[illegible]	
HRV1	29.[illegible]	[illegible]	1.05	[illegible]	[illegible]	[illegible]
HAR2	[illegible]	[illegible]	2.80	30.0	2.4[illegible]	[illegible]
			Total Monthly Salt Deposit =			[illegible]
			Harvestable Salt Deposit =			[illegible]

Year = 3 Month = August Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	[illegible]8544	0.41	50.0	0.41	0
PND2	48.8	22047	0.55	50.0	0.56	0
HRV1	29.0	11451	1.03	30.0	1.08	0
HAR2	29.5	0	2.69	30.0	2.91	84[illegible]
			Total Monthly Salt Deposit =			84[illegible]
			Harvestable Salt Deposit =			84[illegible]

Year = 3 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.3	41807	0.41	50.0	0.41	0
PND2	48.7	27567	0.55	50.0	0.64	0
HRV1	28.8	13260	1.04	30.0	0.99	7282
HAR2	29.2	10063	2.74	30.0	2.51	66893
			Total Monthly Salt Deposit =			74175
			Harvestable Salt Deposit =			74175

Year = 3 Month = October Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	22832	0.41	50.0	0.41	0
PND2	49.3	12820	0.65	50.0	0.66	0
HRV1	29.4	6161	1.03	30.0	1.06	0
HAR2	29.7	0	2.64	30.0	2.77	47594
			Total Monthly Salt Deposit =			47594
			Harvestable Salt Deposit =			47594

Year = 3 Month = November Beginning Day [illegible] Days Run This Month [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.[illegible]	[illegible]	0.4[illegible]	[illegible]	[illegible].41	[illegible]
PND2	4[illegible].8	[illegible]	0.6[illegible]	50.[illegible]	[illegible]	[illegible]
HRV1	[illegible]	4137	1.[illegible]	[illegible]	1.11	2[illegible]
HAR2	[illegible]	[illegible]	2.85	30.0	[illegible]	[illegible]46[illegible]
			Total Monthly Salt Deposit =			[illegible]
			Harvestable Salt Deposit =			[illegible]

Year = 3 Month = December Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.3	7673	0.42	50.0	0.42	0
PND2	49.8	3740	0.68	50.0	0.68	0
HRV1	29.3	1168	1.14	30.0	1.16	8523
HAR2	30.0	0	2.96	30.0	2.98	9355
			Total Monthly Salt Deposit =			17878
			Harvestable Salt Deposit =			17878

Summary of year 3
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	0	0	0	0	0	0	0	0	0	0	0
PND2	0	0	0	0	0	0	0	0	0	0	0	0	0
HRV1	0	3	13	8	3	4	7	0	7	0	2	9	56
HAR2	6	15	46	65	81	82	88	84	67	48	31	9	624
Total	6	18	59	73	84	87	95	84	74	48	34	18	680
Net	6	18	59	73	84	87	95	84	74	48	34	18	680

Year = 4 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.9	5595	0.42	50.0	0.42	0
PND2	49.8	2476	0.69	50.0	0.69	0
HRV1	29.9	471	1.19	30.0	1.21	8460
HAR2	30.0	11	2.99	30.0	3.00	3693
			Total Monthly Salt Deposit =			[illegible]53
			Harvestable Salt Deposit =			1[illegible]53

Year = 4 Month = February Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	[illegible]	10406	0.42	[illegible]	0.42	0
PND2	[illegible]	5756	0.70	[illegible]	0.70	0
HRV1	29.7	2472	1.22	30.0	1.24	[illegible]
HAR2	[illegible]	757	3.02	30.0	3.03	[illegible]

Total Monthly Salt Deposit = 21824
Harvestable Salt Deposit = 21824

Year = 4 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	23733	0.42	50.0	0.42	0
PND2	49.5	14496	0.70	50.0	0.70	0
HRV1	29.4	3608	1.24	30.0	1.22	7768
HAR2	29.6	3191	3.06	30.0	3.06	44239

Total Monthly Salt Deposit = 52007
Harvestable Salt Deposit = 52007

Year = 4 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.3	37144	0.42	50.0	0.42	0
PND2	48.9	23324	0.69	50.0	0.69	0
HRV1	29.0	14573	1.20	30.0	1.17	5559
HAR2	29.4	5923	3.06	30.0	3.04	68239

Total Monthly Salt Deposit = 73798
Harvestable Salt Deposit = 73798

Year = 4 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	41569	0.42	50.0	0.42	0
PND2	48.8	26372	0.68	50.0	0.68	0
HRV1	28.9	16760	1.15	30.0	1.13	1629
HAR2	29.3	6705	3.02	30.0	3.00	81751

Total Monthly Salt Deposit = 83381
Harvestable Salt Deposit = 83381

Year = 4 Month = [illegible] Beginning Day = [illegible] Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	[illegible]	[illegible]	[illegible]	[illegible]	0.42	0
PND2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HRV1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HAR2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Total Monthly Salt Deposit = [illegible]
Harvestable Salt Deposit = [illegible]

Year = 4 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	45306	0.42	50.0	0.42	0
PND2	48.6	28485	0.67	50.0	0.6[illegible]	0
HRV1	28.8	17757	1.10	30.0	1.09	1464
HAR2	29.3	6487	3.00	30.0	3.00	91265

Total Monthly Salt Deposit = 92728
Harvestable Salt Deposit = 92728

Year = 4 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	43737	0.42	50.0	0.42	0
PND2	48.7	27496	0.67	50.0	0.67	0
HRV1	28.8	17114	1.09	30.0	1.08	830
HAR2	29.3	6205	3.00	30.0	3.00	88411

Total Monthly Salt Deposit = 89241
Harvestable Salt Deposit = 89241

Year = 4 Month = September Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.3	36855	0.42	50.0	0.42	0
PND2	48.9	22827	0.67	50.0	0.67	0
HRV1	29.0	13900	1.09	30.0	1.09	2193
HAR2	29.4	5039	3.00	30.0	3.00	69693

Total Monthly Salt Deposit = 71886
Harvestable Salt Deposit = 71886

Year = 4 Month = October Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	[illegible]	0.42	50.0	0.42	0
PND2	49.2	15723	0.67	50.0	0.67	0
HRV1	29.3	[illegible]	1.09	30.0	1.10	[illegible]
HAR2	29.6	[illegible]	3.00	30.0	[illegible]	[illegible]

Total Monthly Salt Deposit = [illegible]
Harvestable Salt Deposit = [illegible]

Year = 4 Month = November Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.6	13115	0.42	50.0	0.42	0
PND2	49.5	10799	0.68	50.0	0.68	0
HRV1	29.5	6152	1.11	30.0	1.12	4040
HAR2	29.7	2268	3.00	30.0	3.00	30852

Total Monthly Salt Deposit = 34891
Harvestable Salt Deposit = 34891

Year = 4 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.8	3348	0.42	50.0	0.42	0
PND2	49.7	4432	0.68	50.0	0.69	0
HRV1	29.8	1968	1.13	30.0	1.15	5702
HAR2	29.9	366	2.98	30.0	2.99	9153

Total Monthly Salt Deposit = 14855
Harvestable Salt Deposit = 14855

Summary of year 4
Months Calculated = January to December
Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	0	0	0	0	0	0	0	0	0	0	0
PND2	0	0	0	0	0	0	0	0	0	0	0	0	0
HRV1	8	9	8	6	2	2	1	1	2	2	4	6	51
HAR2	4	13	44	68	82	88	91	88	70	49	31	9	637
Total	12	22	52	74	83	91	93	89	72	51	35	15	698
Net	12	22	52	74	83	[illegible]	93	89	72	51	35	15	38

[illegible] Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.9	3868	0.42	50.0	0.42	0
PND2	49.8	2759	0.69	50.0	0.70	0
HRV1	29.9	782	1.17	30.0	1.19	7466
HAR2	30.0	326	2.98	30.0	2.99	3787
				Total Monthly Salt Deposit =		11254
				Harvestable Salt Deposit =		11254

Year = 5 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.8	10841	0.42	50.0	0.43	0
PND2	49.7	5692	0.70	50.0	0.70	0
HRV1	29.8	2365	1.21	30.0	1.23	9716
HAR2	29.9	626	3.01	30.0	3.02	12785
				Total Monthly Salt Deposit =		22501
				Harvestable Salt Deposit =		22501

Year = 5 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	23747	0.43	50.0	0.43	0
PND2	49.3	14512	0.70	50.0	0.70	0
HRV1	29.4	8586	1.23	30.0	1.22	8362
HAR2	29.6	3136	3.05	30.0	3.05	44351
				Total Monthly Salt Deposit =		52713
				Harvestable Salt Deposit =		52713

Year = 5 Month = April Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.3	37136	0.43	50.0	0.42	0
PND2	48.9	23321	0.70	50.0	0.69	0
HRV1	29.0	14323	1.20	30.0	1.17	6560
HAR2	29.4	5858	3.05	30.0	3.04	68347
				Total Monthly Salt Deposit =		74908
				Harvestable Salt Deposit =		74908

Year = 5 Month = May Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.[illegible]	41590	0.42	50.[illegible]	0.42	0
PND2	48.[illegible]	26402	0.69	50.0	0.68	[illegible]
HRV1	[illegible]	[illegible]	1.15	30.0	1.13	[illegible]
HAR2	29.[illegible]	[illegible]	3.00	30.0	3.00	81[illegible]
			Total Monthly Salt Deposit =			84587
			Harvestable Salt Deposit =			84587

Year = 5 Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	45514	0.42	50.0	0.42	0
PND2	48.6	28726	0.62	50.0	0.68	0
HRV1	28.7	17987	1.12	30.0	1.11	2991
HAR2	29.2	6718	3.00	30.0	3.00	88043
			Total Monthly Salt Deposit =			91034
			Harvestable Salt Deposit =			91034

Year = 5 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	45369	0.42	50.0	0.42	0
PND2	48.6	28558	0.68	50.0	0.67	0
HRV1	28.3	17314	1.10	30.0	1.10	2171
HAR2	29.2	6544	3.00	30.0	3.00	91274
			Total Monthly Salt Deposit =			93445
			Harvestable Salt Deposit =			93445

Year = 5 Month = August Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	43844	0.42	50.0	0.42	0
PND2	48.7	27562	0.67	50.0	0.67	0
HRV1	28.3	17170	1.09	30.0	1.09	1360
HAR2	29.3	6261	3.00	30.0	3.00	88419
			Total Monthly Salt Deposit =			89779
			Harvestable Salt Deposit =			89779

Year = [illegible] Month = September Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
[illegible]	[illegible]	[illegible]	0.42	[illegible]	0.42	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Total Monthly Salt Deposit = [illegible]

Harvestable Salt Deposit = [illegible]

Year = [illegible] Month = October Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
[illegible]	[illegible]	[illegible]	[illegible]	50.0	0.42	0
[illegible]	[illegible]	[illegible]	[illegible]	50.0	[illegible]	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.13	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.99	[illegible]

Total Monthly Salt Deposit = [illegible]

Harvestable Salt Deposit = [illegible]

Year = [illegible] Month = November Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
[illegible]	[illegible]	[illegible]	0.42	50.0	0.42	0
[illegible]	[illegible]	[illegible]	[illegible]	50.0	0.68	0
[illegible]	[illegible]	[illegible]	[illegible]	30.0	1.12	[illegible]
[illegible]	[illegible]	2341	[illegible]	30.0	2.99	30936

Total Monthly Salt Deposit = 34254

Harvestable Salt Deposit = 34254

Year = 5 Month = December Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.8	3392	0.42	50.0	0.42	0
PND2	49.7	4480	0.68	50.0	0.69	0
HRV1	29.8	2022	1.13	30.0	1.15	5596
HAR2	29.9	910	2.97	30.0	2.97	9246

Total Monthly Salt Deposit = 14842

Harvestable Salt Deposit = 14842

Summary of Year 5
Months Calculated = January to December
Deposit in thousands of tons

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
PND2	[illegible]	[illegible]	[illegible]	0	0	0	[illegible]	0	0	0	0	0	[illegible]
HRV1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]
HAR2	4	10	44	68	82	88	91	[illegible]	70	49	31	[illegible]	[illegible]
Total	11	22	[illegible]	75	[illegible]	91	[illegible]	[illegible]	72	51	35	15	[illegible]
Net	11	22	[illegible]	75	85	91	[illegible]	[illegible]	72	51	35	15	[illegible]

Year = 6 Month = January Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.9	5872	0.42	50.0	0.42	0
PND2	49.8	2765	0.69	50.0	0.70	0
HRV1	29.9	738	1.17	30.0	1.19	7478
HAR2	30.0	319	2.97	30.0	2.97	3880

Total Monthly Salt Deposit = 11358
Harvestable Salt Deposit = 11358

Year = 6 Month = February Beginning Day = 1 Days Run This Month = 28

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.8	10695	0.43	50.0	0.43	0
PND2	49.7	5545	0.70	50.0	0.71	0
HRV1	29.8	2192	1.22	30.0	1.24	10300
HAR2	29.9	437	3.00	30.0	3.02	12839

Total Monthly Salt Deposit = 23139
Harvestable Salt Deposit = 23139

Year = 6 Month = March Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	23772	0.43	50.0	0.43	0
PND2	49.3	14543	0.71	50.0	0.70	0
HRV1	29.4	8616	1.23	30.0	1.22	8554
HAR2	29.6	3192	3.06	30.0	3.05	44313

Total Monthly Salt Deposit = 52867
Harvestable Salt Deposit = 52867

[illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Total Monthly Salt Deposit = [illegible]
Harvestable Salt Deposit = [illegible]

Year = [illegible] Month = May Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.[illegible]	[illegible]	0.42	50.0	0.42	[illegible]
PND2	46.[illegible]	[illegible]	0.69	50.0	0.69	[illegible]
HRV1	[illegible]	[illegible]	1.16	30.[illegible]	[illegible]	[illegible]
HAR2	29.[illegible]	[illegible]	3.05	30.[illegible]	3.00	[illegible]

Total Monthly Salt Deposit = [illegible]
Harvestable Salt Deposit = [illegible]

Year = [illegible] Month = June Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.[illegible]	45530	0.42	50.[illegible]	0.42	0
PND2	46.[illegible]	28766	0.68	50.[illegible]	0.68	0
HRV1	28.7	13025	1.12	30.0	1.1[illegible]	3155
HAR2	29.[illegible]	6757	3.00	30.0	3.00	88333

Total Monthly Salt Deposit = 91488
Harvestable Salt Deposit = 91488

Year = 6 Month = July Beginning Day = 1 Days Run This Month = 31

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	45378	0.42	50.0	0.42	0
PND2	48.6	28569	0.68	50.0	0.68	0
HRV1	28.8	17822	1.10	30.0	1.10	2350
HAR2	29.2	6550	3.00	30.0	3.00	91276

Total Monthly Salt Deposit = 93626
Harvestable Salt Deposit = 93626

Year = 6 Month = August Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.2	[illegible]	0.42	[illegible]	[illegible]	0
PND2	48.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HRV1	29.[illegible]	[illegible]	[illegible]	[illegible]	1.09	[illegible]
HAR2	29.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Total Monthly Salt Deposit = [illegible]
Harvestable Salt Deposit = [illegible]

Year = 6 Month = September Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.3	36885	0.42	50.0	0.42	0
PND2	48.9	22866	0.67	50.0	0.67	0
HRV1	29.0	13926	1.09	30.0	1.10	2801
HAR2	29.4	5064	3.00	30.0	3.00	69717

Total Monthly Salt Deposit = 72518
Harvestable Salt Deposit = 72518

Year = 6 Month = October Beginning Day = 1 Days Run This Month = [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.5	25733	0.42	50.0	0.42	0
PND2	49.2	15851	0.67	50.0	0.68	0
HRV1	29.[illegible]	9590	1.10	30.0	1.10	1986
HAR2	29.6	3579	2.99	30.0	2.99	49112

Total Monthly Salt Deposit = 51097
Harvestable Salt Deposit = 51097

Year = 6 Month = November Beginning Day = 1 Days Run This Month = 30

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg %	Salt Deposit
PND1	49.6	18193	0.42	50.0	0.42	0
PND2	49.5	10883	0.68	50.0	0.68	0
HRV1	29.5	6244	1.11	30.0	1.12	3936
HAR2	29.7	2351	2.99	30.0	2.99	30945

Total Monthly Salt Deposit = 34880
rvestable Salt Deposit = 34880

Year 5 : Month December Beginning Day = 1 Days Run This Month [illegible]

Pond	Average Daily Depth	Average Daily Flow	Average Daily Mg %	Ending Depth	Ending Mg	Net Deposit
PND1	[illegible]	5346	0.42	30.0	1.42	[illegible]
PND2	[illegible]	4494	0.55	50.0	[illegible]	[illegible]
HRV1	[illegible]	1027	1.13	30.0	1.15	[illegible]
HAR2	[illegible]	911	2.97	30.0	[illegible]	[illegible]

Total Monthly Salt Deposit = [illegible]

Harvestable Salt Deposit = 14854

Summary of year 5

Months Calculated = January to December

Deposit in thousands of tons.

Pond	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Tot
PND1	0	0	0	0	0	0	0	0	0	0	0	0	0
PND2	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
HRV1	7	10	[illegible]	8	3	3	2	2	3	2	1	6	58
HAR2	4	13	44	68	82	88	91	88	70	49	31	9	638
Total	11	23	53	76	84	91	94	90	73	51	35	15	[illegible]
Net	[illegible]	23	53	76	84	91	94	90	73	51	35	15	[illegible]