UNITED ARAB REPUBLIC

THE INSTITUTE OF NATIONAL PLANNING

التخطيط القومي

Memo., No.926

A MODEL FOR THE OPTIMAL USE OF THE HIGH DAM PROJECT

By

MOHAMMED YEHIA YOUSSEF

NOV. 1969

CAIRO
3. MOHAMED MAZHAR - ZAMALEK

Introduction

With the completion of the High Dam project, it will be possible to use the water of the Nile river in many different ways for different beneficial purposes such as developing irrigation, expansion of agricultural area, generation of electric power, flood protection, improvement of in-land-water navigation, cultivation of lake shores, fishery, etc.

No doubt, that the selection of the best method of operating the High Dam and developing new resources to speed up economic growth and social progress is of great importance to the U.A.R.

The objective of the designer is to identify a satisfactors compromise based upon an economic and hydrological analysis of the relative costs and benefits associated with the competing demands.

The new techniques of operations research and computing mathematics make it possible to examine systematically many alternative operating schemes and to identify the optimal scheme to maximize social benefits.

Finally, the author is grateful to Dr. Aly Nassar, Department of Economic Models, Institute of National Planning for the technic revision of the text he made, and to Mrs. Ellen for the many tedious hours of typing the Memo.

Contents

CHAPTER I.

I.1. Agriculture and the River Nile

Agriculture is the main baise for economic structure in U.A.R. Industrialization evolution in U.A.R is mainly relying on this economic activity as well as being the source of food for population. Moreover agricultural products compose the main items of foreign trade, being thus the essential resource for accumulating hard currency which is used for economic development.

Therefore agricultural activity is taking the major attention of the state. Many efforts are exorted to increase the agricultural area. On the other hand, water being the influencing factor determining the cultivated area, and since the main source for water is the Nile River - because the country is almost deprived from rains - therefore the Ancient mans efforts were concentrated to retouch the river and to control its water. Hence many bridges and weirs were constructed.

Consequently the agricultural continued widening. While it was 1.95 million feddans* in 1813, it gradually increased till it reached 5.6 million feddans in 1952, and protempore it is now some of 6.3 million feddans.

----

* feddan = 0.42 hectares approx.

Hence, attention has been focussed on establishing a high dam to store the Nile water for so many decades, and not only for one year as it was before and to arrange its use throughout by saving the water of the abundant seasons to use it in the drought one.

I.2. The description of the Dam:

The High Dam is a rock filled body 3600 meters long, 250 meters of which lie between the two banks of the river with a sand foundation and aprons with a total height of 111 meters. The Dam is 980 meters wide at river bed and 40 meters wide at the top.

The diversion canal and the power station lie on the eastern bank of the river. The front diversion canal is 1150 meters long and leads to the enterance of the tunnels and the outlets.

The tunnels are equipped with control gates, besides screens to prevent the inflow of floating matter.

At the end of the tunnels lies the electric power station. It is operated by 12 turbines of 175000 Kw/Hour each. The power generated, at very low costs, amounts to ten billion Kw/Hour per eyear.

Water flows from the power station to the down stream canal 450 meters long which leads to the main course of the river. The generated electricity will be carried to the Delta through two power lines and it will give light to the remotest corner of the country.

Six tunnels connect the up stream diversion canal with the down stream diversion canal. Each tunnel is 282 meters long and 15 meters diameter. They are designed to discharge 11000 cubic meters of flood water pass every second/one billion cubic meters a day/. Each tunnel forcs into two branches before it is connected to the power station. Each branch feeds one of the twelve turbines.

On the western bank of the river a 280 meters long spill way canal is dug to drain the water surplus at a rate of 2300 cubic meters a second, when the stored water becomes two meters higher than the maximum level allowed.

The project does not include any canal locks for navigation. A fluvial harbour was therefore built opposite the right wing of the Dam to connect the Sudan and Lake Nasser with the U.A.R. by means of railways lines.

Lake Nasser is the greatest man-made lake in the world. Its capacity is 157 billion cubic meters, twice as the amount of water provided by the Nile in a couple of years. It is 500 Km long and 11 km wide and 95 meters deep. It stretches across the boundaries of the Sudan.

It is worth noticing that the High Dam waters will help restoring 1.3 million feddans which will be reclaimed in the Tahrir province, Edkou, Mariut, Salhia desert and East and West of the Suez Canal. The reclamination of these lands will come to an end before 1972.

The High Dam waters will also help convert lands in Upper Egypt from basin to perennial irrigation. This means vertical agriculture expansion which doubles the yield, and growing sugar-cane in 125000 feddans more, to satisfy the needs of the country and exportation purposes.

I.3. The economic effects of the High Dam

The regulation of the Nile waters has been always a chronic problem. More than 32 billion cubic meters flowed into the Mediterranean Sea, inspite of building a number of dam and the Egyptian's dire need of water for progress of reclaiming new lands to face the problem of the everincreasing population.

So, with the completion of the High Dam project, there are many economic effects will appear as:

i) The expansion of the agricultural area 1.3 million feedans will be restored. 700000 feddans will be converted from basin to perennial irrigation.

ii) Water will be secured for irrigation purposes all the year round. The country will be protected from the damaging floods forever.

iii) Rice production will be expanded and the surplus will be exported.

iv) River navigation will be made use of all the year round.

v) Ten billion Kw/Hour will be generated to be used for industrial and agricultural purposes.

vi) The national income is expected to increase by L.E.234 million per annum.

vii) The project will also provide the Sudan with 14.5 billion cubic meters of water per annum for irrigation purposes. Consequently the area under the plough will become three times as present.

CHAPTER II.

II.1. Agriculture vis-a-vis Hydro-electric power

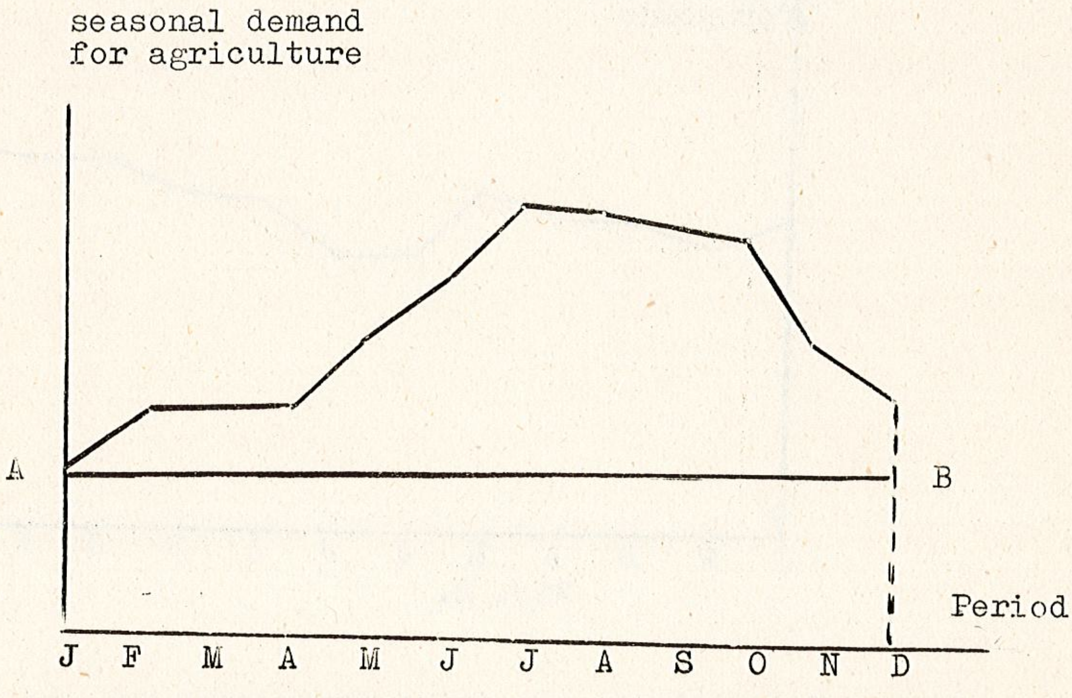
The technical studies for the best ways to utilize the High Dam, need continuous efforts in different sides. Economic analysis are included here to choose the optimal policy of operating the High Dam. Also geometrical and technological problems of utilization , in addition to the importance of interdepedndence of this policy with the general planning of the country specially in the sectors of agriculture, industry, power generation ... etc.

Firstly, we have to clarify a principle idea in this study. Namely these different and competitive sectors that might be impossible to verify them efficiently in an optimum manner at the same time. In other words, to raise the level of a certain sector, may lead to decrease the level of utilization of one or more of other sectors. There is an art of dependency between those sectors.

For example, if we decide to release the water from the High Dam according to the seasonal demand for agriculture, which depends on the cultivated area and climatical conditions which cause evaporation and exudation, it is expected that the released amount of water oscillates during the months of the year, or even within days. Such attitude leads to the oscillation of the electric power generated from the turbines.

Accordingly it becomes quite difficult to realize a regular level of electric power. Thus, we cannot rely on such oscillated electric power for constructing industries, in particular those that requires high capital-intensive-techniques.

Nevertheless, we can embark upon a certain volume of electricity which coincide with the lower seasonal demand for the requirements of agriculture. This volume of electricity is the lowest regular rate that can be obtained throughout the year. Figure 1 illustrates this idea, in which the horizontal axis represents the period and the vertical represents the release amount of water according to the seasonal demand of agriculture and which reflects the obtainable volume of electric power, if the decision is taken to release the water from the



High Dam according to the requirements of agriculture. From the figure, we can notice that the regular level of electric power which can be verified all year round, is the rate which is represented by the straight line AB.

This means that, this method of releasing water demand decreases the possibility of the full utilization of electric power.

In contrary, if the decision is taken to release the water from the High Dam according to the seasonal demand for electricity, which is considered in this case as a principle product and the agricultural products as secondary one, we can see that this system is nearly regular as shown in Fig. 2.

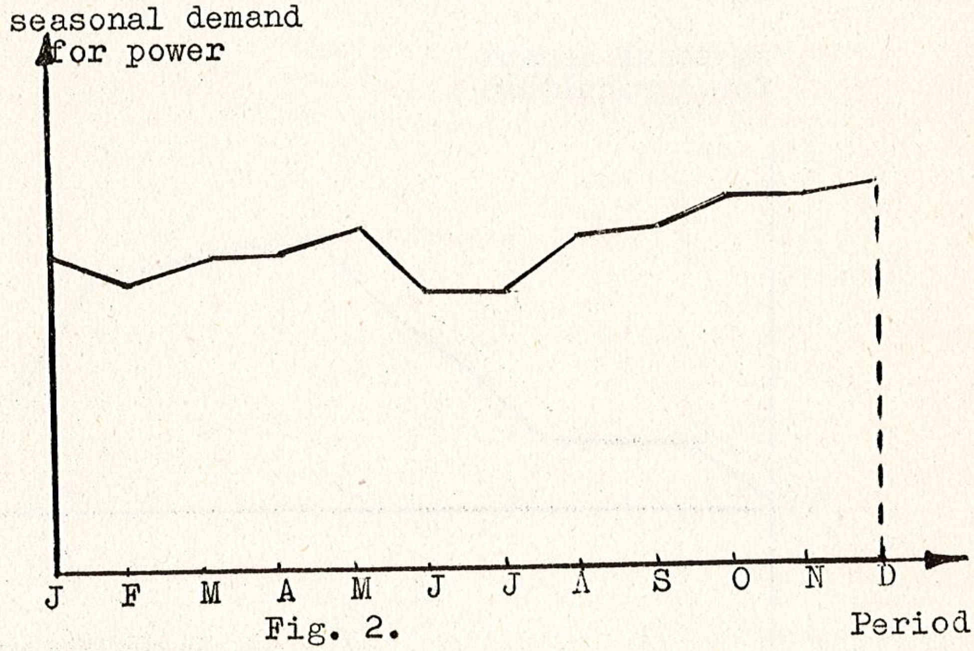


Fig. 2.

Figure 3 illustrate the inter-dependence and the connection between these two systems of water releasing. It is clear from this figure, that it is not easy to supply the sufficient volume of water required for agriculture in the region B. While there is a surplus of withdrawing water for generating power in the two periods A and C, is not used in agriculture.

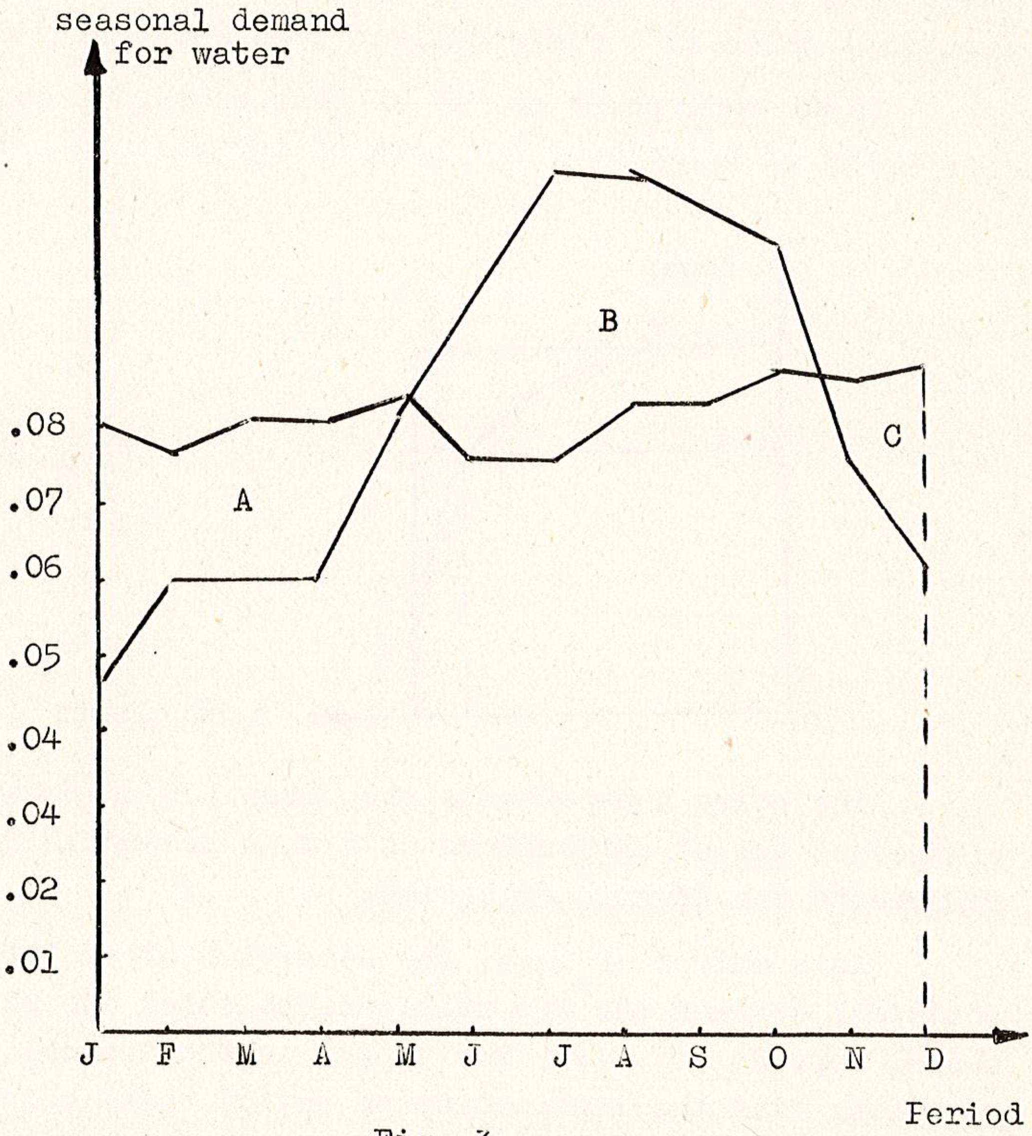


Fig. 3.

It is however possible to prepare some technical study on the purpose as to determine the relationship between the efficiency of various capacities of the High Dam in case of the two variants, viz. agriculture and power, according to the efficiency of the different possible patterns of withdrawing water from the Dam. The following fig. 4 illustrates this relation, which is a curve called "complementarity curve".

If we take a point as "M" on that curve, we can read the degree of efficiency for both of agriculture and power.

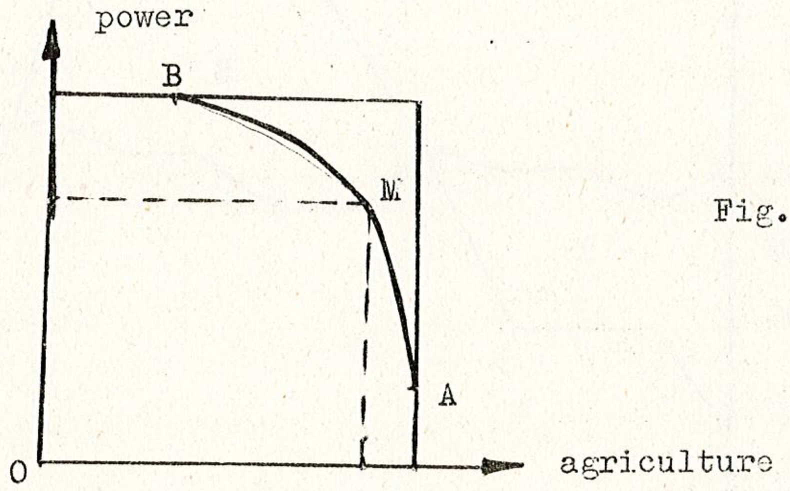


Fig. (4)

The point A represents the situation of power as a bi-product whilst agriculture as a main product. The point B represents the adverse situation.

As a matter of fact, the selection of either coincidence policies, between the two utilizations which are mentioned above, depends to a very far extent on the economic sequences resulting from the implication of any of these coincidence policies, such as its effect on G.N.P. as a whole, or its impact on the volume of exportation and also on the other economic objectives.

II.2. Complementarity between alternative uses:

The technical term "complementarity" is in our case a measure of the efficiency of water resource system that serves different purposes. For any type of water uses, as single-purpose design is always more efficient than a multi-purpose design. However, it rarely happens in a water resource system that perfect complementarity is attainable. If the system is operated to obtain maximum efficiency of obligation for one purpose then less than full efficiencly will be achieved in other uses. The degree of complementarity depends upon several factors including the shpae and size of the reservoir, the magnitude of natural inflow and its variation from season to season and from year to year and upon the patterns of withdrawals for the various uses as determined by agricultural, industrial and municipal requirements. For example, in a typical year nearly two-thirds of the annual rainfall occurs during August, September and October. In the months April through July in which climatic conditions for plant growth are good, the natural river flow is low.

Therefore if water releases from the reservoir are made to meet the demands of growing crops, the volume of stored water will be depleted in the late spring months, reaching a minimum at the end of July. As a consequence the hydraulic head on the turbines will be small and generation of electricity will be inefficient. After a succession of low-flow years the reservoir will be drawn down and the loss in efficiency, in power production will be substantial.

If, on the other hand, the reservoir is maintained at a high level at all seasons to maximize power output, then the efficiency of the dam as a regulating device is reduced and during years of high run-off a large part of the peak flow of the river may have to be discharged over the spillway to the Mediterranean Sea, and thus lost to agriculture.

II.3. Graphical method to derive the complementarity curves

Consider two purposes A and P and let:

N = number of seassons per year/or period (e.g. months)

α_i = seasonal demand coefficient of water for purpose A in season i, i=1,2,... N/AL in the computer prog./.

β_i = seasonal demand coefficient of water for purpose P.

A = total yearly discharge of water allocated for the use of purpose A.

P = total yearly discharge of water allocated for the use of purpose P.

W = maximum discharge of water per year/period/.

X_i = discharge vector of water in season i=1, 2... N.

The discharge vector should satisfy some hydrolic relations:

i) The sum of the elements of the discharge vector should be equal to the maximum discharge of water permitted in that year, i.e.:

$$\sum_{i=1}^{N} X_i = W$$

ii) The discharge vector at any season should not be less than any of the requirements of both benefits A and P, i.e.:

$$X_i \geq \alpha_i P \qquad i=1,\dots,N$$
$$X_i \geq \beta_i A$$

iii) The sum of the seasonal demand for any of the two benefits should be equal to unity, i.e.

$$\sum_{i=1}^{N} \alpha_i = 1, \qquad \sum_{i=1}^{N} \beta_i = 1$$

The geometrical decisional space has been defined by the square OUTVO/ Fig. 5/ in which:

$$0 \leq A \leq W \quad \text{and} \quad 0 \leq P \leq W$$

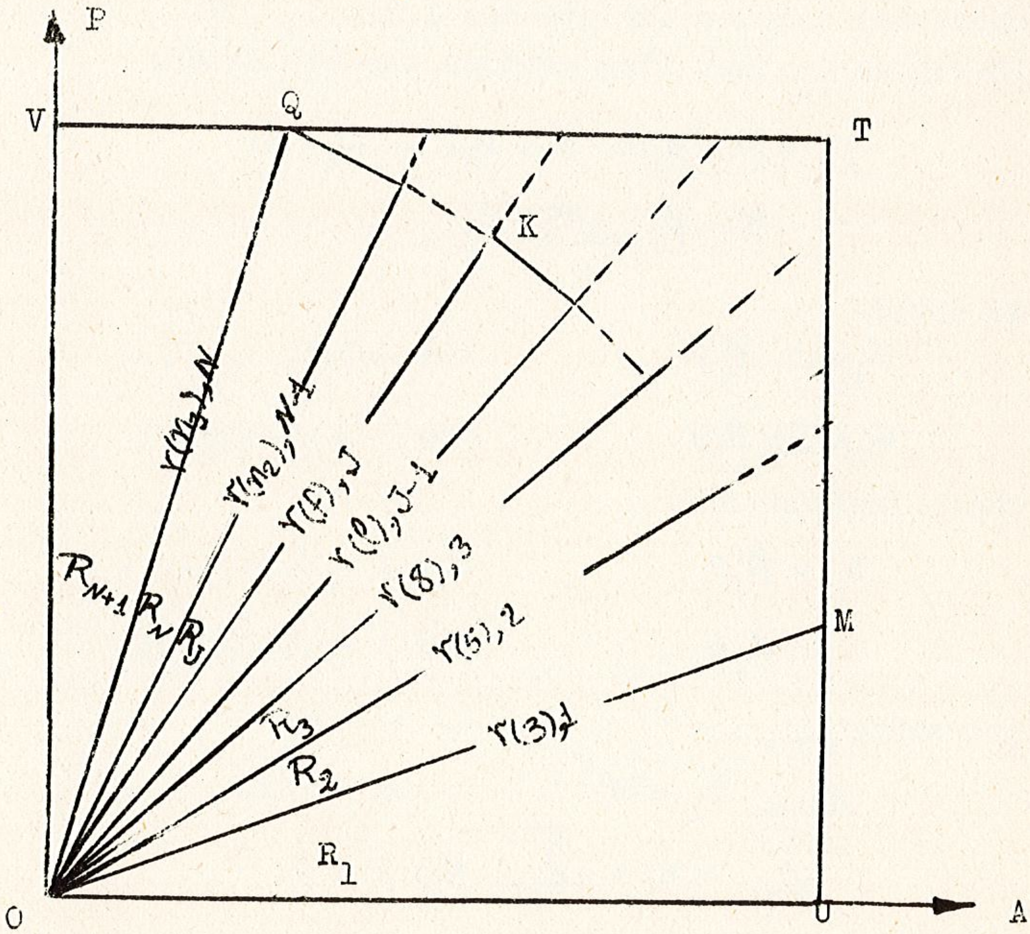


Fig. (5)

Draw the straight lines with slopes $r_i = \alpha_i / \beta_i$ and passing through the origin. These N straight lines divide the square decisional space into N+1 regional decisional space denoted by R_i, i=1,2,3, ... , N+1.

These lines ranking the slopes r_i in non-decreasing order and will be denoted by $r_{(i)}$, j where (i) represents the season and j represents its ranking order, i.e.

$$r_{(s)},1 \leq r_{(s)},2 \leq r_{(s)},3 \; .... \quad r_{(s)},N-2 \leq r_{(s)},N-1 \leq r_{(s)},N$$

where (s) denoted the seasons 1,2, ... , N.

In region R_j that lies between the two lines:

$$P = (\alpha_l / \beta_l) A \quad \text{and} \quad P = (\alpha_f / \beta_f) A;$$

$$\alpha_l / \beta_l \leq \alpha_f / \beta_f$$

we have:

$$\alpha_i A \leq \beta_i P \qquad \text{for } i=3,5, \ldots , l$$

$$\alpha_i A \geq \beta_i P \qquad \text{for } i = \text{otherwise}$$

which implies that

$$X_i = \beta_i P \qquad \text{for } i = 3,5, \ldots , l$$

$$= \alpha_i A \qquad \text{for } i = \text{otherwise}$$

and since $\sum X_i = W$ we obtain

$$(\sum_{\substack{i \\ i \neq 3,5,\ldots,l}} \alpha_i) A + (\sum_{\substack{i \\ i=3,5,\ldots,l}} \beta_i) P = W$$

which will be solved with the upper boundary line of the region R_j (solution in A and P):

$$P = (\alpha_f / \beta_f) A$$

to define the j^{th} point K of the complementarity curve. The discharge vector X is then computed.

The same procedure should be followed up to region R to determine all the N points of the complementarity curve.

As shown from the fig. 5, the point M represents the Dam as a single purpose project of A and the second purpose P as a bi-product. Also the point Q represents the benefit P as a single purpose and A as a bi-product. Between the points M and Q lies an N-2 points on the segmented complementarity curve representing a compromise solution for the Dam as a multiple-purpose project with different degrees of efficiency.

II.4. Mathematical analysis of complementarity:

Let us assume that the mean annual infolw to Lake Nasser is /W/ m.c.m. Let the symbol A denote the number of milliards of cubic meters per year to be allocated to firm agriculture. Let P denote the firm annual power target. For any level of agriculture /A/, the maximum level of firm power may be calculated by linear programming techniques.

The mathematical statement of the problem is as follows:
Maximize P

subject to the following constraints:

$$X_i \geq \alpha_i A \qquad i=1,2, \ldots , 12,$$

$$X_i \geq \beta_i P$$

$$\sum X_i = W$$

where X_i is the release during month i, α_i and β_i represent the monthly distribution coefficients of water demand for irrigation and for power. Thus α_1 represents the irrigation water requirement/Based on estimated evapotranspiration rates/ for January relative to the annual requirements; β_3 represents the proportion of the total annual power demand required in the month of March.

The values of P fall on the segmented line CD ... MN in fig. 8. The vertices of the segmented line intersect rays from the origin with slopes α_i / β_i. The set of points on the line represent all feasible and efficient mixes of agriculture and power. For example, point F represents a compromise scheme in which A = 95.367 m.c.m. and P = 65.734 m.c.m.

The pattern of flow releases for this scheme is listed in table 1. Points falling below and to the left of the segmented line represent feasible but inefficient schemes of multi-purpose operation. Points above and to the right of the line are not feasible. Point C represents single-purpose operation for agriculture with power production treated as a residual; point N represents single-purpose operation for the generation of electricity with irrigation treated as a residual.

II.5. Optimal Operation

It is evident that a wide range of blends of agriculture and power targets are practicable and the problem arises as the proper method of ranking the many alternative operating schemes. It is possible to formulate the ranking problem as a linear programming problem.

The formal statement of the ranking problem is as follows:

$$\text{Maximize} \quad f_a A + f_p P$$

$$\text{subject to} : X_i \geq \alpha_i A, \quad i=1,2, \ldots , 12$$

$$X_i \geq \beta_i P$$

$$\sum X_i = X$$

where f_a and f_p are preference coefficients for agriculture and hydropower respectively. The following values of f_a and f_p were tentatively proposed by Dr. Salib Rofaiel of the Aswan Regional Development Project and the U.A.R. Institute of National Planning from a preliminary analysis of pertinent economic data. The numerical values of f_a and f_p like those of other parameters used in this initial study are not definitive, the are used to exhibit techniques of analysis.

Objective	Preference f_a	coefficients f_p
Maximized value added to the economy	6.86	5.85
Maximized economic surplus	4.80	3.79
Maximized export	2.83	1.67

The parameter f_a is proportional to the present value of the time stream of benefits per unit increment of agricultural production; and f_p is proportional to the present value of benefits per unit increment of power generated.

In addition to the three objectives listed, other objectives such as regional development may be investigated.

The choice of objective is, of course a matter of paramount importance to the nation and must be made at the highest levels of the government.

The optimal policy for these three objectives can be calculated mathematically by computer as a linear programming problem, and also graphically if we draw the three negative ratios of these objectives (f_a/ f_p).

On the A-P domain of fig. 6, the three dashed lines which have negative slopes of f_a/f_p = 1.17, 1.27, 1.69. represent the three functions. Lines parallel to these lines are tangent to the segmented line at points J, H. It may be demonstrated that for any values of f_a and f_p the point of tangency of a straight line of negative slope f_a/f_p with the segmented line/which, in general, will be at once of the vertices C,D, ... , M,N / indicated the optimal target values of A and P that maximize the preference function.

The graphical construction provides a convenient method of investigating the implications of implementing any particular economic objective. If the ratio f_a/f_p is close to zero, points at or near N will be indicated; these represent full or nearly full development of the potential of the system for the generation of electricity. On the other hand, if f_a is large in relation to f_p, points at or near C will be indicated. These points represent high development of the potential for irrigation.

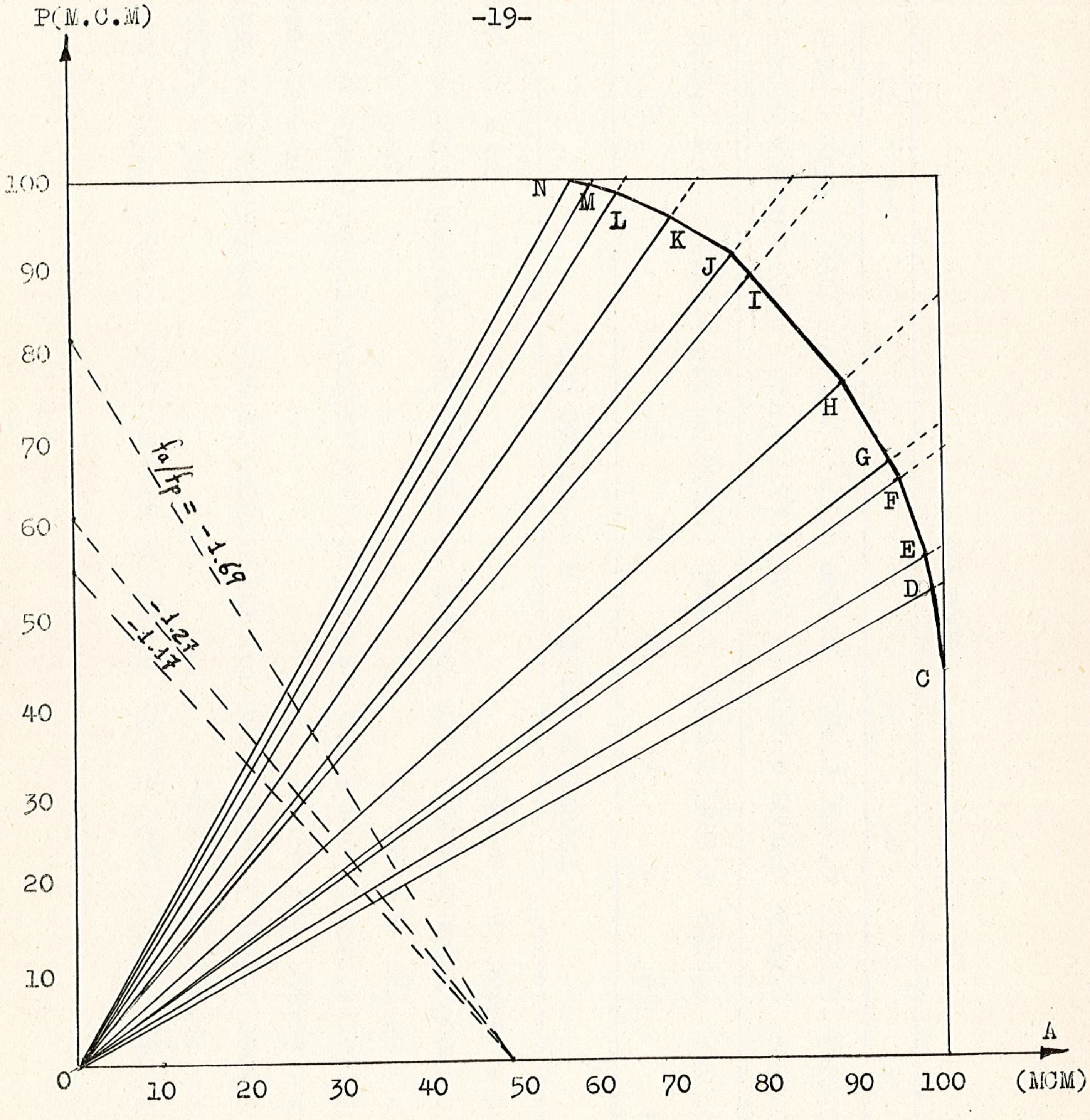

P(M.C.M)
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
A
(MCM)
N
M
L
K
J
I
H
G
F
E
D
C
fa/fp = -1.69
-1.27
-1.17

Fig. (6)

Table 1.

Season	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Al	0.0422	0.0505	0.0610	0.0722	0.0972	0.1036	0.1128	0.1231	0.1199	0.0989	0.0644	0.0542
Be	0.0952	0.0949	0.0885	0.0832	0.0807	0.0744	0.0716	0.0711	0.0718	0.0864	0.0887	0.0936
R	0.0438	0.5326	0.6898	0.8683	1.2050	1.3930	1.5759	1.7319	1.6704	1.1452	0.7265	0.5802
RANK	1	2	12	3	11	4	10	5	6	7	9	8

DISCHARGE VECTOR, W = 100.000 MCM

C PT = 1 A = 100.00 P = 44.328 Sx = 100.000	4.2200	5.0500	6.1000	7.2200	9.7200	10.3600	11.2800	12.3100	11.9900	9.8900	6.4400	5.4200
D PT = 2 A = 99.161 P = 52.768 Sx = 100.000	5.0235	5.0076	6.0488	7.1594	9.6385	10.2731	11.1854	12.2067	11.8894	9.8070	6.3860	5.3745
E PT = 3 A = 98.280 P = 56.971 Sx = 100.000	5.4236	5.4066	5.9951	7.0958	9.5529	10.1818	11.0860	12.0983	11.7838	9.7199	6.3293	5.3268
F PT = 4 A = 95.367 P = 65.734 Sx = 100.000	6.2578	6.2381	5.8174	6.8855	9.2697	9.8801	10.7574	11.7397	11.4346	9.4318	6.1417	6.1461

(con.)

Season	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
G	PT = 5A = 94.139		P = 68.349						Sx = 100.000			
	6.5068	6.4863	6.0489	6.7968	9.1503	9.7528	10.6189	11.5885	11.2873	9.3103	6.0625	6.3906
H	PT = 6A = 88.686		P = 76.960						Sx = 100.000			
	7.3266	7.3035	6.8110	6.4031	8.6203	9.1878	10.0038	10.9172	10.6334	8.7710	6.8264	7.1958
I	PT = 7A = 78.235		P = 89.553						Sx = 100.000			
	8.5255	8.4986	7.9255	7.4508	7.6044	8.1051	8.8249	9.6307	9.3804	7.7374	7.9434	8.3733
J	PT = 8A = 75.994		P = 91.532						Sx = 100.000			
	8.7138	8.6864	8.1006	7.6155	7.3866	7.8730	8.5721	9.3549	9.1117	7.9084	8.1189	8.5582
K	PT = 9A = 68.985		P = 96.060						Sx = 100.000			
	9.1449	9.1161	8.5013	7.9922	7.7520	7.1469	7.7815	8.4921	8.2713	8.2996	8.5205	8.9816
L	PT =10A = 62.763		P = 98.878						Sx =b100.000			
	9.4132	9.3835	8.7507	8.2267	7.9795	7.3565	7.0797	7.7261	7.5253	8.5431	8.7705	9.2451
M	PT =11A = 59.727		P = 99.739						Sx = 100.000			
	9.4952	9.4652	8.8269	8.2983	8.9489	7.4206	7.1403	7.3524	7.1613	8.6175	8.8469	9.3256
N	PT =12A = 57.758		P = 100.000						Sx = 100.000			
	9.5200	9.4900	8.8500	8.3200	8.0700	7.4400	7.1600	7.1100	7.1800	8.6400	8.8700	9.3500

With the computer solution for the complementarity calculations in connection with the preference function that maximizes the value added to the economy(point J), the total benefit in multipurpose operation is proportional to:

$$6.86\ (75.994) + 5.85\ (91.532) = 1056.78$$

Now if the various factors that have been discussed which limit complementarity were not operative, the full potential of the water resources system for both power and agriculture could be realised and the total benefit would be proportional to[1/]:

$$6.86\ (100) + 5.85\ (100) = 1271$$

Therefore the actual degree of compolementarity is

1056.78 / 1271 = 83.14% for this preference function.

II.6. Discussion of results[2/]

It is very useful to compare the different alternative solutions given through the complementarity curve, to decide what compromise solution should be followed so that the national return will be maximum.

So, let us suppose that:

i) there are 12 periods in the year, N=12.

ii) volume of the stored water in the reservoir and which can be used for both two purposes A and P is 100 m.c.n.

iii) the generated electric power is directly proportionate with the amount of the released water from the Dam

---

1/ Assuming the volume of the stored water in the reservoir is 100 m.c.m.

2/ The numerical data used in that example are tentative estimate of several parameters intended to facilitate explanation of methodology.

without taking into consideration the difference of the levels of water in front and behind the Dam during the year.

In table 1 which shows[1/] the computational results and which illustrates the kind of interference that may be made at a later stage when reliable input data are available.

Comparing these different results to know the gains and losses in these different uses, we can design another table 2.

1/ These computations were executed at ZOWAR - Warszawa Computer Center.

Table - 2 -

Compromise alternative	Loss in A QTY	Gain in P QTY	Loss in A %	Gain in P %
2	839	8.440	839	19.040
3	1.720	12.643	1.720	28.524
4	4.632	21.406	4.632	48.291
5	5.861	24.021	5.861	54.190
6	11.314	32.632	11.314	73.619
7	21.765	45.225	21.765	102.028
8	24.006	48.204	24.006	106.490
9	31.015	51.732	31.015	116.705
10	37.237	54.550	37.237	123.065
11	40.273	55.411	40.273	125.007

From the table 2 compromise atlernative No. 2 states that decreasing our use of water for A by 0.839 % will increase the other benefit P by 19.040 %.

The 3rd alternative indicates that a reduction of the use of water for A by 1.720% increases the water used for the other purpose P by 28.524%.

II.7 FORTRAN RUN

```
FORTRAN COMPILATION VER 2 MOD 1
  OBJECT MACHINE SIZE = 11999
     C      THIS PROGRAM WAS EXECUTED AT ZOWAR-WARSAW COMPUTER
             CENTER WARSZAWA POLAND
     C      INSTALLATION = I.B.M 1440 DISK ORIENTED SYSTEM 3/4/1968
     C      A PROGRAM FOR COMPUTING THE DISCHARGE VECTOR
            DIMENSION AL(12), BE(12), R(12),X(12),RD(12),L(12)
          1 READ (1,2) N,W
          2 FORMAT (I5,F10.3)
            READ (1,3)(AL(I), I=1,N)
            READ (1,3)(BE(J),J=1,N)
          3 FORMAT (8X,12F6.4)
            WRITE (3,30)
         30 FORMAT(1H1)
            WRITE (3,31)
         31 FORMAT (1H, 132H-------------------------------------
           A-------------------------------------------------------
           B-----------------)
            WRITE (3,32)
         32 FORMAT (1H, 1HI, 8X, 1HI, 121X,1HI)
            WRITE (3,33)
         33 FORMAT (1H, 10HI SEASON I,5X,1H1,9X,1H2,9X,1H3,9X,1H4,
           A9X,1H5,9X,1H6,9X,1H7,9X,1H8,9X,1H9,8X,2H10,8X,2H11,8X,
            2H12,5X,1HI)
            WRITE (3,32)
            WRITE (3,31)
            WRITE (3,32)
            DO 4 I=1,N
            R(I)=(AL(I)/BE(I)+0.0005
          4 RD(I) = R(I)
     C      R IN NON-DECREASTING ORDER
```

```
      DO 7 I=1,N
      V=RD(1)
      DO 6 J=1,N
      IF(V-RD(J)) 6,5,5
    5 V = RD(J)
      L(I)=J
    6 CONTINUE
      K=L(I)
      RD(K)=99999.9
    7 CONTINUE
      WRITE (3,9) (AL(I),I=1,N)
    9 FORMAT(1H, 10HI AL       I,12F10.4,2H  I)
      WRITE (3,32)
      WRITE (3,10) (BE(I),I=1,N)
   10 FORMAT (1H, 10HI BE       I,12F10.4,2H  I)
      WRITE (3,32)
      WRITE (3,31)
      WRITE (3,32)
      WRITE (3,11) (R(I), I=1,N)
   11 FORMAT (1H, 10HI  R       I,12F10.4,2H  I)
      WRITE (3,32)
      WRITE (3,12) (L(I), I=1,N)
   12 FORMAT (1H, 10HI RANK   I,16,11(4X,I6),6H   I)
      WRITE (3,32)
      WRITE (3,31)
      WRITE (3,32)
      WRITE (3,13) W
   13 FORMAT (1H, 10HI        I,38X,17HDISCHARGE VECTOR, 3HW=
     A,F12.3,4H MCM,47X,1HI)
      WRITE (3,32)
      WRITE (3,31)
      WRITE (3,32)
      DO 23 I=1,N
      II=L(I)
```

```
      C1=0.0
      C2=0.0
      C3=AL(II)/BE(II)
      SX=0.0
      DO 16 J=1,N
      J1=L(J)
      IF(J-I)14, 15, 15
   14 C2=C2+BE(J1)
      GO TO 16
   15 C1=C1+AL(J1)
   16 CONTINUE
      C3D=C3*C2
      A=W/(C1+C3D)
      P=C3*A
      M=I=1
      IF(M)17,17,19
   17 DO 18 J=1,N
      X(J)=AL(J)*A
   18 SX=SX+X(J)
      GO TO 24
   19 DO 22 J=1,N
      DO 21 K=1,M
      IF(J-L(K))21,20,21
   20 X(J)=BE(J)*P
      SX=SX+X(J)
      GO TO 22
   21 CONTINUE
      X(J)=AL(J)*A
      SX=SX+X(J)
   22 CONTINUE
```

```
24 WRITE (3,37) I,A,P,SX
37 FORMAT(1H,1HI,8X,1HI,2X,4HPT=,I6,3X,3HA=,F10.3,2X,3HP=
  A,F10.3, 55X,3HSX=,F10.3,9X,1HI)
   WRITE (3,35) (X(J),J=1,N)
35 FORMAT(1H,10HI         I,12F10.4, 2H  I)
23 WRITE (3,32)
   WRITE (3,31)
   GO TO 1
   END
```

SEASON	1	2	3	4	5	6	7	8	9	10	11	12
AL	0.0422	0.0505	0.0610	0.0722	0.0972	0.1036	0.1128	0.1231	0.1199	0.0989	0.0644	0.0542
BE	0.0952	0.0949	0.0885	0.0832	0.0807	0.0744	0.0716	0.0711	0.0718	0.0864	0.0887	0.0935
R	0.4438	0.5326	0.6898	0.8683	1.2050	1.3930	1.5759	1.7319	1.6704	1.1452	0.7265	0.5802
RANK	1	2	12	3	11	4	10	5	6	7	9	8

DISCHARGE VECTOR, W = 100.000 MCM

	PT =	A =	P =	SX =	1	2	3	4	5	6	7	8	9	10	11	12
C	1	100.000	44.328	100.000	4.2200	5.0500	6.1000	7.2200	9.7200	10.3600	11.2800	12.3100	11.9900	9.8900	6.4400	5.4200
D	2	99.161	52.768	100.000	5.0235	5.0076	6.0488	7.1594	9.6385	10.2731	11.1854	12.2067	11.8894	9.8070	6.3860	5.3745
E	3	98.280	56.971	100.000	5.4236	5.4066	5.9951	7.0958	9.5529	10.1818	11.0860	12.0983	11.7838	9.7199	6.3293	5.3268
F	4	95.367	65.734	100.000	6.2578	6.2381	5.8174	6.8855	9.2697	9.8801	10.7574	11.7397	11.4346	9.4318	6.1417	6.1461
G	5	94.139	68.349	100.000	6.5068	6.4863	6.0489	6.7968	9.1503	9.7528	10.6189	11.5885	11.2873	9.3103	6.0625	6.3906
H	6	88.686	76.960	100.000	7.3266	7.3035	6.8110	6.4031	8.6203	9.1878	10.0038	10.9172	10.6334	8.7710	6.8264	7.1958
I	7	78.235	89.553	100.000	8.5255	8.4986	7.9255	7.4508	7.6044	8.1051	8.8249	9.6307	9.3804	7.7374	7.9434	8.3733
J	8	75.994	91.532	100.000	8.7138	8.6864	8.1006	7.6155	7.3866	7.8730	8.5721	9.3549	9.1117	7.9084	8.1189	8.5582
K	9	68.985	96.060	100.000	9.1449	9.1161	8.5013	7.9922	7.7520	7.1469	7.7815	8.4921	8.2713	8.2996	8.5235	8.9816
L	10	62.763	98.878	100.000	9.4132	9.3835	8.7507	8.2267	7.9795	7.3565	7.0797	7.7261	7.5253	8.5431	8.7705	9.2451
M	11	59.727	99.739	100.000	9.4952	9.4652	8.8269	8.2983	8.0489	7.4206	7.1413	7.3524	7.1613	8.6175	8.8469	9.3256
N	12	57.758	100.000	100.000	9.5200	9.4900	8.8500	8.3200	8.0700	7.4400	7.1600	7.1100	7.1800	8.6400	8.8700	9.3500

Some case studies that can be implemented:

1. Preparation of complementarity curves indicating the alternative uses of the High Dam to find out the extent of consistency or inconsistancy between them in order to reach to the optimal policies of utilization;

2. Investigating the economic effects of the different utilizations of the Nile water in irrigation and generation of electric power. as well as agriculturing the shores, the enhancement of the area under cultivation and other facilities;

3. Studying the total water flow in the Nile for long periods ago, and preparation of all expected probabilities of such water flow in the future;

4. designing mathematical and technical models illustrating each of the utilization policies and determining all the technical and geometrical features for these policies;

5. drafting the appropriate computer programmes which are the instruments for analysing these very complicated studies that cannot be done therewithout;

6. investigating the possibility of storing any surplus of water over the need of agriculture in the given period, in order to increase the electric power. Either this storing is to be on surface or under fround;

7. taking into consideration waste of water as a result of leakage and evapotranspiration and the impact of such attitude on the volume of the stored water and consequently on utilization policies.

References

(1) Harold A. Thomas, Jr.; On the efficient use of High Asswan Dam for hydropower and irrigation

April 1965.

(2) Abdullah El-Naggar; On the complementarity curves.

April 1966.

(3) Mostafa Kamal; The problem of the alternative uses of the High Dam water. (Arabic document)

November 1965.

(4) The U.A.R. Statistical year book.

1967.