Computer use for the Varamin basin, Iran

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SUMMARY

The expanding population of Iran and the effort to raise living standards require better use of the relatively limited water resources of the country. The Government, realizing that an overall approach to area development is essential, has since 1966 been working with FAO on a UNDP project for integrated development of the Varamin-Garmsar area.

The Varamin Plain, located east of Teheran, is supplied by the Jaj Rud (Jaj River) and by groundwater from the underlying alluvium. About half of the good agricultural land is now irrigated. The UNDP/FAO project has studied the surface water supply available and the characteristics of the groundwater basin.

Using a digital computer model of the groundwater basin, consequences of future water engineering works can be determined. A linear programme has also been prepared to show how surface and groundwater can be distributed on Varamin Plain to obtain maximum net benefit.

The unique feature of these two programmes is that the output of the linear programme can be used directly on the groundwater model to test the physical validity of the economic solution. While the project is not yet complete, use of these computer programmes for various alternatives has given much insight into the nature of the economic and physical problems of water distribution and use.

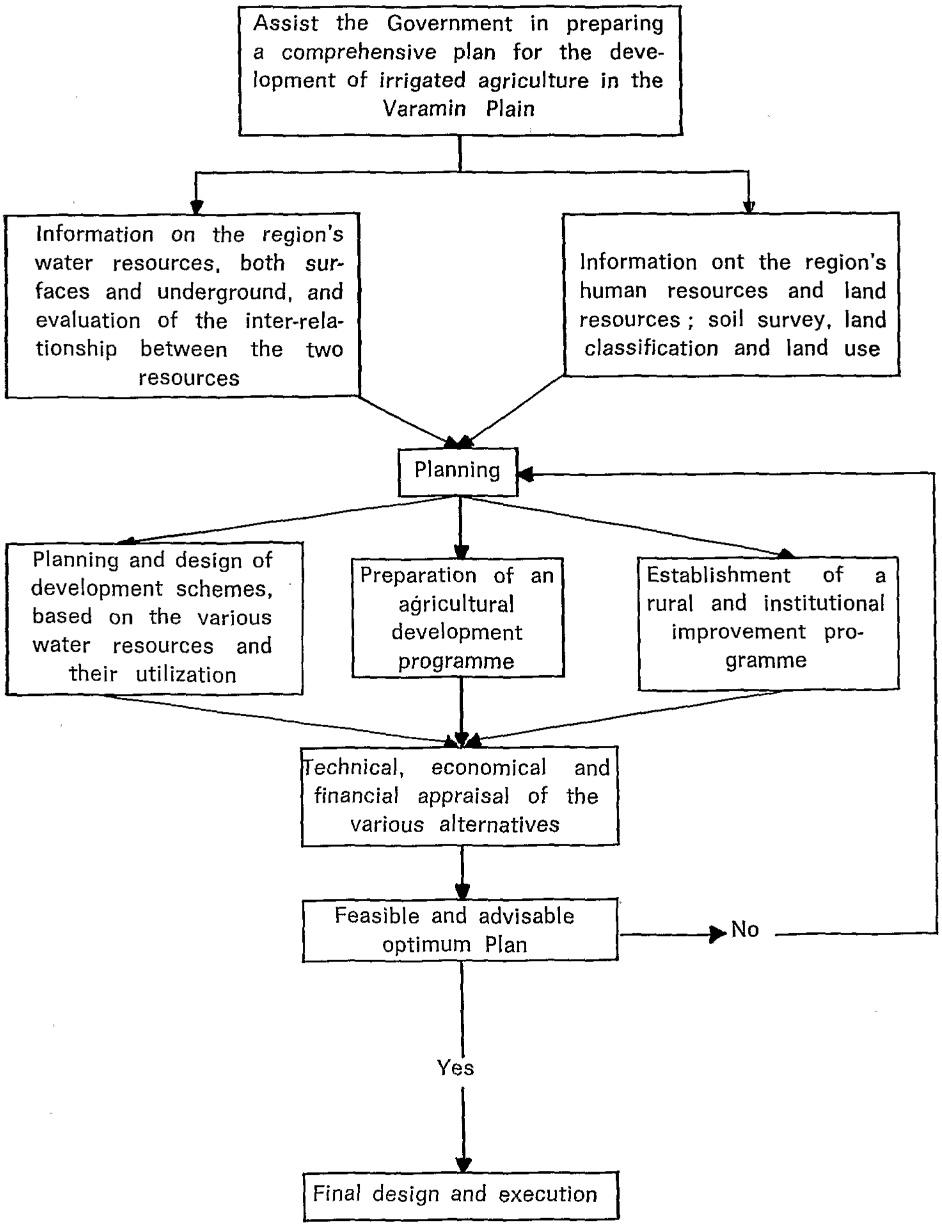

FIG. 1. — *Objectives of the Varamin Projetcs.*

INTRODUCTION

Iran has had at least 7 000 years of civilization and 2 500 years of written history. She has faced the drought problem since the very beginning, because the areas where rain occurs are generally in the higher, less accessible mountains. Irrigation in the more favourable areas has been practised for more than 2 500 years and continues to expand today. The present 26 million population is expected to reach 50 million by the year 2 000, requiring greater efforts to conserve and utilize fully the finite surface and groundwater supplies.

There are now about 50,000 ghanat chains (a ghanat chain is a tunnel or infiltration gallery connected by dug wells) in Iran, most of which were constructed in pre-Islamic days. Of these, about 35,000 are " wet ", average about 5 km long, and still supply about 10 million cubic metres per year for agricultural and other purposes.

In less than 25 years about 5,000 deep wells have been drilled in Iran, pumps have been installed and more groundwater extracted. It is generally agreed that groundwater storage has great value, and therefore in many areas water levels will fluctuate widely as natural underground reservoirs are operated by increased pumping of deep wells. One side effect will be the drying up and eventual abandonment of many ghanat chains. At the same time there has been emphasis on conservation of surface water by construction of dams and diversion works. The need for more long term storage has become apparent as the better surface storage sites are being utilized.

The Government is actively encouraging better management and operation of its widespread and rather complex water resources (Mahdavi, 1967). In 1966 the Government signed the Plan of Operation with the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Programme (UNDP) for a project to try to achieve this and related objectives in a specific area. This project is called " Integrated Planning of Irrigated Agriculture in the Varamin and Garmsar Plains " and FAO is the executing agency for the UNDP. This project (hereafter called the Varamin-Garmsar Project for simplicity) will be completed in 1970 and therefore specific conclusions cannot be given in this article. The general objectives of the project are

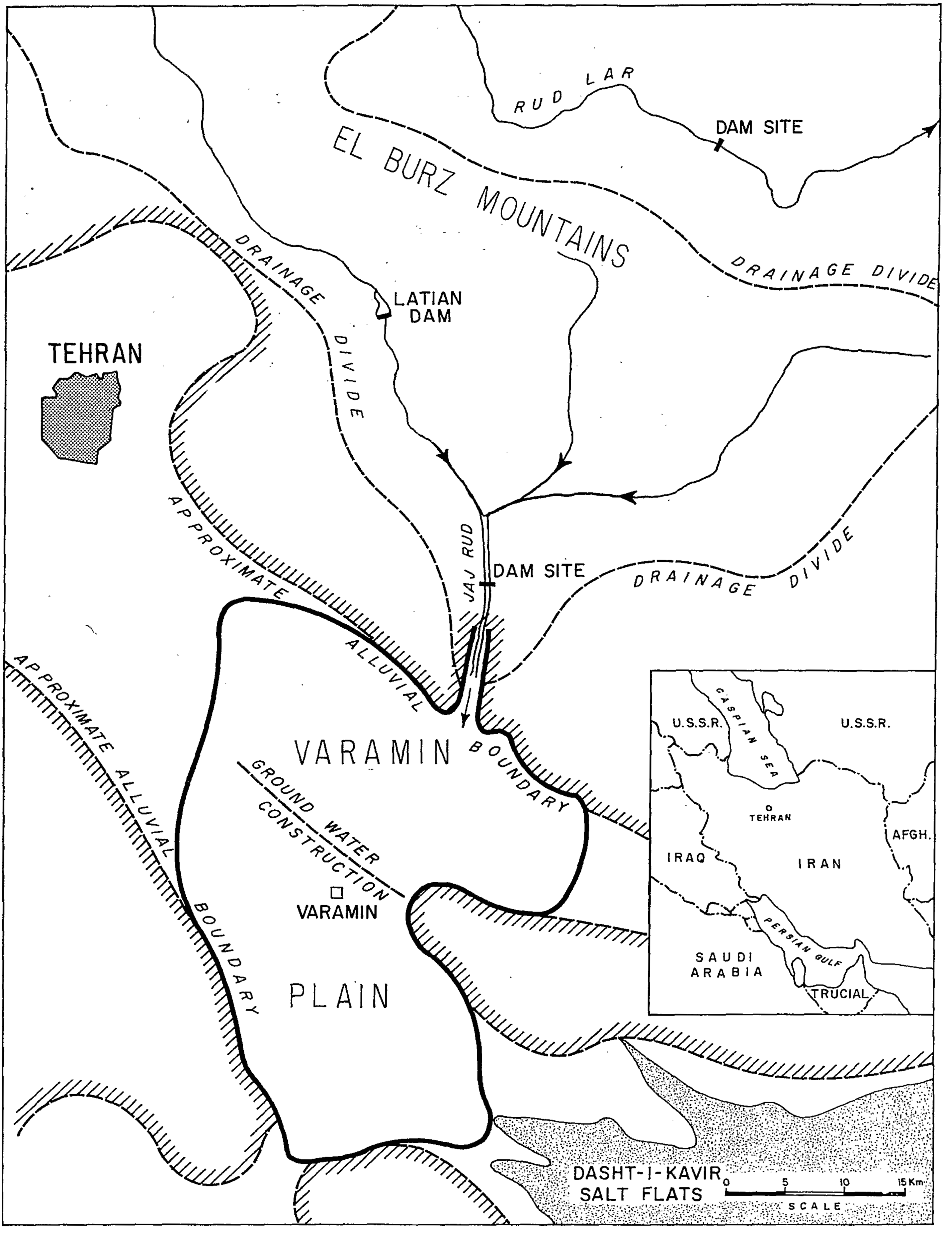

FIG. 2. — *Location map of Varamin plain, Iran.*

diagrammed in fig. 1 (de Ridder and others 1969).

The purpose of this paper is to describe briefly the use of digital computers for an unusual combination study of groundwater and economic optimization of water use for the Varamin Plain. Other important aspects such as engineering plans, farm extension, farm size, etc. are not discussed here, but will be fully covered in the report of the project to be finished in 1970.

THE VARAMIN PLAIN

To understand better the purposes of the computer studies, a brief description of the Varamin Plain is given (see fig. 2).

The Varamin Plain is a southerly trending alluvial fan which has been deposited primarily by the Jaj Rud (rud is river in Parsee). The Plain lies about 40 km east of Teheran, while the Jaj Rud drainage is located to the northeast of Teheran on the south slope of the Elburz mountains. Latian dam is located on the Jaj Rud about 20 km east of Teheran and water from the Jaj Rud is being diverted from it to the city of Teheran, thus reducing surface supplies to the Varamin Plain. Another river, the Rud Lar, drains the north flank of the Elburs mountains and flows to the Caspian Sea; this river is about 40 km from Teheran, northeast of the Jaj Rud. Preliminary studies for diversion of Rud Lar water of Teheran via the Jaj Rud have been carried out, raising the possibility of using Rud Lar water for irrigation on the Varamin Plain.

After being used for irrigation on Varamin Plain, waste water and occasional flood water drain southeasterly to a vast salt flat called Dasht-I-Kavir which extends about 300 km to the east.

The Jaj Rud has a drainage area of 1 775 km² above the apex of the Varamin Plain and has an average discharge of about 250 million m³ per year. The Varamin Plain groundwater basin has an area of about 1 310 km² of which about 750 km² have good agricultural soils.

THE WATER SUPPLY PROBLEMS

There is very low rainfall on Varamin Plain and therefore agriculture depends entirely on irrigation. Present sources of water are the Jaj Rud which is diverted through many canals to the fields, and groundwater. Groundwater was developed first by construction of ghanats and in recent years by drilled and cased water wells.

With the water supplies now available about 300 km² can be irrigated. Surface water supplies vary from 172 to 320 million m³ per year. Latian dam regulates about 50 percent of the Jaj Rud. However, large amounts of surface water percolate into Varamin Plain groundwater basin, which has a total storage capacity of about 20,000 million m³. A 1-metre depth of the groundwater basin represents about 100 million m³, giving some idea of the relative size of groundwater storage. The groundwater presently yields about 240 million m³ per year.

About 80 million m³ per year is presently diverted from Latian dam to Teheran. Even if water is not imported to Varamin Plain, additional population growth of Teheran will put pressure to divert more Jaj Rud water from agriculture on Varamin Plain, while at the same time more agriculture will be required to support its food requirements. It is therefore important to utilize to the fullest extent the occasional flood waters lost to the salt flats, and to use water locally for maximum beneficial purposes.

If water is imported into the Jaj Rud and to Varamin Plain, it will clearly be more costly than local water, and therefore must be used in such a way as to obtain maximum benefit.

The UNDP/SF Varamin-Garmson Project is now completing some studies of these problems. In the following discussion, more details of the Varamin Plain groundwater basin are described as well as use of the computer to study the basin.

THE VARAMIN PLAIN GROUNDWATER BASIN

Groundwater occurs in alluvial deposits averaging about 100 metres in thickness with a maximum thickness of about 300 metres. The alluvium is of late Pleistocene and Recent age and has been deposited as an alluvial fan, probably mostly by the Jaj Rud. The alluvium may be somewhat folded and faulted but appears to be mostly undisturbed. The alluvium is underlain and flanked by various formations which are relatively impermeable.

The central part of the Plain is flanked by low hills which are part of a faulted anticline. This faulted anticline passes beneath the central part of the alluvium. The older formations decrease the width of the waterbearing alluvium in this central part and cause the alluvium to be shallower along the anticline, resulting in a partial barrier to movement of groundwater.

This barrier-like effect is quite important since it divides the Varamin Plain into an upper and lower part, each of which is somewhat, but not entirely, independent of the other. As a result, the use of the basin to store and transmit groundwater has many possibilities.

Groundwater is recharged in the upper area of the Plain from the river where depth to water table is 70 metres. Water levels lie near the surface in the central area where many ghanat chains have skimmed off the water. Below the barrier area the water table depth drops to 20 metres or so and then approaches the land surface near the salt flat at the southeast end of the alluvial fan. Groundwater is also recharged by percolation of canal and irrigation water. Since even well and ghanat water is mostly conducted in unlined channels, some of this water extracted from underground also returns to the water table.

While the alluvium has rather extensive clay and silt layers, the basin as a whole seems to be relatively unconfin-

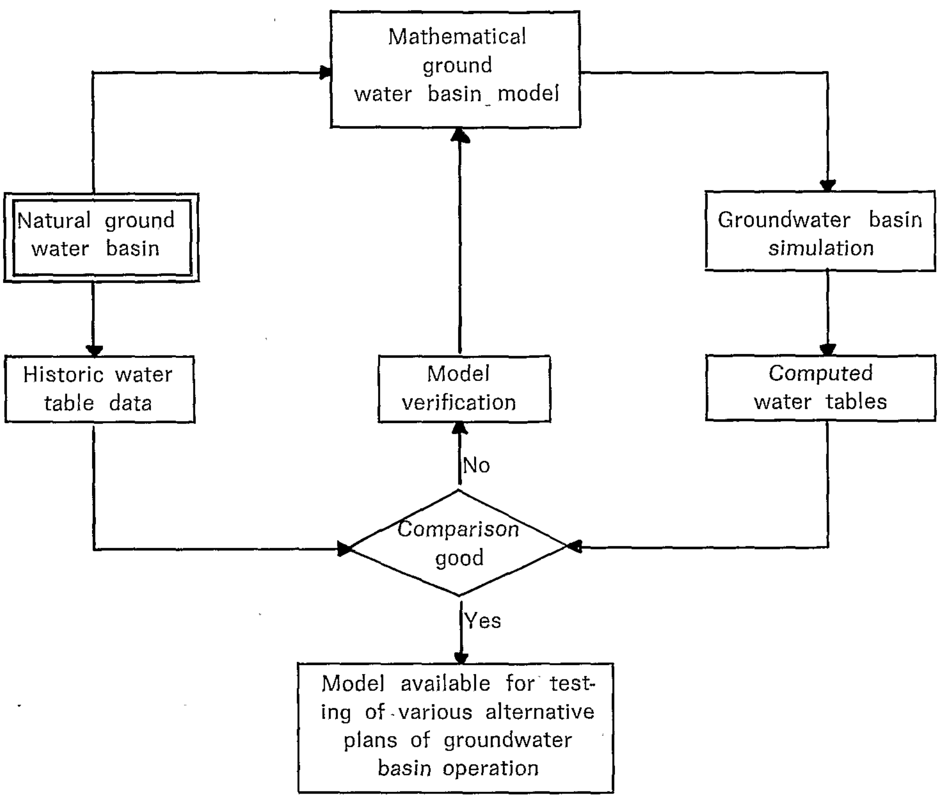

FIG. 3. — *Groundwater basin model analysis.*

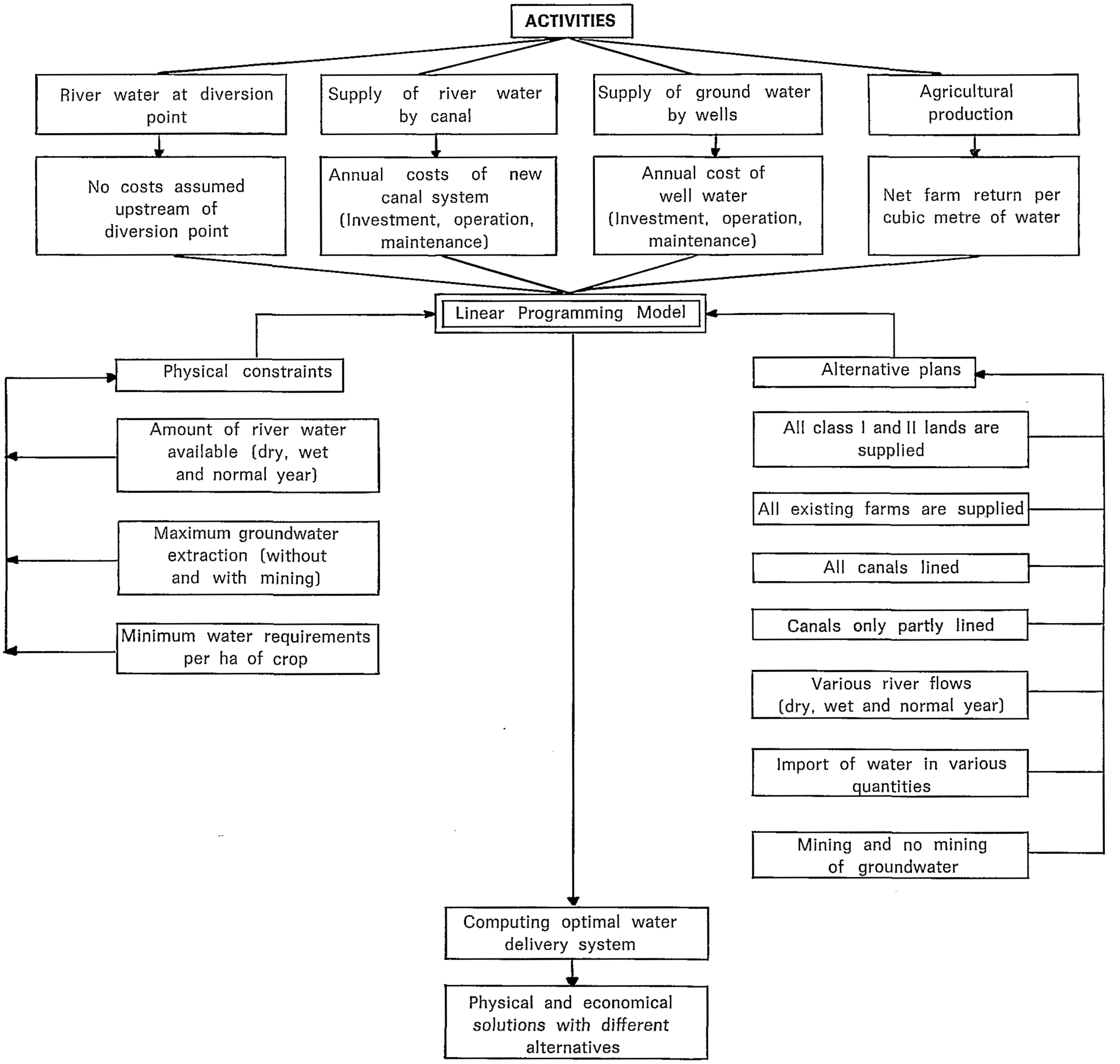

FIG. 4. — *Economic Operation Analysis.*

ed. Thus, deep wells do have pressure water levels, but in spite of this, the basin is rather more free water table than it is confined.

In the lower end of the basin the soils become more saline, probably because of upward moving groundwater as well as waste irrigation water.

It is clear that it may be possible to use water more beneficially by proper operation of the groundwater basin.

THE VARAMIN BASIN COMPUTER MODEL

In order to study the effects on groundwater of possible engineering alternatives, a relatively simple 27 node model was prepared. This model is based on similar models prepared in California by the Department of Water Resources of that State. The mathematical basis of the model is the standard one of the conservation of matter, with flow expressed by Darcy's law. The digital computer solves the equations by a Gauss-Seidel relaxation technique (Tyson and Weber 1963). Both an IBM 360-65 in Iran and an IBM 360-40 in Rome were used for various stages of this simulation using Fortran IV. Fig. 3 diagrams the use of the groundwater model.

The digital model takes into account the usual boundary conditions as well as dewatering of shallow areas and the occurence of effluent flow (rising water) when water levels are at the ground surface. Recharge and pumping are grouped together into net recharge for each nodal area. By changing the patterns of net recharge, new conditions of pumping and recharge are imposed on the model.

The computer model, then, is a simulated representation of the groundwater basin and changes in water level and effluent flow with time are produced by the computer. Since this was the first attempt at a model of this basin, it was felt that 27 nodes gave enough information for the first study phases. As problem and knowledge of the basin become more complex, the model can be made more complex. One aim of the Varamin-Garmsar Project is to demonstrate to Government counterpart personnel how this can be done, and to train them so that other similar work can be done by Government officers in the future.

RUNOFF SIMULATION

The 20-year measured flow of the Jaj Rud (1948-1968) was tested for correlation with rainfall and a linear dependency was established. In order to test runoff estimates the available 61-year rainfall data were converted to extend the flow data. The estimated average runoff for the 61-year period is significantly greater than for the 20-year period.

It became apparent, then, that yield of surface reservoirs should be carefully tested by other techniques in order to fully establish the range of water supply to the Varamin Plain and to have some idea of the probability of these ranges. Using an IBM 1130, 2 000 years of stochastic runoff were generated using the Monte Carlo technique. One hundred series of reservoir operation studies, each 20 years long, were done by computer for Latian reservoir capacities of 40 and 80 million m³ in order to determine reliability of various yields. These yields, then, were used in the linear programme model discussed below (de Ridder and others 1969).

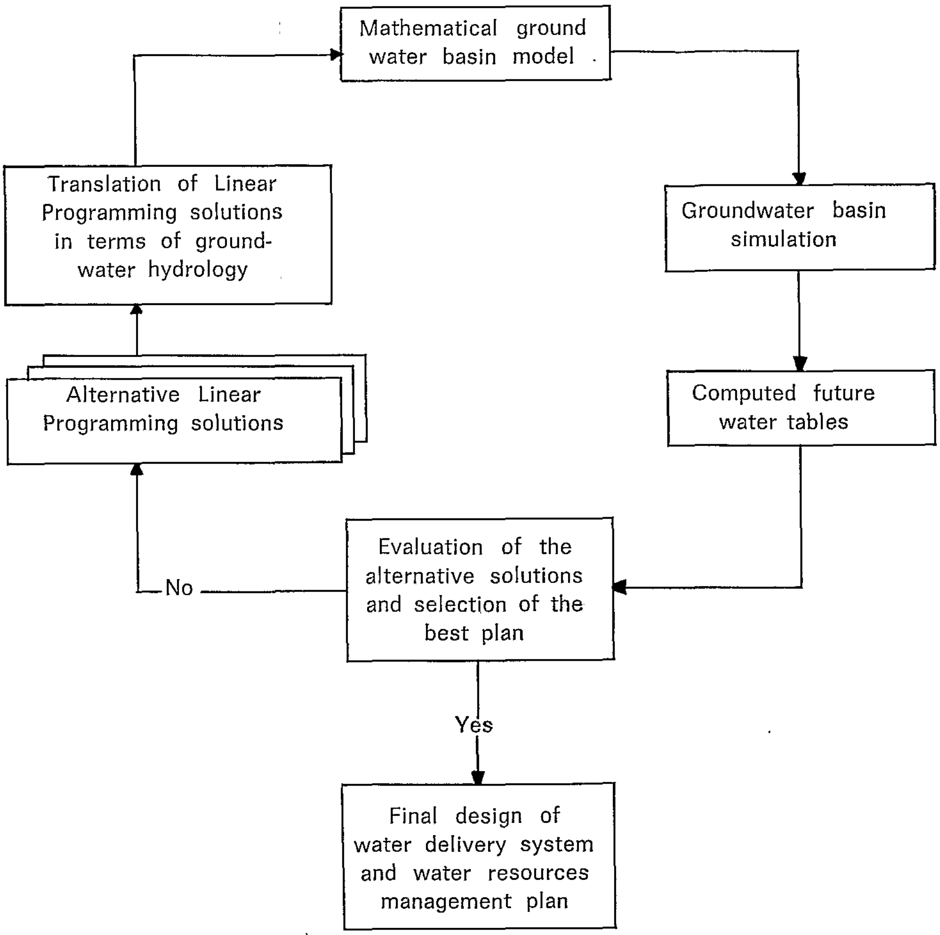

FIG. 5. — *Physical feasibility analysis of the linear Programming result by means of the Mathematical Groundwater Basin Model*

THE AGRO-ECONOMIC SITUATION OF THE VARAMIN PLAN

As has been stated above the present water supplies can irrigate about half of the good land available in the Varamin Plain. In order to increase agricultural production there are many alternatives and combinations which can be studied. These alternatives include more intensive water use on existing land, and more extensive water use on new lands. Farm size, land tenure, crop patterns, etc. must be considered in view of existing social and government structures. While some of these and other alternatives have already been studied, other studies still remain to be done and so full results cannot be given here.

THE LINEAR PROGRAMMING MODEL

In order to study the various engineering and agricultural production alternatives, a linear programming model was formulated. Fig. 4 diagrams the elements of this linear programme. The unique aspect of this model was that the same nodal areas were used as for the groundwater model, allowing some of the results of the linear programme to be applied directly to the groundwater model in order to test the physical validity on the groundwater basin. The combined use is diagrammed in fig. 5.

The linear programme was prepared to maximize the net income. Costs included cost of river water at the diversion point, transport cost of the surface water to various nodes, and cost of groundwater in each node. Capacity of existing wells in each nodal area was considered in order to assess properly cost of water from existing and future wells. It was generally assumed that ghanats would be abandoned and not used.

The benefits were put in terms of net farm return per cubic metre of water. The net farm return depends on soils, cropping pattern, etc.

The linear programme is designed also to take into account availability of surplus surface water during only a part of the year.

Costs of artificial recharge of surface to groundwater will be included in some of the linear programme runs. Other alternatives include a range of water demands and an unlimited groundwater yield to test the results of water mining.

The IBM 360-65 was used and the programme is the " MPS " linear programme package of IBM. This programme allows considerable flexibility in listing of results, a very important aspect when so many alternative computer runs are to be made and studied. In addition to the usual cost and quantity data which are produced, a special programme was prepared so that net deep percolation in each node was computed.

COMBINATION STUDIES

The linear programme is based on an average one-year period. The net deep percolation and other data can be put into the groundwater model to test what would happen to water levels, effluent flow, etc., over a 30-year period. This is necessary since with some particular canal designs, choice of surface or groundwater extractions based on cost may result in pumping rates which exceed the physical capacity of the groundwater basin and cause excessive drawdowns.

Since the reaction of each node depends on the events in the adjacent nodes, there is no simple way to predict just what the yield on an individual node may be. Therefore the entire groundwater basin has had to be tested.

It is fully realized that this approach has weaknesses due to limitations of data and techniques. For example, a monthly schedule for water demand in the linear programme might provide better results, but the size and computing time required may be excessive. Some of the problems could have been more easily handled with the groundwater basin considered a single node, but then output for the groundwater model would not be easily available.

The main advantage of this combination of techniques, as shown on fig. 5, is the ability to determine which areas should be supplied by surface and which by groundwater. On the other hand, there may well be legal and social aspects which might require a water distribution which is not quite the most economical.

The procedures discussed here were carried out to provide a better basis for decisions. We have attempted to demonstrate that these techniques in themselves do not provide decisions, but provide a better understanding of some of the complex relationships between water supply and water use.

ACKNOWLEDGEMENTS

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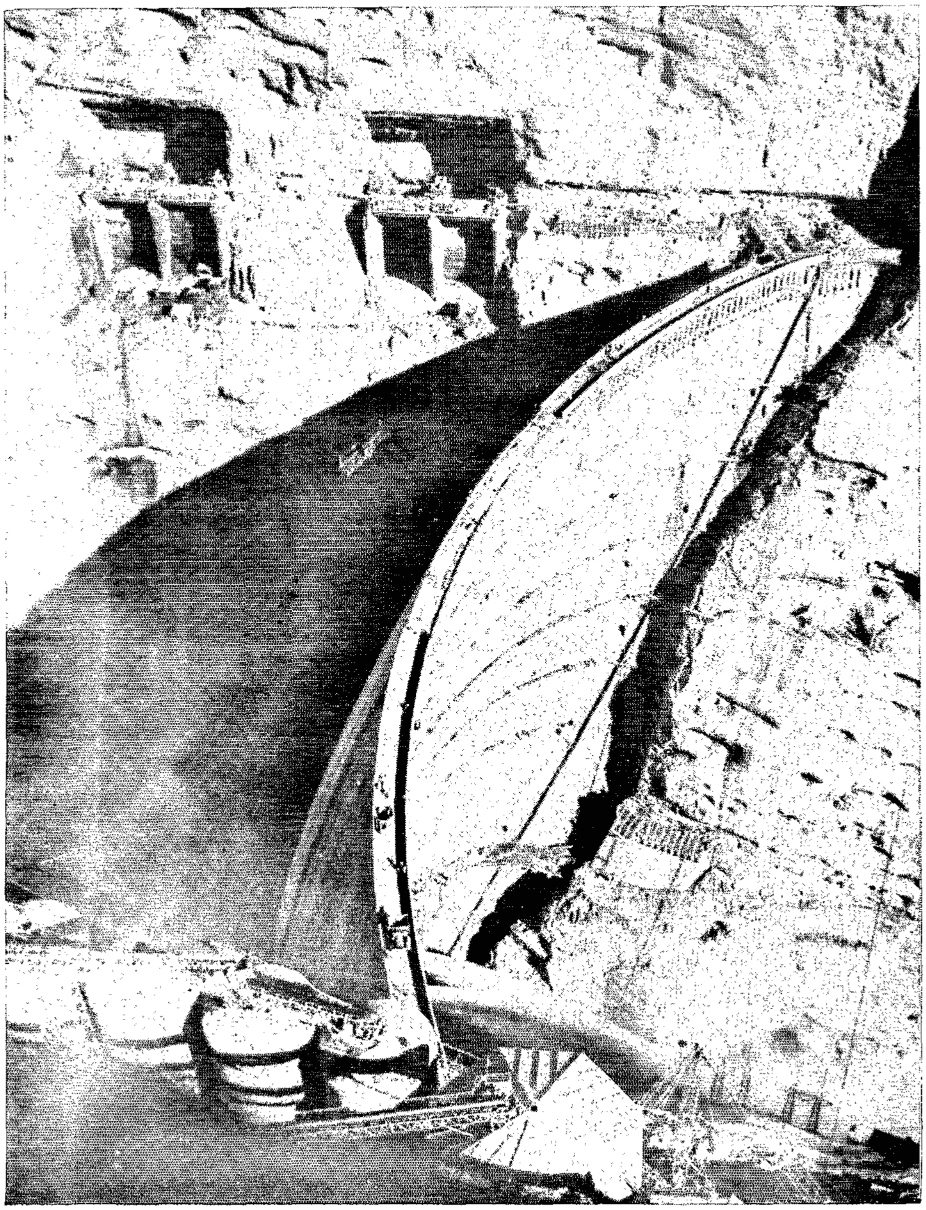

Photo B.I.R.D.

Barrage dans le Khuzestan (Iran).