AGRICULTURAL GYPSUM FOR ALKALI LAND RECLAMATION

A STUDY OF COSTS IN WEST CENTRAL GREECE

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CHARLES M. HARRIS
DIRECTOR

ADVISORY GROUP ON LAND AND WATER RESOURCES DEVELOPMENT

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AGRICULTURAL GYPSUM FOR ALKALI LAND RECLAMATION

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BY

CHARLES M. HARRIS

RENO, NEVADA

February 29, 1956
Approved by

K. H. Nelson
Director of Thesis

Approved by

Vernon E. Scheid
Dean

Approved by

Joy E. Moore
Chairman of Graduate Committee
AGRICULTURAL GYPSUM
for
ALKALI LAND RECLAMATION

A STUDY OF COSTS
IN WEST CENTRAL GREECE

Charles M. Harris
Director
Advisory Group on Land and Water Resources Development

Athens, Greece
June 1, 1955
<table>
<thead>
<tr>
<th>Subject Matter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Problem</td>
<td>2</td>
</tr>
</tbody>
</table>

Cost Studies

Plan I

(A) Type of operation 3
(B) Geological investigations 4
   (1) Gypsum deposit location map 6
   (2) Pictures of deposit No. 10 7
(C) Transportation 8
(D) Mining and processing considerations 8
(E) Cost estimates
   (1) Mining 10
   (2) Crushing and grinding 11
      Plant layout sketch 12
   (3) Transportation costs 15
   (4) Surface spreading 16
(F) Summary cost estimates, Plan I 17
(G) Conclusions 17
Plan II

(A) Typo of operation  
(B) Geological investigations  
(C) Transportation  
(D) Mining  
(E) Crushing and grinding  
(F) Spreading  
(G) Summary cost estimates, Plan II  
(H) Conclusions and recommendations

Appendix

Discussion of present contract operations  
Pictures of contractor's operations  
Pictures, gypsum storage at Pachykalamos
EQUIVALENTS

4 Strommas = 1 Acre

1 Metric ton = 1,1023 short tons = 2204.6 lbs. = 0.9842 long ton

1 Kilometer = 0.6214 mile

1 Kilogram = 2.2046 lbs. av.

1 m³ = 1.3079 cu. yd.

Limestone, in place = 4,536 lbs./cu. yd. = 5,933 lbs./M³

Gypsum, in place = 3,869 lbs./cu.yd. = 5,060 lbs./M³

Gypsum, loose = 2,200 lbs./cu.yd. approx.
INTRODUCTION

There are over 800,000 stremmas (200,000 acres) of saline or saline-alkali soils in Greece which, if reclaimed, could be agriculturally productive. Most of these areas lie near the sea along the outer perimeters of river deltas or border upon lagoons. In many cases the lands below shallow lagoons are also potentially productive and are capable of being drained and reclaimed.

The area mentioned above constitutes over 2% of the national arable land, an important factor in Greece where the export of agricultural products forms the greatest source of foreign exchange earnings. Its potential value is magnified by political and social considerations. There are many landless farmers in Greece. In addition, many refugees could be repatriated from behind the iron curtain if land were available for their settlement or new jobs were created through development of secondary industries supporting agriculture in reclaimed areas.

These factors, when viewed together, make it desirable or perhaps necessary to continue a program of alkali-saline land reclamation in Greece. Much depends, therefore, upon the establishment of sound reclamation procedures which give particular attention to costs.
PROBLEM

It has been established that a considerable amount of the saline soils mentioned above are, in fact, saline-alkali lands having exchangeable sodium percentages appreciably greater than 15 and having conductivities of the saturation extract greater than 4 millimhos per centimeter.

Most soils in the western part of the United States contain some adsorbed sodium in the exchange-complex of the clay colloids. When this exchangeable-sodium percentage exceeds 15, then the soil is classified as alkali. When it appreciably exceeds this value, the soil is in need of chemical amendment in addition to leaching to bring about reclamation.

If adequate quantities of some corrective mineral such as gypsum are not present in the surface soil, then it must be added. Otherwise, leaching may remove the soluble salts, cause an increase in pH value and produce soil changes which would reduce infiltration rates, a circumstance which would defeat efforts towards reclamation.

Investigations so far conducted have indicated that soils around Logarou Lagoon in the Arta Plain (Pachykalamos area) and those on the lower Acheloos River delta (Neochori area) are of this type. They also indicate that considerable applications of gypsum will be required and that this might easily be a controlling factor in economic feasibility of reclamation.
Until this year the cost of agricultural gypsum delivered to the two sites of use mentioned above has been approximately $9.00 - 10.00/M.T. The writer considered this quite expensive and investigations were started to determine what actual delivered costs should be under a well-planned mining, processing and distribution arrangement. This report analyzes costs of production and distribution under two different sets of conditions.

COSTS OF MINING, CRUSHING, GRINDING, TRANSPORTATION AND DISTRIBUTION OF AGRICULTURAL GYPSUM

PLAN I

(A) Type of Operation

In analyzing existing costs of $9.00 - 10/M.T. for agricultural gypsum, it was found that transportation comprises a major percentage of the total. This was due, in part, to the fact that previous orders had often been hauled from considerable distances. Therefore, under Plan I an attempt was made to locate a suitable deposit between Neochori on the Acheloos River delta and Pachykalamos in the lower Arta Plain.

Because of the past tendency of private operators to overcharge Government for gypsum, this plan of operation assumes that the Ministry of Agriculture would acquire rights to and mine a deposit,
since located, in the approximate area mentioned above. The Ministry would purchase capital equipment necessary for mining, crushing and grinding. Transportation of the finished product from a centrally located plant to the two areas of use would be done by private trucking contractors after a call for bids. Application or spreading of the gypsum on the alkali lands would be done by the Ministry of Agriculture through its Mechanical Cultivation Service.

All cost estimates in Plan I are based upon estimated requirements of 300,000 M.T., divided between the two areas, although actual eventual use in the two areas under consideration (including reclamation of Messolonghi Lagoon) could easily amount to several times this figure. In such an event, of course, amortization of capital equipment charges per ton would be lower.

Provisions have not been made for royalty payments, which are very low in these areas, or for purchase of deposits since ownership has not been established. State holdings may include some of the areas mentioned.

(B) Geological Investigations

The first stop was to locate a suitable deposit in the area required. Information on hand had indicated that deposits were located in this general area, but both Mr. Tsakos, the Chief of the Geologic Service of the Ministry of Coordination, and the writer were surprised at the number of deposits available and the high grade
of the gypsum. The map on the following page shows locations of the deposits which were identified together with preliminary estimates of the quantities at each site.

Small amounts of gypsum are now being mined at location No. 4 in the Amvrakikos Gulf and delivered to a site on the mainland south of Arta. This operation is extremely primitive and inefficient.

For purposes of this study, however, the deposit at Site No. 10 near Katouna was chosen. The Geological Institute estimated that the Katouna deposit contained approximately 60,000,000 M.T. of gypsum which contains 90 - 92% CaSO$_4$ • 2H$_2$O. Investigations made by this office indicate that this estimate is very conservative. The deposit has apparently been upended so that a vertical face of gypsum is exposed which is approximately 2,000 meters in length and perhaps an average of 500 meters high along the inclined and exposed face.

The opposite side of the mountain is composed of limestone and it was difficult to ascertain the exact thickness of the bed of upended gypsum, but the visible outcrop is obviously far in excess of any possible requirements.

The pictures on page seven show how the deposit is situated. It is exposed with little or no overburden. A road already exists to the deposit and, in fact, is built along the base of the gypsum hill for approximately two-thirds of its length. Mining could be accomplished under almost ideal conditions.
LEGEND
Scale 1:50,000
Location of Deposits
Villages or Towns
Deposits

LOCATIONS MAP
GYPSUM DEPOSITS
AREAS OF USE

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>M.T.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Filippos &quot;Zinos&quot;</td>
<td>5,000</td>
</tr>
<tr>
<td>2</td>
<td>Paleokhora</td>
<td>1,000</td>
</tr>
<tr>
<td>3</td>
<td>Paleoroforos</td>
<td>500,000</td>
</tr>
<tr>
<td>4</td>
<td>Gouvala Island</td>
<td>3,000</td>
</tr>
<tr>
<td>5</td>
<td>Thyrion Patrambela</td>
<td>3,000,000</td>
</tr>
<tr>
<td>6</td>
<td>Petra &quot;Trypa&quot;</td>
<td>25,000,000</td>
</tr>
<tr>
<td>7</td>
<td>Monastiraki &quot;Ypsas&quot;</td>
<td>2,500,000</td>
</tr>
<tr>
<td>8</td>
<td>Afroxylices</td>
<td>1,000,000</td>
</tr>
<tr>
<td>9</td>
<td>Chimeniki</td>
<td>300,000</td>
</tr>
<tr>
<td>10</td>
<td>Katouna &quot;Ypsas&quot;</td>
<td>60,000,000</td>
</tr>
<tr>
<td>11</td>
<td>Aegliion</td>
<td>750,000,000</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>92,450,000</td>
</tr>
</tbody>
</table>

PROJECT LOCATION MAP

Gulf of Amvrakinos

Location Map

Location of Deposits
Villages or Towns
Deposits
Deposit No. 10
Visible face of hill composed entirely of gypsum.

Deposit No. 10
Extension of hill to the right. Entire face composed of gypsum. Approach road in foreground.

Deposit No. 10
Second hill in right background also contains much gypsum. Note road and topography.
(C) **Transportation**

The deposit lies adjacent to a good secondary road about 5 kilometers from the main Agrinion - Arta highway, which latter would be used for transportation to within short distances of the two sites of operation. The Pachykalamos alkali land area is reached by traveling north over paved road to the town of Arta, a distance of 54 kilometers, and thence to Pachykalamos over 14 kilometers of poor, unpaved road.

After traveling from the mine to the Arta-Agrinion highway, Neochori is reached by proceeding south to Agrinion and Aetolikon, a distance of 66 kilometers over paved road. Neochori lies about six kilometers beyond Aetolikon over unpaved, rural road.

(D) **Mining and Processing Considerations**

Total requirements of gypsum from this deposit are estimated to be 300,000 M.T., and annual requirements under an active program are judged to be about 30,000 M.T. Mining and stockpiling of coarsely broken gypsum could proceed during the entire year, but crushing and grinding must be restricted to six summer months because of the necessity of maintaining minimum moisture conditions for fine grinding.

On this basis the crushing and grinding plant must have a capacity of 5,000 M.T. per month during the six dry summer months or approximately 200 tons per day for a 26 day month. Assuming one
ten hour shift per day, plant capacity would have a maximum of
20 M.T./hr.

Extremely fine grinding is advantageous for application through
irrigation water, but entails a disproportionate increase in cost.
For surface spreading it is proposed to use the product from a hammer
mill with 1/8" bars, which is considered suitable. A typical analysis
of the product produced is as follows:

<table>
<thead>
<tr>
<th>Passes 10 mesh screen</th>
<th>%</th>
<th>Max. Particle size</th>
<th>Ins.</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;</td>
<td>97%</td>
<td>0.0787 (2.00 mm.)</td>
<td></td>
</tr>
<tr>
<td>20 &quot;</td>
<td>87%</td>
<td>0.0331 (0.84 mm.)</td>
<td></td>
</tr>
<tr>
<td>35 &quot;</td>
<td>69%</td>
<td>0.0197 (0.50 mm.)</td>
<td></td>
</tr>
<tr>
<td>65 &quot;</td>
<td>53%</td>
<td>0.0090 (0.23 mm.)</td>
<td></td>
</tr>
<tr>
<td>100 &quot;</td>
<td>42%</td>
<td>0.0059 (0.149 mm.)</td>
<td></td>
</tr>
</tbody>
</table>

If material should be furnished by a private contractor using the
same type of equipment, the specifications should state maximum
particle size (2.00 mm.) and stipulate that no fines should be
removed. As an alternative, specifications may state that "no less than
90% of the product will be less than 1.00 mm. in diameter - no fines to
be removed."

An analysis has been obtained of agricultural gypsum previously
delivered under contract to the alkali land reclamation areas. It is
as follows:

10% of product greater than 1.00 mm.
15% " " between 0.5 and 1.0 mm.
75% " " below 0.5 mm.
Comparison of the two analyses will show that product size is similar within permissible limits.

(E) Cost Estimates

Preliminary cost estimates for production of agricultural gypsum under the type of operation described above are as follows:

(1) Mining

Equipment for breaking and moving rock from the face to the crusher would be relatively simple and inexpensive. It would include:

1 - Compressor, 210 c.f.m., diesel driven, 60 H.P.
3 - J-30 blower type jackhammers, 17½ kilos each, 60 c.f.m.
Air pipe, bits and miscellaneous supplies.

Cost of the compressor would approximate $8,000 CIF, the jackhammers about $200 each and miscellaneous equipment is estimated at $1,400, making a capital investment of $10,000 in addition to equipment necessary to move the broken rock from the face of the quarry to the crushing plant. This latter equipment may be furnished by the M.C.S. and so rental charges only are included.

Mining costs are therefore estimated as follows:

Capital investment, $10,000 amortized in ten years

@ 6% interest equals $13,587
or, on basis of 300,000 M.T. mined \$0.045/M.T.

Cost of drilling and blasting, 9.45 drs/M.T. or \$0.315 "

Transportation, quarry face to crusher, 3.90 drs. per M.T., or \$0.130 "

Reduction of quarry material to crusher size

(30 x 40 cm.) 3.35 drs./M.T., or \$0.111 "

Cost of mining, total \$0.601 "

(2) Crushing and Grinding

(a) Capital Equipment

In order to arrive at an estimate of capital equipment costs for a crushing and grinding plant, it was necessary to prepare a sketch of the proposed layout (see next page) and a list of equipment which would be required. This plant would include two diesel engines for direct drive of the crusher and hammer mill and all auxiliary machinery would be run by electric motors powered by a separate diesel electric generator.

Plant equipment and costs are judged to be as follows:

1 - 24" x 8" Apron Feeder with Crusher Hopper,
Walkway and Railing.

1 - 18" x 24" Roller Bearing Jaw Crusher with V-Belt Drive.

1 - 24" x 100' Channel Frame Conveyor with 15HP Speed Reducer Drive.

1 - 24" x 3' Apron Feeder with 3 HP Speed Reducer Drive (under stock pile).

1 - 24" x 70' Channel Frame Conveyor with 10 HP Speed Reducer Drive.
PLANT LAYOUT SKETCH

(Not to Scale)
1 - 48" x 12' Double Deck Horizontal Vibrating Screen with V-Bolt Drive.
1 - Roller Bearing Hammermill with V-Bolt Drive, 30" opening, rated
15 - 30 tons/hr. of \((-\frac{1}{4})\) Ag. stone.
1 - 18" x 40' Channel Frame Conveyor with 5 HP Speed Reducer Drive.
1 - 18" x 70' Channel Frame Conveyor with 7-1/2 HP Speed Reducer Drive.
1 - 23 cubic yard steel log bin.
1 - Caterpillar Model D315X Diesel Engine (Jaw Crusher).
1 - Caterpillar Model D364X Diesel Engine (Hammermill).
1 - Diesel Generator set, 80 KW continuous, 1800 RPM, 440 Volt,
3 Phase, 60 Cycle, Caterpillar D326 Diesel Engine with self regulated generator, gasoline engine starting, skid mounted radiator cooled with high temperature shut off, fused disconnect.
1 - 15 HP, 1800 RPM, 220/440 Volt, 3 phase, 60 cycle, TEFC electric motor. (for 24" x 100' Conveyor)
1 - 3 HP, 1800 RPM, 220/400 Volt, 3 phase, 60 cycle, TEFC electric motor. (for 24" x 3' Feeder)
1 - 10 HP, 1800 RPM, 220/440 Volt, 3 phase, 60 cycle, TEFC electric motor. (for 24" x 70' Conveyor)
1 - 15 HP, 1200 RPM, 220/440 Volt, 3 phase, 60 cycle, TEFC Hi-torque electric motor. (for screen)
1 - 5 HP, 1800 RPM, 220/440 Volt, 3 phase, 60 cycle, TEFC electric motor. (for 18" x 40' Conveyor)
1 - 7 1/2 HP, 1800 RPM, 220/440 Volt, 3 phase, 60 cycle, TEFC electric motor. (for 18" x 70' Conveyor)
List price, factory ...................... $53,817.00
Assembly and preparation for export .......... 2,500.00
Insurance and freight, estimated .............. 5,443.00
Total .................................. $61,760.00

With the operation as planned and amortization over a 10 year period at 6% interest, the total amount repayable would be $83,913 or $0.28/M.T.

It should be noted that gypsum contains included water and it must be positively ascertained that the material will be free enough of outside moisture to be ground without becoming sticky and causing difficulties in the hammer mill.

(b) Cost of Operation

The following costs are estimated for crushing and grinding:

Labor, 15 men @ 80 drs/day each .................. 1,200 drs/day

Power, 200 H.P., diesel, consumption 0.18 gms/H.P./hr
or 36 l./hr, for 10 hrs/day = 360 l. fuel oil/day

360 l. = 90 imp. gals. per day approx. @ 13 drs.

per gal. equals ................................ 1,170 "

Lubricating oil ................................ 117 "

Maint. and repair (10%) .......................... 117 "

2,604 "

Supervision and O & M (20%) ...................... 521 "

Total ...................................... 3,128 "

$104.00 "

@ 200 M.T./day this would cost .................. $ 0.52/M.T.
Transportation Costs

The Ministry of Public Works formula for computing trucking charges under Greek conditions is given below. Costs of transportation over poor rural roads are calculated separately from paved asphalt roads.

\[ C = a(1.2bL + K) \]

where:

- \( C \) = cost per metric ton
- \( a \) = fixed coefficient
- \( b \) = coefficient related to the road surface
- \( L \) = distance of haul
- \( K \) = cost of loading and unloading

Substituting distances and coefficients for the road conditions described under para. C above, we have:

(a) Cost of hauling from mine to Pachykalamos

5 kiloms, good secondary road -

\[ C = 1.2(1.2 \times 1.25 \times 5 + 2.5) \]

= 12 drs./M.T.

Paved road to Arta, 54 kiloms.

\[ C = 1.2(1.2 \times 0.8 \times 54) \]

= 62 "

Arta to Pachykalamos, 14 kiloms. unpaved,

\[ C = 1.2(1.2 \times 1.75 \times 14 + 2.5) \]

= 38 "

Total haulage cost to Pachykalamos . . . . . 112 drs./M.T., or $3.73/M.T.
(b) Cost of hauling from mine to Neochori

Mine to highway, 5 kiloms. good secondary -

\[ C = 1.2 \times (1.2 \times 0.8 \times 54 + 2.5) \]

= 12 drs./M.T.

Paved road to Aotolikon, 66 kiloms. -

\[ C = 1.2 \times (1.2 \times 0.8 \times 66) \]

= 76 "

Aotolikon to Neochori, 6 kiloms. unpaved -

\[ C = 1.2 \times (1.2 \times 1.75 \times 6 + 2.5) \]

= 18 "

Total haulage cost to Neochori ........ 106 drs./M.T.

or $3.53/M.T.

(4) Surface Spreading

Spreading costs for agricultural limestone, a similar operation, varies from $0.50 per short ton to $1.30 per short ton in the United States. In Greece much ground gypsum is now spread by hand, but the Mechanical Cultivation Service of the Ministry of Agriculture has some mechanical spreading equipment and under large scale operations the latter method would be used.

Fuel costs are higher in Greece and, of course, the metric ton is larger than the short ton, but these factors will be more than offset by lower labor costs. With those considerations in mind, $0.85/M.T. has been allowed for spreading and this is a generous estimate.
(F) **Summary Cost Estimates Under Plan I**

(a) Cost delivered and spread at Pachykalamos in the lower Arta Plain from centrally located deposit #10 would be summarized as follows:

- Mining costs, amortization of equipment: $0.05/M.T.
- "", operation: 0.55 "
- Crushing and grinding, amortization of equipment: 0.28 "
- "", operation: 0.52 "
- Transportation: 3.73 "
- Spreading: 0.85 "
- **Total cost at Pachykalamos**: $5.98/M.T.

(b) Cost delivered to Noochori in the lower Acholoos Plain would be the same except that transportation would be $3.53/M.T. instead of $3.73/M.T. Hence, total cost delivered at Pachykalamos would be **$5.78/M.T.**

(G) **Conclusions**

Although these costs represent a considerable reduction below previous expenses, it is evident that transportation would comprise over 62% of the total cost delivered at Pachykalamos and almost 61% at Noochori. Obviously much saving could be made if deposits closer to the site of use could be located and two separate plants used for crushing and grinding. Plan No. II outlines studies and investigations made towards this end.
(A) Type of Operation

Under this plan of operation it was necessary to locate two deposits, each one closer to its respective site of use than the centrally located deposit No. 10. Results of these investigations are discussed under (B).

Mining, crushing and grinding operations would be accomplished in a similar manner as under Plan I, but on a smaller scale with each plant having a capacity of 10 M.T./hr. instead of one plant with a capacity of 20 M.T./hr.

All work would be performed by Services of the Ministry of Agriculture except hauling, which would be done by private contractors. In order to secure an accurate comparison between Plan I and Plan II, operating conditions are calculated on the same basis insofar as possible.

Total tonnage requirements of gypsum are estimated at 150,000 for each area.

(B) Geological Investigations

(a) The most likely prospect near Pachylamos was deposit No. 1 shown on the map on page six. This deposit needs to be drilled in order to determine whether or not it contains enough tonnage to
satisfy total requirements. The picture below shows one of several outcrops scattered over an area large enough to indicate that the deposit is substantial.

Deposit No. 1
One of several small outcroppings. Unimproved road in foreground.

Some overburden would have to be stripped, accurate amounts of which would have to be determined by drilling. Topography of the area and the nature of the overburden would make this a relatively simple operation.

For purposes of this report an estimation was made of the average depth of overburden and a cost of $0.10 per metric ton of mined gypsum allocated for this purpose.

The deposit lies two kilometers north of the Ioannina - Arta highway over an undeveloped mountain road, part of which may be seen in
the above picture. This short piece of road would have to be graded and improved, a capital cost estimated not to exceed $5,000.

Nowly constructed power lines from the Louros River generating plant pass almost directly over the deposit and electricity could be used in crushing and grinding operations, but diesel-electric power is calculated in this report.

Prospect No. 2 is suitably located, but investigations indicate that an adequate tonnage is probably not available.

Prospect No. 3 is more remotely located than No. 1 and the percent of contained gypsum is lower.

Deposit No. 6 is located across Amvrakikos Gulf south of Pachykalamos. Lying about two kilometers from water it is obviously a large, high grade deposit. Two kilometers of road would have to be constructed to Amvrakikos Gulf and a pier built to load the gypsum on small boats. The gypsum would have to be loaded on truck again at the opposite shore of the Gulf of Amvrakikos below Pachykalamos. It was calculated that this transportation arrangement would be too complicated and costly for operations of presently foreseeable magnitude.

(b) A significant deposit is located almost adjacent to the alkali areas of the Lower Achelocs Plains and Messolonghi Lagoon. It consists of several low hills of gypsum varying from 20 to 40 meters in height and lying about two kilometers north of Aetolikon.
Distance to Neochori is approximately eight kilometers and this distance would probably represent an average length of haul to the Lower Acheloos Delta area. Rough calculations indicate that much more than 150,000 M.T. of gypsum are available from these deposits.

Mining has been undertaken to a limited extent at this site and a usable road exists to Neochori. Having an almost ideal location, efforts to identify other deposits in this general area were abandoned.

(C) Transportation

(a) Haulage costs from prospect No. 1 to Pachykalamos are calculated as follows:

Deposit No. 1 to Ioannina-Arta highway, 2 kiloms -

\[ C = 1.2 \times (1.2 \times 1.75 \times 2 + 2.5) = 8 \text{ drs./M.T.} \]

Asphalt highway to Arta, 18 kiloms -

\[ C = 1.2 \times (1.2 \times 0.8 \times 18) = 21 \text{ "} \]

Arta to Pachykalamos, 14 kiloms rural road -

\[ C = 1.2 \times (1.2 \times 1.75 \times 14 + 2.5) = 38 \text{ "} \]

Total cost, No. 1 to Pachykalamos . . . . . . . 67 drs./M.T.

or \$2.23/M.T.

(b) From the deposit near Aetolikon to Neochori, the following costs result:

\[ C = 1.2 \times (1.2 \times 1.75 \times 8 + 5) = 26 \text{ drs./M.T.} \]

or \$0.87/M.T.
(D) Mining

It is not considered advisable to reduce the capacity of the compressor oven though production from each mine is planned at 10 M.T./hr. instead of 20 M.T./hr. One 210 c.f.m. compressor will operate three J-30 jackhammers or two J-40 machines and this flexibility should be retained. Therefore, capital costs for mining will remain approximately the same, but amortization on a per ton basis will double. Good grade equipment is provided in order that it will last for the full amortization period of ten years. Cheaper equipment, particularly in compressors, can be purchased, but in some cases would not last for the period under consideration.

Road improvement from highway to mine is estimated to cost $5,000 and this is charged to mine development. Estimated stripping cost of overburden is also included, although with two variables involved this is at best an educated guess prior to drilling.

On the above basis the following estimates of mining cost are made:

Amortization of capital investment, $10,000 in ten years @ 6% interest equals $13,587 or, or

basis of 150,000 M.T. mined ..................... $0.090/M.T.

Cost of drilling and blasting, 9.45 drs./M.T. or 0.315 "

Transportation, quarry face to crusher, average

3.90 drs./M.T. or ................................. 0.130 "
Reduction of quarry material to crusher size

(10" x 16") 3.50 drs./M.T. .................. $0.116/M.T.

Road improvement, amortization $5,000 .......... 0.033 "

Stripping of overburden, estimated ............ 0.100 "

Cost of mining, amortization & operation(Pachykalamos). $0.784/M.T.

At Neochori stripping would be negligible and road construction is not necessary, so mining costs at that site would become $0.651/M.T.

(E) Crushing and Grinding

By reducing the capacity of the two crushing and grinding plants to 50% of the single plant considered in Plan I some economies can be effected, but capital costs would not be reduced in the same ratio.

Recommended for each of the two plants would be a crushing unit consisting of a 10" x 16" feed jaw crusher with diesel engine (12 - 15 H.P.), which will produce 11-19 short tons/hr. of minus 1\(\frac{1}{2}\)" products.

A revolving screen is often included following the crusher, but in this case it is not considered necessary since the hammermill will easily take everything passed by the crusher. A typical analysis of material from the crusher mentioned would be as follows:

85% passes 1\(\frac{1}{2}\)" screen
59% " 1" "
39% " 5/8" "
11% " 1/8" "

The above unit could be procured for approximately $8,000 C.I.F.
Convoys could be reduced in width as, for instance the 24" x 70' conveyor used for stockpiling in Plan I would become 18" x 70', which would cost $2,000 C.I.F. with motor.

The hammermill would be reduced to the equivalent of a Cedar Rapids #2033 with a 20" opening ($3,515 C.I.F.) requiring a diesel engine of approximately 75 H.P. such as a Caterpillar D318X ($4,500 C.I.F.). These makes are mentioned as representative of the quality desired and for design purposes only. Other makes would be as suitable.

Electric motors and other equipment listed under Plan I would be correspondingly reduced in size with the exception of the stockpile and storage bin, which would remain the same as under Plan I.

On the basis of the above considerations the following cost estimate has been prepared:

Cost of equipment ...... $34,981
Assembly and preparation for export ...... 1,625
Insurance and freight ............ 3,500
Total ............ $40,106

Amortizing each of these plants over a 10 year period at 6% interest and on the basis of 150,000 M.T. each, the repayable amounts would be $54,400 or $0.37/M.T.

Operation cost of each plant would approximate $70.00/10 hr. day or, on the basis of 100 M.T./day/plant, would equal $0.70/M.T.

Total cost for amortization of plant and operation cost would therefore amount to an estimated $1.07/M.T.
(F) Spreading

Spreading costs would be the same as under Plan I, or $0.85/M.T.

(G) Summary Cost Estimates Plan II

Summarizing, the following cost estimates would apply under conditions of Plan II.

(a) Pachykalamos Area, Arta Plain

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation, Deposit No. 1 to Pachykalamos</td>
<td>$2.23/M.T.</td>
</tr>
<tr>
<td>Mining, amortization and operation</td>
<td>0.78 &quot;</td>
</tr>
<tr>
<td>Crushing and grinding, amortization and operation</td>
<td>1.07 &quot;</td>
</tr>
<tr>
<td>Spreading</td>
<td>0.85 &quot;</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$4.93/M.T.</strong></td>
</tr>
</tbody>
</table>

(b) Neochori Area, Lower Acheloos Plains

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation, Deposit No. 11 to Neochori</td>
<td>$0.87/M.T.</td>
</tr>
<tr>
<td>Mining, amortization and operation</td>
<td>0.65 &quot;</td>
</tr>
<tr>
<td>Crushing and grinding, amortization and operation</td>
<td>1.07 &quot;</td>
</tr>
<tr>
<td>Spreading</td>
<td>0.85 &quot;</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$3.44/M.T.</strong></td>
</tr>
</tbody>
</table>

(H) Conclusions and Recommendations

(a) It is recommended that experiments now being conducted to determine gypsum requirements for reclamation of the Pachykalamos and Neochori areas be continued to conclusion. Upon the results of these experiments a systematic program of reclamation can be planned over the coming years and total annual gypsum needs can be ascertained within reasonable limits. Following this, an operation such as
described above could be implemented on an efficient long term basis. This type of planning is necessary in order to secure efficient operation by Government or by private contractors in the production of Agricultural gypsum.

(b) It is apparent from work done to date that gypsum requirements will eventually be quite substantial in these two areas. It is therefore recommended that arrangements be made to prospect Deposit No. 1 with a churn or rotary drill since this appears to have the best possibilities of development in the more immediate area of Pachykalamos.

(c) This study indicates that agricultural gypsum could be obtained for much less than $9.00 - 10.00/\text{t}, by developing and utilizing deposits near the two sites of use. Further, Plan II is preferable to Plan I and the former is recommended for a program of development.
Discussion of Present Contract Operations

After initial investigation had been made into costs of ground gypsum the Alkali Land Reclamation Committee was able to secure a contract for delivery of 800 metric tons at a price of less than $5.00/ton delivered at Pachykalamos.

Operations under this contract were studied in order to determine the reason for the large reduction in cost over previous contracts. The work was not sufficiently advanced to assess what the ultimate outcome of the operation will be with respect to contract terms, but it is apparent that methods were quite primitive and unsuitable for relatively large scale operations.

Gypsum is being mined on an island identified as deposit No. 4 in Amvrakikos Gulf. The face of the deposit is some 50 meters high and lies close to the shore of the island. Gypsum is broken from the face by hand drilling with a sharp bar or by placing explosives in cracks in the deposits and scaling with mud before blasting.

Pictures of the face of the deposit and loading operations are shown on the concluding pages of this report. Because of shallow water close to shore small boats are used, one having a capacity of 18 M.T. and the other 6 M.T. They are loaded with difficulty by hand,
larger pieces being selected and carried on board individually. Boats are loaded by waterline tonnage, an arrangement which does not seem to be too accurate in this case.

The coarse pieces of gypsum have been unloaded at three rather widely separated points on the mainland. A stockpile said to be about 400 M.T. in extent exists at Salohora, but this apparently was abandoned because of the long haul over poor roads from Salohora to Pachykalamos.

The present unloading point is further south about 4\(\frac{1}{2}\) kilometers below Pachykalamos. Here the 6 ton boat is beached in the mud about 500 meters from shore and the gypsum is transferred by hand to small row boats 15 or 16 feet long having a capacity of about \(\frac{1}{2}\) ton. The 18 ton boat is unloaded a similar manner except that it is beached about 800 to 1,000 meters from shore. Each of the larger boats is said to be able to make three trips a day.

No crushing and grinding plant is in evidence yet, but it is presumed that a portable or semi-portable plant will eventually be either moved to the three stockpile sites or at Pachykalamos. No costs were available for crushing and grinding, but the contractor estimated his other costs as follows:

- Mining, drilling and blasting: 15 drs./M.T.
- Water transportation in larger boats: 15 "
- " lighters or small boats: 10 "
Royalty, owner of deposit

3 drs./M.T.

Truck transportation, beach to Pachykalamos,
a distance of 4 - 4½ kilometers

10 "

Total estimated cost of coarse gypsum
delivered to site. .............. 53 drs/M.T.
or $1.77/M.T.

These costs include truck transportation from the present unloading point to Pachykalamos over the 4 kilometer route only. No cost estimates were available for hauling the gypsum from Salohora to Pachykalamos, a distance of approximately 30 kilometers over very poor roads. In all probability the contractor will find it to his advantage to abandon the stockpile at Salohora entirely after calculating transportation charges. In fairness to the contractor, it must be pointed out that he is making an effort to provide low cost gypsum on a very small contract. Larger operations planned well in advance would allow procurement and amortization of needed capital equipment, a factor which would improve contractor operation.

It may be mentioned that the storage of ground and sacked gypsum at Pachykalamos could be improved. 137 M.T. are stored in a quonset hut, but 370 M.T. have been left in the open and have more or less solidified. It will now have to be broken and spread by hand. Agricultural gypsum should always be stored under shelter in a dry place. There is room in the quonset hut for all of the gypsum.
All of the sacks laying outside the quonset hut had deteriorated to the point where they were no longer serviceable. At Neochori 800 tons were stored outside in the weather between two quonset huts. It was also solidified and contained too much moisture for mechanical spreading. Pictures on the last page of this report illustrate existing conditions.
Contractor's boats. Loaded by carrying individual pieces to boat over planks visible in picture. Note tonnage load lines on boats.

Deposit No. 4 On island in Amvrakikos Gulf. Now being mined by contractors.

Lighter or small rowboat used to transport gypsum from beached positions of larger boats 500 - 1,000 motors offshore.
Warehouse at Pachykalamos
137 M.T. of gypsum stored inside, 370 M.T. stored outside.

Contractor's stockpile of coarse gypsum at Salohora.

Ground gypsum stored in open at Pachykalamos. Moisture has caused solidification of gypsum and deterioration of bags.