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THE GHARDIMAOU IRRIGATION PERIMETER

AN EVALUATION

A Report Prepared by

Engineering Consultants, Inc., Denver, Colorado

in Collaboration with

Office de la Mise en Valeur de la Vallée de la
Medjerdah et Périmètres Publics Irrigués

and the

United States A.I.D. Mission to Tunisia

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PREFACE

The many years of study, the many reports prepared and the many schemes proposed have produced no tangible results in the development of the Upper Medjerdah River Valley. To bring the results of all the investigations to a common denominator and chart a course of future action this report has been prepared. A team of four engineers and economists from Engineering Consultants, Incorporated, Denver, Colorado, U.S.A. in collaboration with the Office de la Mise en Valeur de la Vallée de la Medjerdah and Périmètres Publics Irrigués (OMVVM and PPI) and the United States Agency for International Development Mission to Tunisia (AID/T) have prepared this document.

It is our hope that progress in developing the perimeter may be real and tangible.

Members of the ECI team extend their thanks and appreciation to the staff and management of both OMVVM and PPI and AID/T for the assistance and encouragement given us during our study.

1. INTRODUCTION

Development of irrigation in the Upper Medjerdah River Valley has long been a dream. Many studies of the valley's potential have been made over a period of more than fifteen years. These studies have generated many reports containing voluminous data and several schemes for developing an irrigation perimeter in the area. In the reports many varying and sometimes conflicting findings were presented.

The various governmental agencies involved in implementing design, construction and operation of the perimeter were unable to choose one scheme from the many presented (21), (33), (43)[1/]. The study herein documented has been prepared to assist in making the choise of plan. The study includes review of all available data and reports, field reviews of soils, terrain and farming practices on the perimeter and on other operating perimeters. Layouts and estimates for a sprinkler system, a pipe distribution system and an earth canal distribution system for surface irrigation, along with economic evaluation of each were made. From these a combination of pipe distribution and sprinkler systems was evolved.

There are several constraints imposed on the perimeter by previous actions and decisions which limited the scope of our studies. The location of the perimeter and its boundaries were established and fixed. The size of the intensive and semi-intensive units and maximum size of holdings were also set. The size of holdings had no influence on the studies as irrigation water will be furnished each unit. The duty of water which had been set at twenty liters per second per unit was relaxed to permit larger deliveries for more efficient use of available water. The semi-intensive land was to receive a partial supply of water and be alternated with dry-farm crops. The intensive

land was to receive an adequate water supply for producing high value crops. The location of the intensive land was set in three large blocks. Fourteen of the wells are already drilled, thus determining the location of the major water supply source. Maps of scale 1:2,000 planned to be available for system layout were not completed.

Construction of the perimeter is to be done on a rectangular grid system of subdivisions. A basic premise upon which our studies were made is that the land redistribution would be completed before beginning of construction of the perimeter works. Without this being done the economic findings have little meaning.

1/ Numbers in parenthesis are references in the bibliography.

2. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

As a result of this evaluation, the following conclusions were reached:

1. With minor exceptions, the soils and topography of the lands within the perimeter are suitable for the development of irrigated agriculture.

2. There are enough soils with suitable aptitudes to meet the needs of the recommended cropping patterns.

3. The water needs of the project can be easily met from the available surface and ground water sources.

4. Each of the three irrigation systems, sprinkler, pipe distribution, and earth canal, is economically justified.

5. The most practicable irrigation system for the perimeter is a pipe distribution system, except on the steeper slopes where a sprinkler system should be used.

6. The recommended system is both economically and financially feasible.

Recommendations

Based on the evalua n and the conclusions reached, the following recommendations are made:

1. The project should be implemented as soon as possible.

2. A combination of sprinkler in Sector C1 and pipe distribution system best meets the needs of the perimeter.

3. A ground water level observation program should be initiated at once and continued throughout the life of the project.

4. A surface and ground water quality monitoring program should be continued throughout the life of the project.

3. PERIMETER DESCRIPTION

Location

The Ghardimaou Irrigation Perimeter is situated in the upper valley of the Medjerdah River in northwestern Tunisia in the Jendouba Governorat. It extends from the town of Ghardimaou downstream to the town of Oued Meliz and extends across the valley and up the slopes to the south of the Medjerdah River and north of the Rarai River. The gross area of the perimeter is 5800 hectares. The valley floor varies in elevation from 190 meters to 165 meters at the lower end of the perimeter and extends up the slopes to 200 meters. The relation of the perimeter to northern Tunisia and the Mediterranean Basin is shown on Frontispeece. It is 30 kilometers from Jendouba and 180 kilometers from Tunis Highway No. 6 and the Souk Aras - Tunis railroad traverse the perimeter. The sectors (branches) designated A through E on the plates and in tables are construction phases.

During a meeting of the Consultative National Commission for Public Irrigated Perimeters on 31 May, 1974 under the chairmanship of the Minister of Agriculture and in compliance with Decree No. 65-24 of 21 January, 1965 the Ghardimaou Irrigation Perimeter in the Jendouba Governorat was created. It included approximately 5500 hectares in the vicinity of Ghardimaou. The boundaries of the perimeter established by a technical commission were approved. The maximum and minimum size of units were established. These are the boundaries within which irrigation is to be provided. The land distribution will be completed before construction is started.

Population and Labor Force

A very cursory evaluation of the population in the Jendouba Governorat was made in conjunction with this study. The purpose of the evaluation was to form an idea of the magnitude of the population and the labor force with respect to consumption of the project's produce and to the availability of hiredlabor.

The field work of a national census has been completed during the time of this study, however, no results are yet available. Therefore, the population estimates are available only for large areas and are probably based on birth and death rates modified by an immigration/ emigration factor. According to the Institute National de la Statistique the population in the Jendouba Governorat for the last several years was as follows:

Historic Population in the Jendouba Governorat

Year	Population in 1000 habitents	Annual Rate of Growth in percent
1956	202	-
1961	227	2.4
1967	266	2.9
1968	270	1.5
1969	273	1.1
1970	277	1.5
1971	280	1.1
1972	285	1.8
1973	290	1.8

The compound growth rate for the entire Republic of Tunisia between 1967 and 1973 was calculated from reported data (3) to be about 2.2 percent,while for the Jendouba Governorat, it was only about 1.5 percent. Unofficial estimates have placed the Republic's growth rate at between 2.5 and 3 percent. In any event, it appears that there is considerable migration from the Jendouba area. It probably would be correct to assume that lack of opportunity for employment is a

major cause of this emigration. It also could be assumed that this outward migration does not affect the unskilled farm labor component of the labor force.

In the early 1970's, about 45 percent of the population was 14 years old or less, and about 50 percent were between the ages of 15 and 64. This latter group can be assumed to represent the potential labor force. Based on unofficial figures for Tunisia and other countries, we have assumed that the labor force equals about 60 percent of this age group and for the Jendouba Governorat, agricultural labor comprises about 60 percent of the labor force. Therefore, it is assumed that the agricultural labor force in the Jendouba Governorat in 1973 amounted to about 55,000 persons. If growth of this component of the labor force parallels the total Governorat population rate of about 1.5 percent, the number of new agricultural laborers available for work may be as shown below. Demand for agricultural production is partially determined by the population of the area served by the project and so an estimate of the population in the Jendouba Governorat for the same growth rate is shown. There is presently no reason to expect the net outward migration to cease.

Population Estimates in the Jendouba Governorat

End of Year	Agricultural Labor Force	Average Increase per Year	Jendouba Governorat
1973	55,000		290,000
1980	61,000	900±	322,000
1990	71,000	1,000	374,000
2000	82,000	1,100	433,000

We cannot evaluate the effect of the project on the labor force or the effect of the population on the demand. However, it is assumed that the project will not eliminate unemployment or underemployment, and that the truck crops will find a ready market locally.

4. LAND USE

Present Land Use

Present land use is set in a framework of traditional agriculture dating back thousands of years. The principal crops grown are the cereals such as wheat and barley; to a lesser extent the legumes, such as horse beans and chickpeas, and the forage crops, such as vetch and oats. As a part of the traditional pattern, 30 to 40 percent of the land planted to these crops is left fallow each year.

With the introduction of drilled wells, which are managed by the OMVVM/PPI, the development of dug wells, and pumping from the surface water supplies, some irrigated agriculture has begun. The irrigated crops grown are mainly vegetables, but also include some tobacco, berseem, alfalfa, and fruit trees. The fruit trees are mainly located at the Chemtou Tree Farm. A breakdown of the sources of irrigation water is shown below.

Sources of Irrigation Water (1975)

Area	Dug Wells	Drilled Wells	River Pumps
A	20	5	8
B	29	7	-
C	10	-	2
D1	21	-	8
D2	15	-	4
E	2	-	2
Total	96	12	24

The estimated present land use for the perimeter and its sectors is shown in table 1. There is no complete land use study available for the perimeter. Fairly good records are kept of the irrigated agriculture, i.e. fruit trees, truck crops, and industrial crops such as tobacco and sunflowers. The remaining area was reduced from

35 to 40 percent for fallow and then divided up among the remaining crops roughly according to the following percentages: wheat 75%, barley 7%, chickpeas 10%, horse beans 5%, and vetch/oats 3%. These percentages were assumed from discussions with the various agricultural entities in the area and also from information gained during the field studies. Approximately 2.5 to 3 percent of the total area was assumed to be villages, roads, etc.

At the present time, wheat is the most extensively grown crop. From the Office of Cereals agencies in the area, the following tabulation of the types of wheat grown were obtained.

Sales of Wheat Seed

Hard Wheat Variety	Percent of Total	Soft Wheat Variety	Percent of Total
5825	30	Inia (Mexican)	19
Mahmoudi	4	T 2123	1
Chily	7	Florence-Aurore	4
563 A	30	Soltane	1
Kokini	4		
	75		25

Tobacco and watermelon are the most widely planted irrigated crops and account for about 50 percent of the truck and industrial crops.

Future Land Use Without The Project

It is anticipated that there will be little change in the future land use pattern if no project is built. There does not appear to be enough interest, desire, incentive, or facilities to change away from traditional cultivation practices. Minor changes were made to the present land use pattern to reflect the thoughts of knowledgeable people in the area, however,the pattern has remained essentially the same. It is expected that the crop yields will increase in the future.

The estimated future land use in each sector of the perimeter, assuming that no project is built, is shown in table 2. The totals were divided among the sectors in the same manner as for the present pattern.

Future Land Use With The Project

If the irrigation project is constructed, it is expected that a completely different pattern of land use will develop. Estimated land use patterns for an open channel and a pipe irrigation system are shown in table 3 and table 4, respectively. The differences in the two estimates are attributable to the different right-of-way requirements and the different conveyance efficiencies of the two irrigation systems. The procedure for determining the area planted to the different crops and the location of the crops by sector is explained in another section of this report. The main considerations for the development of these patterns were that there should be approximately 1500 hectares of intensive agriculture and that the entire perimeter area should receive some irrigation. The latter consideration is in accordance with the GOT wish to improve the income of as many farmers as is reasonably possible.

The land use for the area classified as intensive will be planted to irrigated orchards, irrigated forage for sale to livestock owners outside of the perimeter, truck crops, and artichokes. For orchard crops, it would be acceptable to use:

Citrus
Deciduous Fruit
Olives
Nuts

Fruit trees with high water requirements, such as apples and to a letter extent, pears, should be limited to conserve water. For irrigated

forage, berseem appears to give as good a return as any, although any other annual forage crop is satisfactory. Because of the limit of irrigation water, perennial forage crops such as alfalfa may not be used in this pattern. Some of the truck crops which are suited to the area are:

Tomato	Carrot	Squash
Pepper	Turnip	Corn
Egg plant	Red beets	Peas
Watermelon	Green beans	Spinach
Melon	Lettuce	
Cabbage	Cucumber	

The area in vegetables is being kept relatively small because they are high water using crops and because the timing of the harvest brings the crops to the market later than from other areas when the prices are already low.

In the semi-intensive area, a four-year rotation is planned. The rotation would start with sugar beets, and be followed by dry farmed wheat, irrigated forage, and legumes, such as chickpeas, horse beans, or green peas. The legumes would be given only a very limited amount of water.

5. WATER RESOURCES

Surface water and ground water have been considered as a source of irrigation water for the Ghardimaou perimeter. Both sources of water have been studied with respect to availability, quality, and possibility for economic development.

International Engineering Company of the United States developed estimates of the average monthly runoff for the Oued Medjerdah and its tributaries in the Upper Medjerdah Valley area (43). The monthly estimates were developed from limited runoff data, more widely available rainfall data, and standard correlation techniques.

Parsons Company of the United States evaluated the ground water potential of the area while trying to determine the best way to develop and conserve the water resources of the area (34). These studies made use of piezometers, observation wells, and production wells to collect the information necessary for an analysis. In addition, in order to estimate the safe yield of the ground water basin, a surface water measurement program was also initiated. The program included the construction of discharge measurement stations on almost all of the rivers in the area. The conclusions of the study with respect to the availability of ground water for irrigation use, were that about 31.4 million cubic meters (MCM) could be withdrawn annually from the ground water basin. The report stipulated that controlled basin management would be necessary to develop this amount. The Parsons report also indicated that the present ground water recharge from surface streams totals about 18,5 MCM. This amount was considered by Parsons as the present available safe yield.

The Division des Resources en Eau (DRES), in 1972, reported on

studies which they had made to validate the Parsons estimate of safe yields under present consitions (9). From their estimates of the hydraulic characteristics of the aquifers, they recommended that the safe yield should be reduced to 14 MCM.

As a result of these studies, ECI was instructed to limit the quantity of water available for irrigation to 18.0 MCM to be developed as follows:

Source	Quantity in MCM
Oued Medjerdah	4.0
Ground Water Basin	14.0

It is ECI's opinion that these amounts are conservative and can be relied upon. It is most likely that additional amounts of both surface and ground water could be developed without adversely affecting the ground water regime or the downstream use of surface water.

It has been indicated that it is the Government's idea to initially use these conservative amounts of water, to monitor the effects of this use, and to reevaluate the irrigation operation when more firm data are available. We agree with this approach. The irrigation system must be constructed with a degree of flexibility to permit increasing the quantity of delivered irrigation water if it is determined that more can be taken from the sources.

Ground Water

In the Upper Medjerdah Valley, three aquifer zones have been defined as to areal extent and depth. These aquifers are described as the shallow, the principal or main, and the deep aquifers. Parsons initially defined the extent of the aquifers from information obtained from the construction and operation of 32 piezometers, 8 observation wells, 2 production test wells, interpretation of geologic features

and previously collected data.

The shallow aquifer is thin and provides moderate amounts of water. The main aquifer has the greatest potential. The deep aquifer is limited in areal extent, has relatively low permeability, and is not considered a source of water.

Parsons has made an estimate of the storage capacity or the static reserve of the shallow and main aquifers in the Upper Medjerdah Valley. Based on these estimates, the following very rough estimate of the static reserve that can be drawn upon for irrigating the perimeter was made.

	Static Reserve in MCM
Shallow aquifer	160
Main aquifer	500

It is apparent that storage capacity of the ground water basin will not place any constraint on the use of ground water as presently envisaged.

The amount of ground water available for irrigation, assuming that the water is to be conserved and not mined, is limited by the long-time average amount of water that enters the ground water basin.

Parsons made a fairly extensive evaluation of the surface water hydrology during 1966-67 from which estimates were made of the annual recharge potential. The ground water hydrology was also evaluated during this same period to estimate the capability of the shallow and main aquifers to absorb, store and transmit water.

With this information, an estimate was made of the gound water supply for the period studied. The quantity of water entering the ground water basin was estimated by two methods: 1) by determining the sum of ground water use and surface flow, and 2) by determining the total quantity of surface water which percolates to the ground water

table within the basin limits. By method 1, the total supply was estimated to be 17.2 MCM and by method 2, the total supply was estimated to be 19.6 MCM. Based on these estimates, the total supply under present conditions for the period under study was assumed to be 18.5 MCM. The water year during which time these studies were done was conservatively assumed to represent an average or normal water year As reported by Parsons, the available long-time data indicated that runoff during the year may have been as much as 25 percent below normal From these studies, Parsons suggested that it would be possible to immediately make use of 18.5 MCM of water from the ground water supplies without incurring any reduction in the ground water potential over the long term.

Parsons also estimated that up to about 31 MCM could be pumped annually under modified hydraulic conditions. As this is not under study at the present time, no comment will be made on the possibility.

The Division des Resources en Eau decided additional studies were necessary to better define the limits of the aquifers and the amount of water that could be safely extracted. In 1971, DRE initiated their studies making use of 26 wells, most of which had been constructed by the Subdivision Special des Sondages since the Parsons study, 32 piezometers and electric logs taken at 76 locations.

By means of pump tests, DRE estimated the hydraulic characteristics of the shallow and main aquifers. From a seismic analysis, done at 76 locations, the areal extent and thickness of the aquifers were confirmed or revised as necessary from the Parsons studies.

The dynamic resources were estimated empirically making use of calculated transmissibility and gradients under present conditions.

The present safe yield was evaluated by two methods. The first method considered how much water comes out of the ground water basin into the stream channels. The second method considered the amount of ground water used in the area, the subsurface flow, and the amount of surface flow that would be attributable to ground water. Estimates by the first method ranged from 9 to 13 MCM over a three-year period; a one-year study by the second method yielded an estimate of about 15 MCM. No mention was made in the report with regard to the normality or the deviation from normal of the water years. Based on these studies, DRE recommended that the annual extraction from the ground water basin be limited to 14 MCM.

From the information available, DRE also made an estimate of the capacity of the ground water reservoir underneath the Upper Medjerdah Valley upstream of Oued Melitz. They estimated that the total static reserve was about 780 MCM. This is in the same order of magnitude as Parsons' estimate.

Long duration pump tests were done for all of the test wells and from these tests, estimates were made of the yield of the wells. These well yields, which were considered as a first estimate by the DRE, have been adjusted based on the knowledge of the investigators gained during the study of the basin. The yields are admittedly conservative and can be varied somewhat to meet the needs of particular irrigation requirement. DRE indicated that a variation of up to 10 percent would be acceptable to them. In 1975, OMVVM made some additional pump tests and found that the specific capacity (yield divided by drawdown) had increased in many instances. Of the nine wells tested, only one of the specific capacities decreased and that by less than 5 percent.

We consider the yields as proposed by the DRE and shown in table 5 as acceptable for design purposes. It is DRE's recommendation and OMVVM's plan to monitor the discharges from the wells for several irrigation seasons and then modify the discharge as seems appropriate.

According to the requirements and the pumping schedule as set up by the DRE, the existing wells will not supply enough water to meet irrigation demands. Therefore, the DRE has proposed that six additional wells be constructed as shown on plate 1. The estimated yields of these wells are not based on any physical testing, but rather on what the investigators expect from a well in the indicated location, reduced by a factor of safety.

Aquifer Development

Both Parsons and the DRE consider that from 45 to 50 percent of the water that is to be considered as a present safe yield now leaves the area as surface water. This is water that enters the aquifer system in the upper reaches of the valley and then discharges from the ground water basin back into the stream channels where these channels have been entrenched into the aquifer. Most of this water must be considered as traveling through the shallow aquifer.

The existing wells were checked as to where the perforated levels intersect the shallow and main aquifers. This check was made using the DRE aquifer configurations developed from the electric soundings and the Parsons' figures on aquifer thickness. As was expected, the aquifer delineations did not check too closely, but it was evident that almost all of the wells penetrated only the main aquifer.

In order to reverse the present operation and to cause the surface waters to infiltrate into the ground water basins in the Chemtou

area, it appears that more consideration should be given to drawing water from the shallow aquifer in this zone. In addition, the shallow aquifer should probably also be drawn from in the recharge area. There is not enough time during the present studies to determine if pumping the existing wells will, in effect, sufficiently draw down the shallow aquifer. If this cannot be conclusively determined from an analysis of the existing date, more tests should be made.

In our report we recommend that the new wells, designated as number 6 and another new well, number 7, be developed to penetrate only the shallow aquifer. These wells, along with BIRH well 6777 will pump from the shallow aquifer and hopefully cause enough drawdown in the Chemtou area of the shallow aquifer to allow recharge from surface water in this area.

A tabulation of the proposed design discharges from the well field is shown in table 6.

Surface Water

The surface water used to meet the irrigation needs in addition to that to be taken from the ground water basin will be supplied from the Oued Medjerdah. The volume of this surface water supply has been set at 4 MCM.

The surface water aspects of this project were not studied in any detail because the volume taken from the Oued is very small in comparison with the available volume. We have inspected the data collected by Parsons and by the DRE as well as flow-duration data based on monthly discharge and limited frequency analyses. The limit of the diversion from the Medjerdah was set by the DRE and, we were informed, based on a rigorous analysis of the quantity, duration, and frequency of the discharge of the Oued Medjerdah at Ghardimaou.

We were also informed that this information is in the process of being published.

ECI accepts the 4 MCM contribution from the surface water system as being easily obtainable. As this water is of a higher quality than the ground water supply and is possibly cheaper to develop, it may be prudent to develop more from this source in the future.

6. WELL FIELD DEVELOPMENT

Pumping Head

As a part of the economic evaluation, an estimate of the annual operating costs must be made. A significant portion of the annual cost for this project is for energy to be used to operate the well pumps and motors. In previous studies, this aspect of cost does not appear to have been completely evaluated. The total energy requirement is that needed to lift the water to ground surface and then to provide enough pressure or head in the system to transmit and apply the water to the crops.

The well field pumping head is here defined as the depth from the ground surface to the water level in the well. Only one estimate of this head has been for all the irrigation systems because each system pumps essentially the same volume of water, i.e. 14 million cubic meters. This procedure is not exactly correct because the timing of pumping for each type of system is different because of the minor differences in cropping pattern and system efficiencies. However, the input data inaccuracies and the insignificance of the timing differences warrant making only one estimate of the head for all systems.

The analyses done to date provide only an estimate of the drawdown for each well operating at or near design discharge. Therefore, it is additionally necessary to estimate the interaction of the wells and the variation of the static water level in the wells throughout the year.

The ground water requirement was developed by distributing the surface water volume of 4 million cubic meters and the ground water volume of 14 million cubic meters to meet the schedule of estimated water requirements. Several alternative distributions were considere and it was most efficient, from the standpoint of minimizing the pumping head, to delay using the surface water as long as possible in the Spring and to use it as early as possible in the Fall. From the values of surface flow reported by EGTH (21) as representing flows at Ghardimaou having a 20 percent chance of nonoccurrence (on the average, discharge will equal or exceed indicated discharge 4 years out of 5), an arbitrary distribution of surface flows was made. Because of the time limitations of this study, no attempt was made to verify the frequency distribution of surface water. One object of the surface water distribution was to have no groundwater pumping during December and January so that pump maintenance and repair could be accomplished during these two months. The monthly groundwater requirement is thus the estimated water requirement less the surface water contribution.

It has been indicated by the OMVVM that the well field will be operated on a 16-hour basis whenever possible. Using the total well field capacity, the estimated requirement from groundwater can be met by pumping from 5 to 29 16-hour days per month. This implies that all wells will be used the same length of time during any month regardless of the volume pumped. Therefore, the well field drawdown, based on the operation of the entire well field, may be estimated by assuming an operation schedule of 16 hours of pumping and 8 hours for recovery. It was assumed, perhaps optimistically, that full recovery would take place in 8 hours, i.e. the water level would return to its initial position in less than 8 hours.

Well Field Drawdown

The drawdown is defined as the lowering of the water level from some initial elevation by the operation of all wells in the field. The drawdown of a well caused by the operation of that well was estimated from long duration pump tests. The drawdown of a well caused by the operation of other wells was estimated using an equation developed by C.E. Jacob (54) where

$$h_0 - h = ,183 \frac{Q}{T} \log \frac{2.25\ T\ t}{r^2 S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

in which

$h_0 - h$ is the drawdown at any radius r in meters,

Q is the rate of pumping in m^3/sec.,

T is the Transmissibility in m^2/sec.,

t is the time in seconds,

r is the distance to the point at which the drawdown occurs in meters, and

S is the storage coefficient of the aquifer.

From the data presented in the DRE report (9), T and S were assumed to be constant and equal to 0.025 m^2/sec. and $5 \cdot 10^{-4}$ respectively. By setting the log portion of Eq. (1) to zero, an estimate of the radius of the cone of influence is obtained. For a 16-hour pumping schedule, drawdown will be observed up to about 2.5 kilometers away from the pumping well. The distances between wells were measured from a map with a scale of 1:50,000. The drawdown at each well caused by pumping at other wells within the zone of influence was calculated and added to the drawdown caused by pumping the well at the center of the influence area. This drawdown represents the

full operation drawdown for the entire well field operating at design capacity for a 16-hour period. The drawdown was assumed to be constant for the given well field operation regardless of the initial depth to water in the well.

Well No. 7010 is used as a source for the water supply for the town of Ghardimaou. As such, it is expected that it will operate 24 hours per day rather than 16 hours. The additional drawdown caused by pumping this additional time is included in the full operation drawdown estimates.

Variation in Static Water Level

The drawdown above discussed must be added to the depth from the ground surface to the water in the well before pumping is started or to the static water level. Because the amount pumped each month cannot always be replaced by recharge during that month, the static water level varies from month to month. However, since it is assumed that the amount recharged equals the amount withdrawn during the year, the static water level will return to full basin conditions during every average or wetter year.

The recharge to the groundwater basin totals 14 million cubic meters and was distributed by month according to the distribution of the 20 percent discharge in the Oued Medjerdah at Ghardimaou. Comparing the recharge with the groundwater pumping requirements shows that discharge from the basin begins in June and reaches a maximum in November. Then, recharge is greater than discharge until the end of May and the static water level returns to its original level. An example of these calculations is shown in table 6.

Once the monthly volumes of discharge and recharge have been defined, it remains to determine the variation in static water level due

to these occurrences.

The water yielding capacity of a confined aquifer is expressed in terms of a storage coefficient which defines the change in storage per unit of surface area per unit of head. For these studies, the storage coefficient for the Main Aquifer is $5 \cdot 10^{-4}$ and for the Shallow Aquifer is $1 \cdot 10^{-2}$. For an unconfined aquifer, the storage coefficient corresponds to its specific yield which is about 18 percent for both aquifers. It is readily apparent, from these values, that as long as the aquifer is confined, relatively small changes in storage will cause the static water level to change significantly. If the aquifer becomes unconfined, the same change in storage will cause little change in the groundwater level.

It then became necessary to determine the depth to the top of the aquifer or the point at which the aquifer becomes depressurized or unconfined. The assumption of this depth was based on information collected by Parsons, DRE, and from electric logs taken at the time of well construction. Among the three sources, there was not too much data for comparison. The depth to the static water level at full basin conditions was assumed to be the present depth to water or, if this was not available, the depth to water during earlier pump tests.

Each well was operated through an average year and the average operating head to the ground surface was calculated. This head represents the average static water level during the month indicated plus the drawdown caused by operating the well field. Maximum and minimum operating heads as well as other pertinent data for each well are shown in table 5.

7 WATER REQUIREMENTS

In the many studies that have been done on the Ghardimaou perimeter and the Upper Medjerda Valley, several estimates of water requirements have been presented. Some of the crop requirements did not appear to be correct and, therefore, it was decided to determine, if possible, how the requirements were developed and to make an independant check.

The most recent report on the perimeter was published by EGTH in October, 1973 (21). OMVVM has indicated that the requirements presented in this report represent the latest information and ideas, and were to be generally accepted for use in the present studies.

The requirements presented in the EGTH report were reported to be based on estimates by ECCO for citrus trees, and by INRAT for the remaining crops in the pattern. The tabulation of requirements also represented an irrigation schedule. We are informed by OMVVM that the requirements reflect highly efficient use of the available soil moisture and represent an amount of water which will produce a maximum return per unit of water rather than a maximum yield.

From a cursory evaluation of the requirements, it appears that some of the summer months values are too low, and that the irrigation scheduling would not make efficient use of the soil moisture.

In all of the Tunisian studies, the requirements were developed by INRAT. In two of the reports (9)(13) different values for evapotranspiration (ETp) were shown. In no instances were we able to locate different crop coefficients which, when multiplied by ETp result in crop consumptive use. A trip was made to the Centre de Recherche du Genie Rural where we learned that the ETp values were based on measured data. These values are continuously being revised because of new data becoming available every year. This explained why different values had been published in the different reports. It was learned that the ETp values published in 1971 by the Bureau of Planning are the best available estimates for the Chardimaou perimeter. As a rough check on these values which were, we believe, a transposition of data measured in another area, we calculated a set of ETp values based on limited data from the weather station at Jendouba. Our estimates were based on a radiation equation explained in FAO's recent publication "Crop Water Requirements" (53). The results are shown below.

Evapotranspiration in mm

	J	F	M	A	M	J	J	A	S	O	N	D	Total
INRAT	40	53	78	103	139	168	190	170	130	86	56	38	1251
Check	28	31	56	90	118	174	183	214	102	68	42	28	1134

The annual total [illegible] thin 10 percent and although the monthly variation is large, it can be attributed to the deviation of the limited

data from the norm. The INRAT data were reported to be a long-time average. We are not sure what the long-time period is, but believe it to be more than 10 years. We accept the INRAT figures as suitable for this study.

Unfortunately, no data relating to the development of water requirements from the ETp values were made available nor were we able to contact any individual who had been connected with these studies.

We were given publications by the Centre de Recherche (41) which, for specific crops, recommended crop consumptive use values which could be applied in the general area of the perimeter. These requirements represented the optimum application of water or that which produces the maximum return per unit of water. We were also given a publication concerning citrus (24) published by the Division de la Vulgarisation Agricole which included water requirements. Two methods were used to develop estimates of water requirements to check against the EGTH values. The two methods are 1) research data transposed to the perimeter area (41)(24) and 2) INRAT values for ETp with crop coefficients as shown in the report by FAO (53). The lower results of these two methods were compared with the EGTH values and a change was made only if significant deviations occured.

The EGTH values were assumed to represent consumptive use less

effective rainfall divided by an application efficiency. The efficiency used for fruit trees was 75 percent and for all other crops, 70 percent. These efficiencies were assumed by ECI not to include any conveyance losses, not because they were forgotten, but because the expected conveyance efficiency for a sprinkler system was very high and could be neglected.

Effective rainfall, as used in the Tunisian studies, was represented by rainfall that would occur four years out of five. We would not normally use this method of estimating effective rainfall and believe that a schedule similar to that proposed by the U.S. Department of Agriculture (1969) -0-(53) would be more appropriate. However, for these studies, we have used the same values as shown in the Bureau of Planning report (9) which is the basis of the EGTH estimates. The following is a tabulation of these estimates.

Effective Rainfall in mm

J	F	M	A	M	J	J	A	S	O	N	D	Total
68	55	46	42	36	10	-	-	18	55	43	65	438

As effective rainfall is limited by the amount of water required, these values are to be considered as potential effective rainfall.

The application efficiencies reported in the EGTH report were 75 percent for fruit trees, and 80 percent for all other crops.

These efficiencies are very optimistic, especially for the sprinkler system. According to the USDA (SCS) and ICID (53) an efficiency of 60 to 65 percent might be more realistic when considering the constraints placed on the project operation. In some instances, efficiencies of around 50 percent could be expected. OMVVM believes that they can reach these high efficiencies and, therefore, we have continued to use them.

Generally the EGTH water requirements are acceptable to us. For this report, the requirements for citrus, sugar beets, artichokes, and winter vegetables were taken directly from the EGTH report. As no estimates were included in this report for Berseem, values published by HER were used. These estimates for Berseem were referenced to INRAT. The requirements for artichokes are an average value of the first and second year requirements. The estimates for apples and pears were made using method 2 (see above) because no local values were readily available. The water requirement for the fruit trees assumes that no cover crops will be grown except during the high rainfall months when the potential effective rainfall exceeds the crop water requirement. The requirement for almost all summer crops appears to be underestimated according to both check methods. Therefore, estimates for summer vegetables, which are represented by tomatoes, were revised upwards.

The irrigation requirement in mm at the farm gate, which consist of crop consumptive use less effective rainfall divided by application efficiency, are shown in table 7. These requirements are the basis for apportioning the available water for all crop rotations.

The requirement for apples is also suitable for walnuts, and the requirement for pears is suitable for peaches, apricots, plums almonds and pecans. The winter vegetable requirement can represent various kinds of beans, peas, onions, garlic, carrots, etc., while the summer vegetable requirement, based on tomatoes, is enough for corn, malons, pepper, and tobacco. The quantity of water designated for Berseem should be adequate for 5 cuttings assuming 2 1/2 months to the first cut and then cutting every 1 1/2 months until mid-May.

We do not understand many of the monthly distributions as presented in the EGTH report nor were we able to locate any background data that would enable us to generate these values. We are satisfied that the annual values are adequate and that they can be used to apportion the available water among the various crops. It is assumed that these requirements produce some plant stress, and are assumed to produce a maximum return per unit of water rather than a maximum yield.

In the design phase, we would expect an irrigation schedule to be developed that would be different from the schedule of consumptive use requirements and different from the proposals in the EGTH report.

8 CROPPING PATTERN DEVELOPMENT

The cropping pattern defines the crops and their areas, and is used to estimate the with-project benefits. Two major constraints of the project which affect the development of the cropping pattern are the limited water and the social rather than economic definition of the project boundaries. These combined constraints require a rather different approach to developing the cropping pattern. It was also considered desirable to have about 1500 hectares in intensive cropping and to have about 25 percent of the semi-intensive area planted to wheat.

The OMVVM has selected project areas which are to be used for intensive cropping. In addition, they have provided crop rotations and a general approximation of the area for each crop. These initial approximations of crop area were revised according to the available water and the available area of soil suitable to these crops.

Sprinkler and Pipe Distribution Systems

The gross irrigable area of the Perimeter (5800 ha) was reduced by 20 percent to give a cultivated area of 4600 hectares. This reduction is to allow for roads, rights-of-way, and lands that cannot be served by the irrigation system. It should be noted that land for the population centers have already been allotted. The reduc-

tion for the sprinkler and pipe distribution system is less than for the earth canal system to account for the difference in right-of-way between an earth canal and a pipe system. The conveyance efficiency for the pipe distribution and the sprinkler systems was assumed to be 97 percent, giving an overall system efficiency of from 68 to 73 percent. The conveyance efficiency also includes evaporation and seepage from the small reservoirs included in the systems. Because of the high efficiency, there is enough water to irrigate slightly more than the minimum desired area of intensive crops. Of all the crops considered, it was decided to increase the area in deciduous fruit trees; specifically pears or peaches.

A tentative balance was made between water and crop areas.

Before finalizing these areas, the soil aptitude maps were checked to ensure that enough lands with suitable soils we were available to actually meet the needs of the pattern. These soil aptitude maps are shown on Plate 16, sheets 1 through 4.

A cropping pattern and its water requirements for the sprinkler and pipe distribution system is shown below.

Cropping Pattern for Sprinkler and Pipe Distribution Systems

Crop	Area in Ha	Water Requirement in MCM
Intensive		
Fruit trees	800	6.49
Artichokes	200	.98
Vegetables	200	2.00
Berseem	400	1.52
Semi-Intensive		
Sugarbeet	800	2.40
Berseem	800	3.04
Edible Legume	700	1.05
Subtotal Irrigated Area	4,000	
Wheat	600	-
Subtotal	4,600	17.48
Conveyance Loss		.53
Total	4,600	18.0

A detailed tabulation of the water requirements is shown in table 10 and of the crop distribution by perimeter sector in table 11.

This water allocation will be sufficient for any of the other rotations given in this report.

There are enough suitable soils in the intensive area for the

for the indicate area of fruit trees. However, because of the location and the configuration of these soils and because of the practical realities of locating an orchard, it is likely than some fruit trees will be planted on soils with less than average aptitude for the crop. Our analysis of the soil adaptability maps was very rough, but if it proves fairly accurate, some portion of the orchards shouls probably be located in the area now designated as semi-intensive.

A detailed tabulation of the water requirements is shown in Table 8 and the crop distribution by Sector is shown in Table 9.

Earth Canal System

For the earth canal system, the gross area was reduced by 25 percent to give a cultivated area of about 4400 hectares. The conveyance efficiency for the earth canal system was assumed to be 85 percent, giving an overall system efficiency of from 60 to 65 percent.

In Balancing the water and land, it was found that if 1500 hectares of intensive area were included in the pattern then substantial more than 25 percent of the semi-intensive land would need be planted to wheat.

A cropping pattern and the related water requirements for the earth canal system are shown below.

Cropping Pattern for Earth Canal Distribution System

Crop	Area in Ha	Water Requirement in MCM
Intensive		
Fruit trees	700	5.59
Artichokes	200	0.98
Vegetables	200	2.00
Berseem	400	1.52
Semi-Intensive		
Sugarbeets	600	1.80
Berseem	600	2.28
Edible Legumes	800	1.20
Subtotal Irrigated Area	3500	
Wheat	900	-
Subtotal	4400	15.37
Conveyance Loss		2.68
Total	4400	18.05

A detailed tabulation of the water requirements for the earth canal system is shown in Table 9 and of the crop distribution by perimeter Sector in Table 11.

9 IRRIGATION SYSTEMS

Introduction

Three different systems for irrigation of the perimeter have been considered; a sprinkler system, a pipe distribution system, and an earth canal distribution system. All systems will utilize the same sources of water; 25 wells and the Medjerda river. Each of the systems has limitations of satisfactory application. To determine an optimum system several combinations have been considered. All of the systems would serve approximately the same lands within the previously delineated Ghardimaou perimeter. Service would be provided to 5 ha rectangular plots of semi-intensive land and to 1.25 ha rectangular plots of intensive land. To utilize the available water supply in a manner which will provide the maximum benefit to all of the land within the perimeter the intensive or high value crop lands will be provided nearly adequate water and the semi-intensive or low value crops alternating with dry farmed crops would be provided about one-third as much. To achieve the utilization of water the systems must be able to deliver water at about 70 to 75 percent efficiency.

In order to meet the 70 to 75 percent efficiency, water must be delivered at about the time the crops need it, at a rate that can be modified to meet crop, soil, irrigation method requirements, and for a duration of time needed to infiltrate the water at the minimum

point of application. If these requirements are met the user can then apply water when the soil is "dry enough to irrigate" (flexibility of frequency), run the stream sizes needed (flexibility of rate), and turn the water off when the soil is "wet enough to stop (flexibility of duration).

The proposed systems reasonably meet these requirements utilizing what may be called a "limited demand schedule". The limit is a result of the economics of system capacity which requires that several users utilize the same lateral limiting the potential frequency and the maximum rate that can be supplied.

Basically, the systems will have the capacity to serve most of the intensive plots during 12 days out of a 16 to 18-day period. The semi-intensive peak demand capacity of the system which might be needed during the pre-irrigation period in the fall, will permit all the area to be covered in a 36 day period and any one 5 ha plot to be covered in six days with sprinkler or four days with surface methods.

In order to get the maximum benefit from the wells, they should be operated steadily. Small reservoirs are necessary to regulate flows from the wells since their delivery rates will vary as the piezometric level changes and to supply each farm at a flexible rate and duration.

The perimeter will be provided with a complete system of access

roads to provide efficient transportation from farm to market. Surface drainage and stream channel protection will be completed during construction. Sub-surface drainage will not be included in initial construction. The cost estimates include it as future years' work. The need for and location of sub-surface drainage cannot be determined in advance of the need.

For the surface distribution systems, land levelling will be required for any type of on-farm system used. Quantities of excavation per hectare for light, medium, and heavy levelling have been determined from the work done in the pilot area at Ed Deura (N 52-54 N 125-126). The sprinkler system will require only minimum land preparation.

The river pumping station will be located on a stable reach of the Medjerda River. It will have the same capacity and head for all plans. Its capacity will be 1000 liters per second with a static head of about 20 meters. The design will be similar to that described in the SGTH report (21).

Construction of electricity transmission lines to the pumping stations will be done by the Societe Tunisienne de l'Electricite et du Gaz (STEG). Their cost is included as a project cost.

All of the irrigation system layouts were made on topographic maps with scale of 1:10 000. Layouts made on this scale maps and the

cost estimates made therefrom are of a reconnaissance grade. They are of sufficient accuracy to adequately differentiate between economics of the systems and to define the upper limits of project costs.

An oxbow on the Medjerda River and an abandoned channel on the Barai River give promise of economical storage of surface water as a means of extending the perimeter or augmenting the irrigation within the perimeter. Although these are outside the scope of this study, some comments for consideration for future investigations are presented.

It is possible to cut off an oxbow on the Oued Medjerda near the middle of the perimeter. Two dams and two low dikes would create a reservoir storing about one million cubic meters. Since it is anticipated that under the well pumping regime, the present river flow in the fall would recharge the ground water rather than being available to the semi-intensive operation, the well system will have to supply the rather heavy fall demand. This must be made up for by the river flow later. The reservoir will provide this ability by supplying the demand in the late spring.

By using the reservoir, water can be taken from the river at a slower rate than needed to meet a peak. This permits a smaller pumping plant. Water can be taken when flows are at a moderate rate thereby obtaining a less saline water, silt will settle out of the

stored water, the stored water can be in excess of 4 MCM thereby making more water available to the project, water can be pumped from the reservoir after normal river flows are too low thereby prolonging the season and making it easy to meet the spring peak demand when both the intensive and semi-intensive areas may desire water.

The reservoir would probably be empty by July so evaporation losses would be low. Seepage losses through the fine textured soils should be small. Those that may occur can be covered by pumping in which case the reservoir would be serving as a recharge area for the underground basin, a very desirable condition. Losses laterally into the banks would partially return to the reservoir as bank storage seepage. Seepage losses are not anticipated to be a problem.

An additional reservoir usable in conjunction with the pipe distribution system but not practical for the sprinkler system, may be constructed in an "abandoned" channel of the Oued Raram. Nearly 500,000 m3 can be stored here. It will also serve as a part of the distribution system since it extends for about four kilometers and water can be pumped from it several locations. It can be filled by pumping from the Medjerda diversion station.

Sprinkler System

Sprinklers are well adapted to rolling terrain, steep slopes, soils or variable intake rates in adjacent areas, small steady streams of water, soils of high intake rates, and continuous use.

The method has limitations -- on fine textured soils where low intake rates prevent the application of desirable depths of water and create muddy conditions making the moving of the laterals an onerous task; the problem of wind of high velocity and long duration reducing application efficiency; saline water causing crop leaf damage, evaporation of water in the air especially under dry conditions may be appreciable with consequent increase in salinity; proper use and maintenance not easily obtained; contribution to excessive losses of water thru deep penetration due to non-uniform patterns and running water too long; rapid depreciation of equipment; once established as a method is difficult to convert to surface irrigation; on small fields, which for cultural reasons should be covered in a few days, requires a large capital investment; the cost of pumping to create the necessary operating pressure.

Applying the advantages and limitations to the perimeter, indicate that sprinklers are most applicable on the sloping areas on the south side of the project and on other areas too cut up with gullies to be adaptable to surface irrigation methods. The problems

of fine soils requiring low application rates can be helped by using high pressures, small nozzles, and stream straightener varied nozzles. These corrections, however, are more affected by wind which is not appreciably helped by wind breaks which create competition for nutrients, water and sunlight. The problems of saline water and water evaporation cannot be alleviated. The training of people to properly operate and maintain sprinklers can be done, but it is not as simple as training people to properly use the furrow method. The elimination of over-irrigation by turning off the water on time can be taught. The design of the sprinkler system can be done properly to obtain a reasonable uniform pattern even in moderate wind. On the small 1.25 ha fields, a minimum portable main and lateral system will cover the plot in 12 days use out of a 16 to 20 day cycle. This system consists of a portable main down the long middle (120 m) and two half laterals both operating on the same side of the main for six days, then the other side for six days to make cultural operations practical. It requires a flow of 2.2 l/s. The sprinklers are spaced 9 x 12 m. A water meter should be supplied for each plot.

In intensive areas planted to orchards other than citrus where slinity may be a problem, the use of small under-tree sprinklers on hoses (hose pull method) should be satisfactory. They are operated 24 hours per day every day at peak demand thereby meeting

most of the requirement for a good sprinkler operation. The system requires a steady flow of 1.2 l/s.

For the semi-intensive 5 ha plots, the design sprinkler line consists of a portable half main along the short end and one portable lateral the long way. The field could be covered in 12 days and would then be fairly uniformely wet which is essential for uniform cultural operations. Several plots could use the same system. The flow rate needed is 8.4 l/s. One meter is needed for each plot and is typically located in the center of the short side.

The design application depth is 125 mm applied in 16 hours. A larger application would be desirable if the soil intake rate is not exceeded by the end of the application. This can be accomplished by running 24 hours but would undoubtably create a mud problem during moving which can be overcome by alternate day or dry-line operation. A smaller application is definitely undesirable because the soil surface evaporation loss is fairly large and occurs each time an application is made. For small applications evaporation becomes a larger percentage of the application leaving less for transpiration. Because the evaporation is large, the depth of penetration becomes smaller and essentially no salt leaching will occur. Further, because the soil is maintained moister, there is more upward capilary movement which further builds up the salt in the surface soil.

In other words, small applications quickly compound the soil salinity problem.

For economy in pumping, the project is separated into pressure zones at about 10 m intervals. Pressures are to range from 40 to 50 m in each zone. Nearly one-third of the area operates below one free surface reservoir at elevation 240 m MSL so that small variations in flow are automatically adjusted while variations in pumping rates take care of larger changes in demand. The remaining areas have the demand in flow rate and pressure met by operating different combinations of pumps. It is planned to do this manually and operators can be easily trained to vary the pumping capacity in conformance with a program of certain pumps operating for a particular flow rate and needed pressure at the booster plant to overcome friction losses in addition to the desired minimum pressure. This operation can be easily automated in the future.

The proposed pressure system operation will result in varying flow rates and consequently variations in pipe friction. These will cause pressure variations at farm turnouts. These can be minimized at the booster plants and with the high operation pressure at the sprinkler the variations are unimportant.

For the high pressure system in which many sprinklers will operate for about 12 to 18-hour durations, capacity of reservoirs

typically located beside each well, must absorb water during non-use period and also readjust the non-uniform well flow rate as the piezometer level changes. To deliver water to the sprinklers, the number of which will vary from day to day and in hours of operation, a booster pump system of variable capacity will feed from the reservoirs into the high pressure distribution system. The variable capacity will be obtained by having several pumps of different capacities which may be operated to provide the demanded flow, e.g. 3 pumps of 25 l/s capacity and 3 of 10 l/s capacity at one booster station. When pressure at a station drops below a pre-determined value for any specific flow rate, the operator will activate another pump. For services areas V, VIII, IX and X comprising about 1300 hectares evenly divided between intensive and semi-intensive use, a single reservoir at elevation 240 m MSL will control the variations in flow thereby simplifying operation in those areas.

For the other areas, no economical reservoir sites at a high enough elevation are available.

The perimeter is divided into 20 service areas. The operating pressure, measured as elevation above mean sea level, ranges from 220 m to 265 m. A low pressure supply system delivers water from the wells and the river pumping station to a series of equalizing reservoirs. Sprinkler booster pump stations equiped with multiple pumps of various sizes furnish water to each service area at the

pressure elevation required by the sprinklers. The multiple pumps promote the necessary flexibility to maintain the proper operating pressure at the sprinklers as the flow demand varies. The equalizing reservoirs balance the daily demand and supply as they vary in amount and periods of operation. Lands irrigated by Sprinklers do not require levelling. Rough grading is required to smooth out major variations in topography. A nominal amount is included in the estimate for land preparation.

Irrigation of orchards in the intensive areas will utilize an orchard hose pull system. Eight hoses with three heads will cover a 1.25 ha unit within 16 days continuous sprinkling. The hoses will be served from a buried pipe from the meter at the center of a short side with the laterals at the 1/4th and 3/4th length of the unit. For the intensive crops, a portable main will extend the length of the unit from the meter at the center of a short side. The main will serve two movable sprinkler lines on the same side of the main. By using the sprinklers on the same side at the same time, the other side will be available for farming operations. This system will cover the unit in 12 16-hour days. Irrigation of semi-intensive units will be similar.

The services areas and pressure zones for the sprinkler system are shown on plate 1. The complete system is shown on plate 17 sheets A-D.

Pipe Distribution System

Surface irrigation methods of furrows, border-strip, and basin are well adapted to nearly uniform surface of less than about 2% slope. On steeper slopes, the run may be flattened by placing them along contours. Intake rates should be nearly uniform within a field which means soils should be large and should be available as needed.

The three methods of irrigation have somewhat different requirements which must be considered, but all are improved by having the land levelled. The objective of this is to improve irrigation and not necessarily to create a plane surface. Warped surfaces, resulting in fairly uniform gradients in the direction of irrigation are usually more economical. The depth of cuts should not be great from the economic aspect and should not drastically change soil conditions. "Contour" planting, particularly of permanent crops such as orchards is a very acceptable way to greatly reduce grading costs since only a smoothing job is needed.

This requirement of flat grades and uniform slopes practically eliminates the south part of the perimeter and areas badly cut up by old stream channels from consideration for surface irrigation. The system is, however, designed for the whole perimeter.

Intake rates for the project with its consistently fine textured

soils should be quite uniform and quite slow. The slow rate can be easily handled by the furrow and basin methods. For the border-strip method to apply the design depth of 125 mm would require strips longer than the plot lengths of 150 or 300 meters. Lengths up to 500 to 600 meters would be best. For the proposed short lengths, only small depths at frequent intervals can be applied which will result in a surface soil salinity problem. The border-strip method is not well adapted to this project.

The furrow method is the most adaptable one. Variations in furrow spacing, shape, and width are easily made, and lengths can be very short.

Basins, to permit high irrigation efficiencies, must be very carefully levelled because all water ponded in the low spots after the high spots are exposed, will be lost through deep percolation. However, no water is lost by runoff.

Runoff water from furrows and border-strips is a practical necessity to assure that the lower end of the field is adequately irrigated. Under some conditions, this water can be collected and reused resulting in very high efficiencies since the losses to deep penetration are easily held to less than 10 percent for furrows. For the project with its small fields and many owners, it is not practical to gather and reuse the runoff except as it does go back into the river is waste ditches. Since border-strip will be used

in only a limited way, basins being better and having no runoff, the problem of high efficiencies and runoff is a problem only on furrows and requires a major design condition -- the water delivery must be large and must be flexible in rate and duration.

The proposed design satisfies the large stream requirements by supplying a stream of 50 l/s for each 1.25 hectare unit and runs for four days on a 5.0 ha unit. This stream will permit the starting of all furrows, about 90 long way furrows or about 140 short way furrows, with a large enough initial stream to reach the lower end in about 1/3 to 1/4th of the time, estimated to be 12 to 16 hours. Water needs to stay at the lower end to apply the desired depth.

Several hours after the water is through the furrow, the stream must be reduced so that there is very little runoff. This requires flexibility in rate controlled by the irrigator. A second cutback may be desired to further reduce runoff. When an adequate depth has infiltrated at the lower end, the water must be turned off since all water run after this time is wasted and efficiency drops rapidly. This requires that the irrigator be able to turn off the water when he no longer needs it.

The project design satisfies the rate and duration requirements by supplying the farm with water from a reservoir from which water

can be taken at any rate up to the limit of the system, or none can be taken. The practical control of these variable conditions to permit a limited demand schedule is accomplished as follows: Laterals are limited to six farm turnouts for 5 ha plots so that all could be supplied water within a 24 day period with four days per ha. At the turnout from the main to the lateral, a valve and a totalizing meter are installed. Upon "demand" by a farmer, he is allocated the use of the line for up to 4 days. The water guard reads the meter, unlocks the gate and opens it filling the lateral. He then unlocks the farmers turnout so that it can be used by the farmer with full flexibility. At the completion of irrigation, the farm turnout is locked and the meter red.

The operation of the intensive areas is similar with a lateral turnout and meter serving a maximum of twelve 1.25 ha plots. Very few laterals will have more than eight turnouts.

Where more than the desired number of turnouts does occur, a second meter is installed in the line and the difference in readings would be used in the upper part of the system which is sized to convey two streams of water.

The location of turnouts is preferably in the middle of the field if that side is nearly level. If not, then the turnout is at the high corner. When property lines conform closely to contour

lines, the concrete pipe laterals can be located along alternate property lines to distribute water to each side. This would reduce the number of laterals.

The concrete pipe considered for the project is to be used at pressure of 5m or occasionally at 6m. Since the project is sloping, pressure plateaus are essential to stay within the limits. The pressures will be controlled through the use of flost valves to create a semi-closed system.

For the pipe distribution system, water is typically fed from the wells into a pipeline which may have several reservoirs all at the same elevation desirably alternating with the wells at about one kilometer spacing. This permits water to be taken from the well and adjacent reservoir to satisfy demand from within a short distance. The reservoirs refill during the night when demand is small. Reservoirs are sized to retain about 8 to 12 hours of pumping and vary in capacity from 1,000 m3 to 10,000 m3.

The perimeter is divided into 27 service areas with pressure zone elevations ranging from 175 to 223 meters above sea level. Location of the zones is shown on plate 2. The elevations of the water surface in pressure zones is maintained by

b
use of 8 booster pump stations and 16 small equalizing reservoirs. The system of pipelines delivering water from the wells to the intensive area is shown on plate 3. The complete system is shown on Plate 18 sheets A-D. The intensive area may also be served from the river pump station.

Earth Canal Distribution System

The earth canal distribution system will consist of a supply system of concrete pipelines carrying water from the wells and from the river pump station to a 25,000 cubic meter distribution reservoir and for carrying water to equalizing reservoirs at the high points of each sector. From these equalizing reservoirs the water is conveyed by the open earth canal to blocks of eight secondary system five hectare units semi-intensive and 16 intensive units. In each block a tertiary lateral system will deliver water to each unit in turn. The nominal delivery to each unit is 20 liters per second. To provide flexibility comparable to the pipe distribution and sprinkler systems, the canals can deliver up to 40 liters per second to each unit.

Sector C1 has not been included in the system because the narrow strip of steep, rough terrain precludes the construction of a usable open canal system to serve the small intensive units.

The irrigable area served by the earth canal system will not be as large as the other systems due to the greater right of way required for the canals and higher seepage losses from the canals than from pipes. The canals will be of unlined earth construction. The fine grained soils of the perimeter are well suited for construction of reasonably imperious canals. The amount of water that could be saved by lining would not be sufficient to justify the cost of the lining.

The delivery water surface at each block has been set at 0.40 meters above the adjacent ground surface. This is required to permit

delivery into the tertiary laterals and then into the farm head ditches at a height sufficient to irrigate all the land of each unit. On level terrain and near turn-out structures this requires long reaches with the canal section all in fill. Such canals are difficult to operate and maintain and create problems of access to adjacent lands. A typical section is shown on plate 21. Delivery will be made to the secondary laterals through metering turnouts or adjustable weirs which will assure each user an equitable share of the water available and give the government a means of measuring the water for the purpose of assessing water use charges. Reinforced concrete is to be used for all structures. The mortared tile structures observed on existing perimeters all indicate inadequate strength and short life. These are not compatible with a project life of fifty years.

Adequate maintenance of a canal system is necessary to assure continuous delivery of water to the farms and to gain acceptance by the farmers. Sufficient funds for proper maintenance and operation must be available on a continuing basis to assure success of the undertaking.

On-farm irrigation practices will be the same for the open canal distribution system as for the pipe distribution system.

Operation of the system is simple. Most of the wells discharge into the distribution reservoir designated Res. A-B on plate 4. The other wells feed into the supply system serving the sector in which they are located. Sector A is served by gravity from the distribution reservoir. A pumping station at the reservoir feeds water to the high points of the other tranches except C2 which is served independently.

Small relift pumps are required to reach isolated high points in sectors D1 and E.

To avoid excessive losses of water and time at shut-down and start-up in the open canals they must be operated continuously until all of the land served has been irrigated.

A generalized map of the system is shown on plate 4. The supply and primary systems are shown on plate 19, sheets A through D. Typical canal profile and secondary systems are shown on plate 21. Structure estimate data are shown on Plates 22 and 23.

Combination Sprinkler and Pipe Distribution System

The system of distribution for the perimeter with its great variations in topography is a combination of sprinklers for the steep rough terrain in sector C1 and pipe distribution for the remainder of the area. With pipe distribution it is possible to convert areas of any size and location to sprinklers by installation of booster pumps and small regulation ponds. The supply system is so arranged that only well water need be provided for the sprinklers, thus avoiding the problems of silt and trash interfering with operation of the individual sprinkler heads. Irrigation methods for

surface application may be those best adapted to the individual units, as the water will be supplied at the high point with sufficient head to reach all irrigable land in it. Details of the system are the same as the applicable parts of sprinkler and pipe distribution systems described earlier.

A generalized map of the system is shown on plate 5. The completed system is shown on Plate 20 sheets A - D.

Other Irrigation Schemes

The proposals presented by EGTH (21) were reviewed in detail. We concur with their conclusion that the sprinkler system is preferable to the open flume system. Therefore, no further study was made of the open flume system. The sprinkler system they suggest was omitted from consideration because of the following serious problems in operation and maintenance and in farming practices. The very long and involved supply lines floating on one reservoir at one end of the system will make maintaining proper pressures very difficult. The pressure provided is inadequate for proper sprinkling with the high pressures required for the fine grained soils of the perimeter. The large variations of pump head in the wells cannot be compensated in single pumps feeding directly into the supply system. Without provision for settling, silt and debris from the river will interfere with operation of the sprinkler heads. The cost of electricity for pumping all the water to a high elevation is over fifty percent more than for a zoned system. Applying water with relative high dissolved salts by sprinkling in warm weather is damaging to crops.

10. COSTS

Construction Costs

The construction costs used for the different systems of serving the perimeter were computed from quantities determined from the layouts for the three systems and unit prices for construction and equipment as of July 1975. All of the capital costs required to have the project lands ready for irrigation farming have been included. Except for land levelling for surface irrigation and land preparation for sprinkler irrigation, on-farm costs have not been included. Contigencies have been included as is standard practice in project planning estimates. Gittinger says, in "Economic Analysis of Agricultural Project", page 100 (55),

> "Cost estimates for the investment period of a project generally are prepared on the assumption that there will be no modifications in design which will lead to changes in the physical work required; that there will be no exceptional conditions such as an unanticipated underground geology and that there will be no adverse phenomena such as floods, landslides, or unusually bad weather. Normally, too, project cost estimates assume there will be no relative changes in domestic or international prices during the investment period, and that the general price level will not rise. Clearly, it would be unrealistic to rest project cost estimates simply on these assumptions of perfect knowledge and complete price stability. Sound project planning requires provision be made in advance for possible physical or price changes that are likely to add to the base line costs by including contigency allowances as a regular part of the project cost estimates ... These contigency allowances then are expected, if unidentified, project costs and properly form part of the cost base when computing the internal financial and economic rates of return or other measures of project worth."

Contigencies have been included as 15 percent of the total of the identified costs.

Pipe prices, which make up a major part of all schemes were developed from manufacturer's list prices; transportation and laying, excavating and backfill of trenches, were indexed from recent bid

prices for similar types of work in other parts of Tunisia. Earthwork prices for open canal, road and reservoir construction were similarly obtained.

Land levelling costs were determined on a per hectare basis utilizing quantities determined from the demonstration in the Ed-Doura area near the center of the perimeter.

Pumping equipment for relift pumping plants were determined for installed kilowatt costs extracted from recent bid prices. The river pumping plant was indexed from the costs used by EGTH (21). Drilling and equipping wells were also indexed from the EGTH report. Electric transmission lines were the same as used by EGTH and were verified by STEG. All prices were determined on the basis that all construction work would be performed by local contracting firms equipped for and experienced in the types of work required.

Operation and Maintenance

Operation and maintenance costs per year are based on a percentage of the construction costs. The percentages used are standards based on experience of many projects. They conform with those used by Itaconsult. (52)

Energy

Electricity for operating pumps will be furnished by STEG. Based on their established tariff of 5 mill/kWh for 10 hours, 10 mill/KWh for 11 hours, 15 mill/kWh for three hours and a demand charge of D 12 per kVA installed an average rate of 8.54 mill/kWh for pumping has been adopted.

Energy costs for the various irrigation systems are tabulated below:

Energy Costs in Thousand Dinars

Irrigation System	Cost
Sprinkler	65
Pipe distribution	36
Earth Canal	56
Combination Sprinkler-Pipe Distribution	41

Replacements

Replacements of structures and equipment will be made at the end of each one's useful life. Structures with adequate maintenance will last the life of the project. The useful life values conform to those proposed by Itaconsult. (52)

Construction Schedules

Construction programs for the earth canal distribution system and for the combination system are shown on Plates 6 through 9. These are based on starting a new sector each year and a construction period of one and one half years for each. The costs shown on the schedule do not agree with those shown on the cost estimate. Much of the construction done in sector A is to develop the water supply for all the sectors. These costs have been distributed equitably among all the sectors as shown in the cost estimate. The total cost of the construction remains the same.

Cost estimates, operation and maintenance estimates and replacement estimates are shown in tables 12 thru 23.

11. BENEFITS

Primary Benefits

The primary benefits accruing to the project result from increased agricultural production. The benefits should result in satisfactory returns on investments made under the project and in higher net incomes for the participating farmers. The benefits for the project have been evaluated by subtracting the cost of production from the gross value of production. The net benefits, which are used in the economic evaluation, are the difference between the benefits from agricultural production in the area without the project and the benefits from agricultural production with the project.

Prices and Marketing

In an economic analysis, the prices should reflect the value of the goods or services to the nation while in a financial analysis the prices should reflect the value of the goods or services to the entity being considered, which in this case is the farmer. The two prices are not always the same. In a financial analysis the market price, or an estimate of this price at the point of the first sale, is generally desireable. In an economic analysis, some other price may be a better indicator of the value and a so-called shadow price may be used.

No attempt was made to predict future prices. No evaluation was made of year-to-year and longer term price fluctuations. No adjustment was made for inflation, assuming that prices of both the costs and the benefits would rise uniformly.

Estimates of the farm-gate prices in the Ghardimaou area for the crops pertinent to this study are shown in table 24.

Forage crops such as berseem, alfalfa and vetch/oats are marketed locally as feed. Forage corn and sorgo, on the other hand, are grown only on a small scale and are used on the farm.

Tobacco is sold to the Government Tobacco Office in Ghardimaou, and sunflower to the Office of Oils. The price shown for tobacco is the average price paid, based on a consideration of the various grades of leaf, as suggested by the Tobacco Office. Sugar beets, the other industrial crop, is sold to the sugar beet factory at Beja, a distance of about 80 kilometers from the perimeter. The cost of transporting sugar beets from the farm to the railroad has been considered as a cost of production. It should be noted that payment is made based on two factors: sugar content and cleanliness. Because the beets are weighed, a penalty is incurred if they are extra-dirty. This may be a factor to consider with regard to sugar beets grown in the heavy clay soils of the project area.

Cereals are sold to the Office of Cereals. There are many factors controlling the quality of cereals that determine the prices paid and the price shown in the table represent an average as suggested by the local manager of the Cereals Office.

Truck crops present the most varied picture as far as marketing is concerned. One of the major problems regarding production from the project area is the matter of crop maturing dates. The climate in the area prohibits early planting and the crops usually mature when the market is full with produce from other areas. Tomatoes, for example, command a good price for only a short period of time. Much of the crop is sold for a relatively low price to the canning factory at Le Kef. On the whole, a market is sought locally in Ghardimaou and

Oued Meliz, and then in Jendouba. However, much of the production is sold out of the Governorat at a reduced price.

The production of Tobacco is encouraged. The Tobacco Office offers free plants, extension services, and will spray against pests and disease free of charge. Sugar beet production is also encouraged and easy credit is given for seed and fertilizer.

It is suggested that experiments be carried out at the INRAT station, or on demonstration farms, with different truck crop varieties to determine which varieties mature early enough to be effective in the markets.

Shadow Prices

There are ususally certain imperfections in the markets which take the form of subsidies, price controls, lack of information concerning prices, etc. Because of these imperfections, the use of market prices for some goods or services may not reflect the real cost to the economy. Therefore, some estimate of the real value (shadow price) must be estimated. There are generally only three areas where shadow pricing should be considered in agricultural projects (55): foreign exchange, commodities which are important in the world market, and unskilled agricultural labor.

In Tunisia, the official exchange rate closely indicates the real cost of foreign exchange to the nation. Therefore, no correction is necessary.

The Government presently protects the local wheat market and offers a price substantially above the world market price. Therefore, in the economic analysis, an estimate of the world market price for wheat with an allowance for the cost of marketing from the farm to the

point where the world market price is offered was made at 35 dinars per ton. This price is not the result of a rigorous analysis as the effect on the project analysis is quite small. No other crop shadow prices were considered.

Developing a shadow price for labor is arbitrary because initially it is difficult to assess the degree of unemployment and secondly, because it is more difficult to project that rate of unemployment. The basis for the evaluation is that if labor is not producing before the project and is then used by the project to produce something, nothing is being given up to produce the new product. Because nothing is being given up, the economic cost to the nation is zero and the proper price to charge for the labor in an economic (not financial) analysis is zero. Some estimates of unemployment are over 10 percent of the labor force. We do not know how these estimates were developed nor do we have any estimates of underemployment which is usually very high in an agricultural community of a developing country. On the other hand, the minimum wage for agricultural workers was raised in 1974 to 900 millimes per day predominantly, it is reported, because of a shortage of workers. Parsons (27) reported that in 1966, 5 percent of the labor force was unemployed and 9 percent was underemployed. Thus it appears that during some parts of the year, such as during harvest times, there may be a shortage of labor. For the project analysis, the price of hired unskilled agricultural labor was valued on an annual basis considering time when labor is scarce and when there is an abundance of labor available. For the economic analysis this labor has been valued at 600 millimes per day as representing the cost of labor to the nation.

This condition was assumed to remain in effect for the forseeable future and no change was made to this assumption for later in the economic life of the project.

In most cases, skilled labor is quite scarce in this type of community and is sometimes shadow priced above its normal wage. This was not done, however, for the Ghardimaou project analysis.

Yields

Yields in the project area were estimated for three conditions: present, future without project, and future with project, and are shown in table 25.

The yields are based on conversations with more than 30 farmers in the project area, and on conversations and group meetings with representatives of farmer organizations, extension agents and government officials. In addition, reports containing information published by the Tunisian National Institute of Agricultural Research, the agency in charge of the principal experiment stations, by the United Nations and others was reviewed.

The significant difference between the yields for the with-project and without-project conditions reflects the anticipated production in an agricultural environment where the crops will benefit from the residual nutients remaining from a previous crop. This is particularly noticeable where dry farmed wheat follows irrigated sugar beets. Not only does the wheat benefit from the fertilization of the sugar beet, but it is becoming customary to "green chop" the beet tops and plow them under as green manure. The advantage of this procedure is now being demonstrated in the Beja and Bou Salem/ Badrouna areas. In

addition, the improved environment caused by a more intensive extension program will facilitate acceptance and adoption of better practices which will result in higher with-project yields.

Crop Production Costs

Cost of production schedules were developed for all major crops grown and to be grown in the perimeter area. These schedules were developed after discussions with local farmers and other knowledgeable people in the region. The costs include unskilled labor, which was arbitrarily divided into family and hired labor, skilled labor and equipment costs, seed or plant costs, and fertilizer and pesticide costs. As previously explained, the hired labor cost was calculated using a shadow price. Many of the fertilizers are either imported or can be exported. Therefore, to reflect the cost to the nation, the official prices to the farmer were adjusted to more closely reflect the real cost or the possible selling price rather than using the subsidized price.

The quantities used in developing the costs of production were for the future with-project condition. The present and future without-project costs of production were based on these calculations but reduced to reflect the less intense use of farm inputs if no project were constructed. The production costs used are shown in table 26.

Clean seed for cereal crops and some legumes are available from the Office of Cereals. Seed and plants for the other crops are available from the OMVVM/PPI. There appears to be a limited demand for seeds supplied by the government agencies and a substantial amount of seed is purchased from the markets. Table 27 shows the amount of seed used and the cost for selected crops.

Fertilizer and pesticides are available from the OMVVM/PPI and from the Office of Cereals. These inputs are conceded to be readily available although there are reports of sales in the market place and by private suppliers. Table 28 shows prices for some of the fertilizers and pesticides used in the project area.

From discussions with local farmers and agricultural people, it is evident that much of the work will be done by private contractors. The private contract rates were used in the analysis and are shown in table 29. An office of the Cooperative Central de Motoculture (COCEMO) was opened in Jendouba in 1972, and there are now smaller offices in Ghardimaou and Oued Meliz. COCEMO rents all kinds of equipment, and services equipment for private farmers, contractors, as well as for themselves. The Jendouba office serves the whole of the Governorat. The representative in Jendouba explained that if there were enough demand, additional equipment would be made available from other areas. However, it is doubtful that equipment will ever meet the needs unless a careful analysis of need is made well prior to the time the equipment is actually needed in the field.

It is suggested, therefore, that as part of the development program, the machinery requirements be estimated by season and that this requirement be balanced against the machinery available from private contractors and COCEMO, and requisitions be made accordingly.

Although it appears that most of the work in the area will be done by private contractors, the COCEMO rates are also included in table 29. COCEMO has 4 programs of equipment supply; however, the only one of interest is that where farmers must pay the entire rental fee as equipment is available. This implicitly favors the large farmer

who is more likely to have ready capital. The small farmer cannot take advantage of these rates and he must turn to the private contractor who will permit late payment in return for higher rates.

Net Value of Production

The net value of production is the difference between the gross value and the sum of the cost of production and the economic cost of land which has been included as a rent at the following rates.

	Land Rent in Dinars per Hectare		
	Intensive/Irrigated land	Semi-Intensive	Dry-farmed
Without project	80		12
With project	80	40	

The net value of production for the three time conditions necessary to determine the net benefit stream are as follows:

Condition	Net Value of Production (in 1000 dinars)						
	Total Perimeter	Sector A	B	C	D1	D2	E
Present	309.8	88.5	96.1	69.9	29.5	24.9	0.9
Future- Without Project	594.6	177.4	200.7	126.9	44.4	35.1	10.1
Future- With Project - Earth Canal Distribution System	3045.0	291.7	272.2	1269.2	128.8	163.7	919.4
-Sprinkler & Pipe Distribution Systems	3498.7	325.7	245.7	1283.2	212.3	268.0	1163.8

The sector net values are based on an arbitrary definition of what crops would be grown in each of the areas. In the semi-intensive sectors, some rearranging is possible if it is desired. The total

value for the perimeter represents a fairly well rounded cropping pattern, which could probably be increased if only the higher cash crops were used. The value for sector E does not include any estimate for the 150 hectares of fruit trees at the Chemtou Tree Farm. No information was forthcoming from them and as the quantities will cancel out when the present is subtracted from the future values, no estimate was made. If the general value used for orchards other than at Chemtou were included, the net value figures for sector E would increase by about 420,000 dinars in all three conditions.

The maximum net benefit depends upon the time it would take to develop from present conditions to future without conditions, if no project were built, as well as the time assumed for the area to develop to future with-project conditions. This will be explained in more detail in the section on economic analysis; however, the maximum net benefit will be very close to the difference between the future with and the future without conditions as shown below:

Approximate Maximum Net Benefit
(in 1000 Dinars per year)

	Net Value		Net Benefit
	With Project	Without Project	
Earth Canal Distribution System	3045.0	594.6	2450.4
Sprinkler & Pipe Distribution Systems	3498.7	594.6	2904.1

Secondary Benefits

Secondary benefits are generally considered as those which arise outside of the project itself as a result of happenings inside the project. There are several types of secondary benefits but two kinds usually receive the most attention. The first is that increased output

involves increased activity by merchants, transportation concerns, and processors. The second is that increased employment generates new wealth which is spent to increase employment, i.e., a multiplier effect is generated. The two most common ways to account for these secondary benefits is by accounting for it in the primary benefit by means of a shadow price or by applying a factor representing the multiplier to the primary benefits or to the investment.

During the four-month study, no attempt has been made to evaluate secondary costs or benefits. In previous reports and summaries, two estimates have been made which were 0.27 times the gross value of production at farm prices and 2 times the primary net benefits. Neither estimate appeared to be based on any factual data from within the country. The first estimate was based on studies from the Central Valley of California, U.S.A.

The evaluation of secondary benefits requires estimation of their magnitude which must then be divided into those that are national and those which are local in nature. The national benefits, which could be included in the economic analysis are estimated to range from nothing in times of full employment (58) to 10 percent by the Soil Conservation Service (52) to almost any value, but no one has conclusively proved a net (secondary) benefit to actually exist.

No secondary benefits have been included in the economic analysis for this study. However, with the information presented in this report and a table of discount factors, it should be quite easy to change the benefits to reflect whatever multiplier is desired.

Intangible Benefits

By definition, it is not possible to assign a monetary value to intangible benefits. These benefits are usually considered when there are major differences among technically feasible plans. Examples of these benefits are the saving of life, the improvement of health, the improvement of the esthetics of the environment, or the preservation of areas of interest or beauty. No consideration was given to these concepts nor was any attempt made to define the benefits. It is the responsibility of those who are more familiar with the Republic and its needs to make any decisions with regard to intangible benefits.

12. ECONOMIC ANALYSIS

Introduction

The economic analysis is a means of assessing a project in terms of its real costs and benefits to the nation. Its purpose is to determine whether or not a project involves a better use of national resources than its possible alternatives. The analysis evaluates the total return to the whole society of all the resources committed to the project regardless of who contributes the resources and regardless of who receives the benefits.

The decision has already been made to proceed with the project, in fact, a substantial amount of money has already been invested in the construction and development of wells. The primary purpose of this evaluation is to select a type of irrigation system or a combination of systems which most economically provides water to the perimeter area within the limits of the constraints. The selection of the system could be greatly simplified by eliminating from consideration all costs and benefits which are common to all irrigation systems. However, since no quantitative evaluation has been done, it was decided to proceed as if the decision for or against construction had not yet been made.

Of the several common discounting techniques available, it was decided to use the rate of return method. The rate of return method is widely understood by all concerned, the rates of return are meaningful to those who are responsible for investing money, and the rates can be compared with those for many other types of investment.

The economic life of the project, or the period over which the benefits and costs are compared, was arbitrarily set at fifty years from the beginning of any new construction.

Sunk costs, or those which have already been expended on the project were not included in the analysis. The decision to proceed or not starts from the present and all occurrences in the past are ignored.

No farm surveys have been conducted in connection with the study nor have any been made at any time in the project area. Therefore, no statistically valid farm management information has been obtained. The agricultural economist has talked with a small sample of farmers (about 30) and finds them to be quite open to change and able to carry out more modern techniques. The sample was probably largely weighted toward the better farmers because of the type of information desired. The general opinion of the OMVVM and others is that the farmers may have more than normal difficulties in adopting new techniques. For this reason, conservative estimates of time to develop to full development have been given more emphasis.

For the without-project condition, it was assumed that production and benefits would increase to a maximum in 20 years and then remain constant. This without-project benefit stream was subtracted from the with-project stream to develop net benefits.

Orchards were assumed to reach full production 8 years after planting. During the first 3 years, no production was assumed. In the fourth year, enough produce was assumed available to warrant harvesting it and the production gradually developed until it was a maximum in 8 years. It was assumed that all the orchards in each sector could be planted in one year. The development period for orchards was held constant at 8 years regardless of the assumed development period for the rest of the crops.

For each sector, the extension costs were assumed to reach a maximum in three years after the beginning of construction. The energy costs were assumed to reach a maximum four years after the beginning of construction.

Economic Costs and Benefits

The economic costs are obtained by deducting from the total project costs any transfer payments such as duties and taxes. These transfer payments are a part of the net return from the project which is turned over to the government to spend on behalf of the Republic. In other words, these payments are paid by the Republic to the Republic and the net effect is zero.

We were not able to identify these tax components of the prices except on a very small scale. Based on some data on customs duty and production taxes, the equipment portion of the capital costs and replacement costs was reduced by 10 percent.

The costs for field canals needed with the gravity or low-pressure systems and the cost of the sprinkler equipment were assumed to be the responsibility of the farmer and were not included as a project cost.

The economic benefits are obtained by valuing the production at its real cost to the Republic and estimating the difference between the benefits with the project and without the project. The real cost to the Republic are those based on the prices from unprotected markets, on unsubsidized agricultural input, and on a labor charge which considers the degree of un- or under-employment in the area. As explained in the section on benefits, some attempt was made to quantify these real costs. The results are not very

refined, but should be on the conservative side. By far, the majority of the input data for the benefits is good.

Economic Selection of the Irrigation System

The first step in the analysis was to decide which of the three irrigation systems, pipe distribution system, sprinkler system, or earth canal system, develop the highest internal rate of return. The benefits in each sector were assumed to reach a maximum in 5 years. Orchards were assumed to have no production for 3 years and to reach full development in 8 years. The results are shown below:

Irrigation System	Rate of Return in percent	Benefit - Cost Ratio @ 10 %
Sprinkler	15.6	1.8
Low-pressure	14.3	1.6
Earth canal	15.0	1.7

A graphic display of these results is shown on plate 10.

From the tabulated data, it must be concluded that there is no clear basis for selection of an irrigation system based on the results of the economic analysis. However, because the returns for each system are so close, it is possible to select whichever system is best from the standpoint of ease of operation and maintenance, and other factors.

For reasons explained in detail elsewhere, it was decided to recommend a low-pressure system in all sectors except the major southern portion of sector C. In this area, because of the terrain, a sprinkler system is most suitable.

Economic Analysis of the Recommended System

The recommended irrigation system, which consists of a low-pressure pipe system in all the sectors except a part of C and a sprinkler system in this area has a rate of return of 14.7 percent. This rate is based on a 5-year development period. The cash flow or the incremental net benefit stream is shown in table 30, the present worth of costs and benefits at different discount rates is shown on plate 11.

Each of the sectors was analysed to ensure that all were economically viable and to see if changing the construction schedule would have any beneficial effect. For the 5-year buildup condition, the results are as follows:

Sector	Internal Rate of Return in Percent
A	12.3
B	11.9
C (intensive)	27.8
D	15.0
E (intensive)	21.0

It is apparent that the earlier sectors C and E can be constructed, the better will be the rate of return. It was assumed that the construction sequence be revised to A, C, B, E and D and the rate of return was increased by about 5 percent to 15.4 percent. Based on the available data, this is not at all significant.

Sensitivity Analysis

The uncertainty of the basic assumptions may, to some degree, be considered by means of sensitivity tests. The tests would provide the answers to such questions as how sensitive is a project rate of return to changes in costs, benefits, or development period.

The tests that have been run are as follows:

1. Decrease buildup period for benefits in each sector to 3 years.
2. Increase buildup period for benefits in each sector to 8 years.
3. Increase capital costs by 25 percent.
4. Decrease benefits by 20 percent.
5. Increase benefits by 25 percent.

The final test approximates the condition of including a multiplier effect representing secondary benefits. The effect of the tests on the internal rate of return is shown below:

Sensitivity Analysis - Economic Rate of Return

Condition	Internal Rate of Return in percent
Basic run - 5 year development period	14.7
3 year development period	15.6
8 year development period	13.7
25% increase in capital costs	13.3
20% reduction in net benefits	13.1
25% increase in net benefits	16.4

13. FINANCIAL ANALYSIS

Introduction

The purpose of this financial analysis is to determine if there is a possibility for the repayment of project costs after ensuring that the farmers are given adequate incentive to participate in the project.

Whereas the economic analysis is based on a comparison of the situation with the project and without the project, the financial analysis considers only the with-project condition. The analysis shows the cash expenditures which are required to construct, operate and maintain the project as well as the cash repayments which may be expected from the beneficiaries.

To make the analysis it was necessary to assume a "model" farm plan. Because of the variety of crops to be grown in the area and the range of permitted farm sizes, it was necessary to make a basic assumption concerning "model" farm size and cropping pattern. The size of farm initially considered was the minimum, as suggested in previous studies (9), for the project of 1.25 hectares in the intensive areas and 5 hectares in the semi-intensive areas. The "model" farm cropping patterns were based on the patterns developed for each sector in connection with the development and scheduling of the water requirements. For example, if one-half of a sector was planted to sugar beets, then one-half of any 5 hectare farm in that sector was also assumed to be planted to sugar beets. This procedure was followed for all farms except those consisting of fruit trees. In this case, the entire 1.25 hectare farm was assumed to be planted in orchards. The farm plans are shown in table 31. During the cash flow calculation, it was found that farm plans 5a and 6 required greater that the minimum areas to

meet the assumed income and incentive requirements of the farmer.

The financial rate of return was estimated by subtracting the net return from production, after considering all costs and needs of the farm family, from the project financial costs and discounting the resultant net value of production. No attempt has been made to evaluate methods by which the costs may be recovered. It was only the purpose of this analysis to decide if there was a capacity for repayment.

Financial Costs and Benefits

The financial costs are the costs of the project features, operation, maintenance, replacement, energy, and extension including all taxes and duties. The financial benefits are taken as the net production value from the with-project condition. Commodities and services should be valued at prevailing market prices rather than at shadow prices unless clear indications exist that these market prices will change. No adjustment was made to the present prices although rises due to inflation are almost a certainty. The net production values should also be corrected for taxes and subsidies.

Farm Plan Budget

Farm plan budgets were developed to determine how much money is available for repayment of the project costs. A budget was developed for each of the farm plans at full development conditions and then analysed to determine the effect of the buildup period on the calculated returns. The budgets were developed from the following items:

Gross Value of Production: This value is obtained by multiplying the future with-project yield by the present market price.

Cost of Production: The cost of production is the sum of costs for hired skilled and unskilled labor, equipment rental, and seeds, fertilizer, and pesticides at their subsidized prices. Interest on seasonal loans to buy the seeds, fertilizer and pesticides was also included at 10 percent over the length of the growing season.

Other Farm Costs: An amount of 20 dinars per hectare was included for any land preparation necessary in connection with providing a conveyance system from the project supply to the plants. In the sprinkler section of Sector C, this amount would be for the purchase of on-farm sprinkler equipment. The equipment is assumed to have a 10-year replacement life.

Water Costs: It is presently expected that the total cost of operation and maintenance (C & M) will be recovered by requiring the farmers to pay a water charge. The full development cost of C & M is 88,000 dinars per year and the annual applied water volume is 17.5 MCM. The water charge to pay for the C & M is calculated to be 5 millimes per m^3. This charge was assessed in the budgets according to the water used by each crop.

Energy Costs: In a similar manner, it was decided to charge for the energy required for pumping on the basis of the water used. The total energy cost of 41,000 dinars per year divided by the metered water volume of 17.5 MCM results in a charge of 2.3 millimes per m^3. This charge was also assigned according to the water used by each crop. We do not imply that the energy cost should be recovered in this manner, rather that if it were, it would cost the above indicated amount.

Land Costs: The farmer is required to make a direct contribution to public investments which enable his land to be irrigated. This contribution may either be in land or money. For simplicity, a land cost was assigned in the first year after the beginning of construction in the farmer's sector. The cost to be used for the land, as indicated by the OMVVM, was 250 dinars per hectare in the intensive areas and 200 dinars per hectare in the semi-intensive areas.

Value of Home Consumption: The value of home consumption, or the value of farm family labor was assumed to be 250 dinars per family per year. This is the value of food the farmer grows and does not take to the market or the value of the food the farmer buys.

Incentive: The amount of money the farmer received as a clear profit is very important as it can determine if he is willing to participate in the project or not. The value used in these analyses was 500 dinars per family and was provided by OMVVM. This amount is the cash which the family will have to live on during the year.

Interest and Repayment of Loans: The loan term was assumed to be 14 years at 10 percent interest with a grace period extending through the fourth year. Interest due during the grace period was capitalized. Repayment of capital and accumulated interest would begin at the end of the 5th year and be completed at the end of the 14th year.

Return Available for Repayment: The gross value of production less all costs, values, and incentive payments results in the amount which could theoretically be made available for the repayment of project costs. The net returns for each farm plan are shown in table 33.

Financial Return

A cash flow was developed from the project costs and net returns. A very important part of this cash flow is the stream of net returns during the buildup period of the project. It was assumed, as in the economic study, that the buildup period would be 5 years. In the early years of this period the incentive money was reduced. The value of home consumption remained the same except for orchards where it was assumed that the farmer could grow some food in between trees. It is hoped that this practice will stop in about the 5th year. It was also expected that this practice will reduce the overall yield of the orchards at full development. It was in the analysis of the buildup period returns that it was discovered that the minimum size farms in the semi-intensive areas of sector C and the non-orchard areas of sector E were not financially viable. We had the option of increasing the area to 6 hectares for the farms in sector C and to 2 hectares for the farms in sector E, which we did, or extending the development loan to more than 14 years.

The net returns for the Chemtou Tree Farm have not been included. The financial condition of this farm has not been made available and we have no idea of how its net returns are used.

The number of farms in each sector was calculated using the future with-project land use pattern. This value times the net return per farm generated the total net return available for repayment.

The financial rate of return for the project is about 13 percent. If money were borrowed at an interest rate of 13 percent and all the funds assumed available for repayment were used for that purpose, the loan for the project would be recovered at the end of 50 years.

Table 33 shows the cash flow developed for the analysis.

The total number of viable farms, using the assumed cropping patterns and costs is 1674. We believe, from information presented by EGTH during a meeting, that an information survey in the perimeter indicated that there are 3849 owners of the perimeter lands and 855 family groups (1974).

If it is decided to provide the value of home consumption and the incentive money to all of the owners, then some adjustments must be made. One solution would be to put more than one family on each farm, assuming that each owner has one family. The financial rate of return for this condition would be reduced to about 4 percent.

Credit Requirements

During the buildup period of the project, money must be made available to the farmers to allow them to establish their crops and orchards, buy their land, and maintain their families. These amounts will be much in excess of the seasonal loans now made available by OMVVM.

To meet the credit requirements, all kinds of credit must be increased. Especially of importance will be the medium and long-term loans without which the farmers will never undertake the necessary development practices.

To assist in planning for the credit needs of the project, the requirements, which were calculated in connection with the financial analysis, are shown by year.

Credit Requirements

Year after beginning of Construction	Requirement in 1000 dinars
1	-
2	1060
3	970
4	715
5	1133
6	747
7	100
8	99

Repayment of the loans will begin at the end of the 6th year and will be completed at the end of the 20th year.

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15. TABLES AND PLATES

Table 1

Estimated Present Land Use in Hectares

Land Use	Perimeter	Sector A	B	C	D1	D2	E
Wheat	2200	500	400	500	200	250	350
Barley	300	50	40	50	80	30	50
Vetch/Oats	100	20	10	20	30	10	10
Chickpeas	400	60	50	60	150	40	40
Beans	200	40	30	40	50	20	20
Industrial Crops 2/	200	30	70	50	10	10	30
Forage	30	20	10	-	-	-	-
Truck Crops 2/	430	190	140	30	50	20	-
Fruit Trees 2/	240	20	30	30	-	10	150 1/
Fallow	1550	340	290	340	120	190	270
Roads, Villages, etc. 3/	150	30	30	30	10	20	30
TOTAL:	5800	1300	1100	1150	700	600	950

1/ Chemtou Tree Farm

2/ Good records available

3/ About 2.5 to 3 percent of total area.

Table 2

Estimated Future Land Use Without Project

in hectares

Land Use	Perimeter	Sector A	B	C	D1	D2	E
Wheat	2100	440	340	480	210	260	370
Barley	300	50	40	50	80	30	50
Vetch/Oats	100	20	10	20	30	10	10
Chickpeas	400	60	50	60	150	40	40
Beans	200	40	30	40	50	20	20
Industrial Crops	300	60	120	50	30	10	30
Forage	200	80	80	40	-	-	-
Truck Crops	320	150	110	20	30	10	-
Fruit Trees	240	20	30	30	-	10	150 1/
Fallow	1490	350	260	330	110	190	250
Roads, Villages, etc. 2/	150	30	30	30	10	20	30
TOTAL:	5800	1300	1100	1150	700	600	950

1/ Chemtou Tree Farm

2/ About 2.5 to 3 percent of total area.

Table 3

Estimated Future Land Use with Open Channel Irrigation System

in hectares

	Perimeter	A	B	C	D1	D2	E
Intensive Area							
Fruit Trees	700	-	-	290	-	-	410 1/
Berseem	400	-	-	90	-	-	310
Vegetables	200	-	-	190	-	-	10
Artichokes	200	-	-	200	-	-	-
Sub-total:	1500	-	-	770	-	-	730
Semi-Intensive							
Sugarbeets	600	250	180	100	40	30	-
Wheat	1000	280	220	-	300	200	-
Berseem	600	140	140	-	150	170	-
Legumes	700	300	290	-	30	80	-
Sub-total:	2900	970	830	100	520	480	-
Roads, R/W, etc.	1400	330	270	280	180	120	220
TOTAL:	5800	1300	1100	1150	700	600	950

1/ Includes 150 ha of Chemtou Tree Farm

Table 4

Estimated Future Land Use with Pipe Irrigation System

in hectares

	Perimeter	A	B	C	D1	D2	E	
Intensive Area								
Fruit Trees	800	-	-	290	-	-	510	1/
Berseem	400	-	-	130	-	-	270	
Vegetables	200	-	-	190	-	-	10	
Artichokes	200	-	-	200	-	-	-	
Sub-total:	1600	-	-	810	-	-	790	
Semi-Intensive								
Sugarbeets	800	350	300	-	40	110	-	
Wheat	700	200	250	50	200	-	-	
Berseem	800	180	100	-	250	270	-	
Legumes	700	270	240	10	60	120	-	
Sub-total:	3000	1000	890	60	550	500	-	
Roads, R/W, etc.	1200	300	210	280	150	100	160	
TOTAL:	5800	1300	1100	1150	700	600	950	

1/ Includes 150 ha of Chemtou Tree Farm

Table 5

WELL OPERATING HEAD

Well Number	Design Discharge in l/s	Draw-down in m	Full 1/ Operation Drawdown in m	Depth 2/ to Water in m	Depth 3/ to Aquifer in m	Operating Head in m Max	Operating Head in m Min
7057	80	7	8.3	9.2	40	49	20
6090	95	7	7.6	8	65	73	19
6091	95	4	4.9	9.6	55	60	16
6100	85	5	7.2	17	45	52	26
6777	60	5	6.0	13	35	42	22
6854	60	8.5	9.5	9	45	55	22
6908	15	16	16.4	10	40	57	28
6910	30	5	6.7	24.6	45	52	32
6911	80	5	7.3	18.4	50	58	27
7007	95	5	6.9	12.6	50	57	20
7008	95	5	6.4	8.4	40	47	16
7010	40	9	9.7	27.6	40	50	38
7011	80	17	17.5	12	65	83	31
7013	80	13	13.4	12.3	55	69	27
1	80	6	7.4	10	45	53	20
2	80	5	7.2	15	45	53	24
3	60	5	6.8	17	45	52	25
4	80	5	6.2	9	45	52	17
5	60	5	5.5	9	45	51	16
6	60	5	5.8	5	15	18	11 4/
7	60	5	5.7	5	15	18	11 4/

1/ Time = 16 hours per day except for well 7010 which is 24 hours per day.

2/ Full basin condition; wells 1 - 7 are estimates based on other wells.

3/ Wells 1 - 7 are based on surrounding wells.

4/ From Shallow Aquifer

Table 6

Discharge /Recharge of Ground Water Basin for Pipe Irrigation System (10^6 m^3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Irrigation Requirement	-	.57	1.10	2.37	1.48	1.60	2.10	2.02	2.33	2.21	1.44	.79	18.01
Oued Medjerda 20% discharge	11.00	14.00	10.00	7.00	3.10	1.35	.40	.20	.90	1.40	1.70	6.00	57.05
Potential Recharge	2.70	3.40	2.50	1.70	.80	.30	.10	.05	.20	.35	.40	1.50	14.00
Surface Water	-	-	-	1.00	1.00	.50	-	-	-	.30	.42	.79	4.01
Ground Water	-	.57	1.10	1.37	.48	1.10	2.10	2.02	2.33	1.91	1.02	-	14.00
Discharge from Basin	-	-	-	-	-	.80	2.00	1.97	2.13	1.56	.62	-	9.08
Recharge to Basin	2.70	2.83	1.40	.33	.32	-	-	-	-	-	-	1.50	9.08
Accumulated Change in Storage	-4.88	-2.05	-0.65	-0.32	-	-0.80	-2.80	-4.77	-6.90	-8.46	-9.08	-7.58	

Table 7

Irrigation Requirements in MM

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Citrus	-	-	-	50	100	100	150	150	90	60	-	-	700
Apples	-	-	-	50	130	210	250	210	130	30	-	-	1010
Peaches, Pears	-	-	-	40	110	190	230	200	110	10	-	-	890
Artichokes	-	35	75	65	-	-	35	50	125	70	35	-	490
Winter Vegetables	-	-	-	-	-	-	-	-	-	50	50	50	150
Summer Vegetables (tomatos)	-	-	-	80	90	190	220	220	50	-	-	-	850
Berseem	-	40	50	90	-	-	-	-	90	70	40	-	380
Sugarbeets	-	-	40	70	50	-	-	-	-	50	50	40	300

Note: Irrigation Requirement = $\frac{\text{Crop Consumptive Use} - \text{Effective Rainfall}}{\text{Application Efficiency}}$

Application Efficiency = 75% for fruit trees
70% for other crops

TABLE 8

Water Requirements for Sprinkler and Pipe Distribution Systems (in 100 m^3)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Intensive Area														
Citrus	400 ha	-	-	-	200	400	400	600	600	360	240	0	-	2,800
Pears	300 ha	-	-	-	120	330	560	680	610	340	40	-	-	2,680
Apples	100 ha	-	-	-	50	130	210	250	210	130	30	-	-	1,010
Artichokes	200 ha	-	70	150	130	-	-	70	100	250	140	70	-	980
Vegetables	200 ha	-	-	-	160	180	380	440	440	100	100	100	100	2,000
Berseem	400 ha	-	160	200	300	-	-	-	-	360	280	160	-	1,520
Subtotal		-	230	350	1020	1040	1550	2040	1960	1540	830	330	100	10,990
Conveyance Loss		-	10	10	30	30	50	60	60	50	30	10	-	340
Total		-	240	360	1050	1070	1600	2100	2020	1590	860	340	100	11,330
Semi-Intensive Area														
Sugarbeet	800 ha	-	-	320	560	400	-	-	-	-	400	400	320	2,400
Berseem	800 ha	-	320	400	720	-	-	-	-	720	560	320	-	3,040
Legume	700 ha	-	-	-	-	-	-	-	-	-	350	350	350	1,050
Subtotal		-	320	720	1280	400	-	-	-	720	1310	1070	670	6,490
Conveyance Loss		-	10	20	40	10	-	-	-	20	40	30	20	190
Total		-	330	740	1320	410	-	-	-	740	1350	1100	690	6,680
Total Requirement		-	570	1100	2370	1480	1600	2100	2020	2330	2210	1440	790	18,010

TABLE 9

Aeral Listribution of Crops for Sprinkler and Pipe Distribution Systems (in hectares)

	Total	A	B	C	D_1	D_2	E
Gross Area	5800	1300	1100	1150	700	600	950
Intensive Area							
Fruit Trees	800			290			510
Artichokes	200			200			
Vegetables	200			190			10
Berseem	400			130			270
Semi-Intensive Area							
Sugarbeets	800	350	300		40	110	
Berseem	800	180	100		250	270	
Legumes	700	270	240	10	60	120	
Wheat	700	200	250	50	200		
Subtotal	4600	1000	890	870	550	500	790
Villages, R/w, etc.	1200	300	210	280	150	100	160
%	21	23	19	24	21	17	17

TABLE 10

Water Requirements for Earth Canal Distribution Systems (in 1000 m^3)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Gravity System														
Intensive Area														
Citrus	400 ha	-	-	-	200	400	400	600	600	360	140	-	-	2,800
Pears	200 ha	-	-	-	80	220	380	460	400	220	20	-	-	1,780
Apples	100 ha	-	-	-	50	120	210	250	210	130	30	-	-	1,010
Artichokes	200 ha	-	70	150	130	-	-	70	100	250	140	70	-	980
Vegetables	200 ha	-	-	-	160	180	380	440	440	100	100	100	100	2,000
Berseem	400 ha	-	160	200	360	-	-	-	-	360	280	160	-	1,520
Subtotal		-	230	350	980	930	1370	1820	1750	1420	610	330	100	10,090
Conveyance Loss		-	40	60	170	160	240	320	310	250	140	60	20	1,770
Total		-	270	410	1150	1090	1610	2140	2060	1670	950	390	120	11,860
Semi-Intensive Area														
Sugarbeet	600 ha	-	-	240	420	300	-	-	-	-	300	300	240	1,800
Berseem	600 ha	-	240	300	540	-	-	-	-	540	420	240	-	2,280
Legumes	800 ha	-	-	-	-	-	-	-	-	-	400	400	400	1,200
Wheat	900 ha		EN Sec											
Subtotal		-	240	540	960	300	-	-	-	540	1120	940	640	5,280
Convyance Loss			40	90	170	50	-	-	-	100	190	160	110	910
Total			280	630	1130	350	-	-	-	640	1310	1100	750	6,190
Total Requirement		-	550	1040	2280	1440	1610	2140	2060	2310	2260	1490	870	18,050

TABLE 11

Areal Distribution of Crops - Earth Canal Distribution System (in hectares)

	Perimeter Total	A	B	C	D_1	D_2	E
Gross Area	5800	1300	1100	1150	700	600	950
Intensive Area							
Fruit Trees	700			290			410
Artichokes	200			200			
Vegetables	200			190			10
Berseem	400			90			310
Semi-Intensive Area							
Sugarbeets	600	250	180	100	40	30	
Berseem	600	140	140		150	170	
Legumes	700	300	290		30	80	
Wheat	1000	280	220		300	200	
Subtotal	4400	970	830	870	520	480	730
Villages, R/w, etc.	1400	330	270	280	180	120	220
% of gross	24	25	25	24	26	20	23

Table 12

SPRINKLER SYSTEM

Cost Estimate in thousand dinars

Item	Total	A	B	Sector C1	C2	D1	D2	E
Primary System	3128	676	546	471	228	441	160	810
River Pump Station	572	100	85	135	0	53	49	150
High Pressure Pipelines	1507	147	338	367	89	150	177	239
Outlets and meters	97	16	17	20	5	10	8	21
Land Preparation	46	10	9	6	2	6	5	8
Surface drains	105	15	12	24	8	10	10	26
Subsurface drains	210	30	24	48	16	20	20	52
Roads	558	107	80	87	30	81	65	108
On farm sprinklers	806	130	116	161	57	72	65	205
Sub-total	7029	1231	1227	1323	435	643	559	1611
Contingencies	1054	185	184	198	65	96	84	242
Field Cost	8183	1416	1411	1521	500	739	643	1611
Design and Engineering	970	170	169	183	60	89	77	222
Total Cost	9053	1586	1580	1704	560	828	720	2075

Table 13

SPRINKLER SYSTEM

ANNUAL OPERATION AND MAINTENANCE EXPENSE

in thousand dinars

Item	Total	Sector A	B	C	D	E
Wells						
Structures	1.3	0.5	0.2	0.2	0.2	0.2
Equipment	3.4	1.2	0.6	0.6	0.6	0.4
Reservoirs	0.9	-	0.1	0.3	0.2	0.3
Primary Pipelines						
Pipe	9.1	2.7	1.2	1.0	0.6	3.6
Appurtanences	1.3	0.4	0.2	0.1	0.1	0.5
High Pressure Pipe						
Pipe	13.8	1.3	3.1	4.2	3.0	2.2
Appurtanences	1.9	0.2	0.4	0.6	0.4	0.3
Outlet & Meters	4.8	0.8	0.9	1.2	0.9	1.0
River Pump Station						
Structures	3.4	0.6	0.5	0.8	0.6	0.9
Equipment	12.3	2.1	1.8	3.0	2.2	3.2
Booster Pump Station						
Structures	3.6	0.5	0.6	1.0	0.7	0.8
Equipment	51.8	7.3	8.8	14.6	9.4	11.7
Surface drains	1.0	0.1	0.1	0.3	0.2	0.3
Roads	5.1	1.0	0.8	1.0	1.3	1.0
Transmission lines	1.1	0.3	0.1	0.3	0.2	0.2
TOTAL	114.8	19.0	19.4	29.2	20.6	26.6

Table 14

SPRINKLER SYSTEM

Replacement Costs in Thousand Dinars

Item	Life Years	Total	A	B	C	D	E
Wells							
Casing	20	79	30	24	15	5	5
Equipment	10	191	50	59	56	13	13
Pump Stations							
Equipment	20	1285	189	213	351	233	299
Pipelines							
Equipment	29	233	41	43	51	38	60
Outlets & Meters	10	97	16	17	25	18	21
Drains							
Subsurface	30	210	30	24	64	40	52
Roads							
Structures	30	57	11	8	12	15	11
Reservoirs							
Structures	30	10	0	1	3	3	3
Sprinklers	10	806	130	116	218	137	205

Table 15

PIPE DISTRIBUTION SYSTEM

COST ESTIMATE

In thousand dinars

Item	Total	A	B	C1	C2	D1	D2	E
Supply System	1902	270	262	324	102	336	197	411
River Pump Station	572	100	85	135	0	53	49	150
Primary System (pipelines)	2991	784	436	614	incl.	278	298	581
Turnouts, meters, float valves	237	21	22	63	31	18	19	63
Land levelling	974	198	196	148	30	112	110	180
Surface drains	112	17	13	26	8	10	10	28
Subsurface drains	214	30	24	48	16	20	20	56
Roads	558	107	80	87	30	81	65	108
Contingencies	1235	229	168	217	33	136	115	237
Field Cost	8695	1756	1286	1662	250	1044	883	1814
Design and Engineering	1043	210	154	200	30	126	107	216
Total Cost	9738	1966	1440	1862	280	1170	990	2030

Table 16

PIPE DISTRIBUTION SYSTEM

ANNUAL OPERATION AND MAINTENANCE COST

in thousand dinars

Item	Total	A	B	C	D	E
Wells						
Structure	1.3	0.5	0.2	0.2	0.2	0.2
Equipment	3.4	1.2	0.6	0.6	0.6	0.4
Reservoirs	2.0	0.2	0.3	0.5	0.4	0.5
Pipelines						
Pipe	35.2	7.4	4.4	7.0	8.6	7.8
Appurtenances	5.3	1.1	0.7	1.0	1.3	1.2
Turnouts, meters	4.8	0.4	0.4	1.9	0.8	1.3
River Pump Station						
Structures	3.8	0.6	0.5	0.8	0.8	1.1
Equipment	17.6	2.1	1.8	3.0	4.9	5.8
Booster Pump Station						
Structures	0.9	0.1	0.1	0.2	0.3	0.2
Equipment	6.1	1.0	0.2	1.6	2.1	1.2
Transmission lines	1.2	0.3	0.2	0.4	0.2	0.1
Surface drains	1.1	0.2	0.1	0.3	0.2	0.3
Roads	5.1	1.0	0.8	1.0	1.3	1.0
TOTAL	87.8	16.2	10.3	18.5	21.7	21.1

Table 17

PIPE DISTRIBUTION SYSTEM

Replacement Cost in Thousand Dinars

Item	Life Years	Total	A	B	C	D	E
Wells							
Casing	20	79	30	24	15	5	5
Equipment	10	177	48	54	45	15	15
Pump Stations							
Equipment	20	387	69	42	100	87	89
Pipelines							
Equipment	20	351	73	44	71	85	78
Turnouts, meters, float valves	10	237	21	22	94	37	63
Drains							
Subsurface	30	214	30	24	64	40	56
Roads							
Structures	30	57	11	8	12	15	11
Reservoirs							
Structures	30	22	3	3	5	4	7

Table 18

EARTH CANAL DISTRIBUTION SYSTEM

COST ESTIMATE

Item	Total	A	B	C1	C2	D1	D2	E
Supply System	2348	190	220	455	185	303	245	750
River Pump Station	572	100	855	135	50	539	49	150
Primary Canals	692	71	41	367	22	55	26	110
Secondary Canals	900	146	124	97	77	104	96	256
Land levelling	784	192	183	0	30	106	106	167
Surface drains	105	15	12	24	8	10	10	26
Subsurface drains	200	30	24	48	16	20	20	52
Roads	558	107	80	87	30	81	65	108
Sub-total	6169	851	769	1213	368	732	617	1619
Contigencies	936	128	116	192	55	110	92	243
Field Cost	7105	979	885	1405	423	842	709	1862
Design and Engineering	849	117	106	167	50	101	185	223
Total Cost	7954	1096	991	1552	473	943	794	2085

TABLE 19

Earth Canal Distribution System

Annual Operation/Maintenance Cost (D1000)

Wells	Total	A	B	C	D	E
Structure	2.3	1.2	0.6	0.2	0.2	0.1
Equipment	8.8	4.8	2.4	0.6	0.6	0.4
Reservoirs	1.4	0.7	0.2	0	0.3	0.2
Primary System						
Pipe	12.5	2.9	1.2	1.6	2.8	4.0
Appurtenances	2.2	0.5	0.2	0.3	0.5	0.7
Secondary System						
Canals	8.2	1.0	0.6	4.0	1.1	1.5
Appurtenances	1.2	0.1	0.1	0.7	0.1	0.2
Tertiary System						
Canals	11.7	2.0	1.6	2.0	2.7	3.4
Appurtenances	1.4	0.2	0.2	0.3	0.3	0.4
River Pump Station						
Civil works	3.4	0.6	0.5	0.8	0.6	0.9
Equipment	12.3	2.1	1.8	3.0	2.2	3.2
Transmission lines	1.1	0.3	0.1	0.3	0.2	0.2
Surface drains	1.1	0.2	0.1	0.3	0.2	0.3
Roads						
Roads	5.1	1.0	0.8	1.0	1.3	1.0
Booster Pumps						
Civil works	0.3			0.3		
Equipment	3.5			3.5		
Total	76.5	17.6	10.4	18.9	13.1	16.5

TABLE 20

Earth Canal Distribution

Replacement Cost (in thousand Dinars)

Wells	Life Years	Total	A	B	C	D	E
Casing	20	79	11	15	25	13	15
Equipment	10	181	15	30	70	29	37
Pump Stations							
Equipment	20	492	43	37	158	122	132
Pipelines							
Equipment	20	151	6	9	60	30	46
Earth Canals							
Appurtenances	20	123	22	16	20	28	37
Drains							
Subsurface	30	210	30	24	64	40	52
Roads							
Structures	30	57	11	8	12	15	11
Reservoirs							
Structures	30	29	4	2	9	6	8

TABLE 21

Combination Sprinkler and Pipe Distribution System

Cost Estimate

Item	Total	Sector A	B	C_1	C_2	D_1	D_2	E
Supply System	2,053	270	262	475	102	336	197	411
River Pump Station	572	100	85	135	0-	53	49	150
Primary System, Pipelines	2,744	784	436	367	incl.	278	298	581
Turnouts, Meters, Outlets	194	21	22	20	31	18	19	63
Land Levelling	832	198	196	6	30	112	110	180
Surface Drains	112	17	13	26	8	10	10	28
Subsurface Drains	214	30	24	48	16	20	20	56
Roads	558	107	80	87	30	81	65	108
Contingencies	1,088	229	168	170	33	136	115	237
Field Cost	8,367	1756	1286	1334	250	1044	883	1814
Design and Engineering	1,005	210	154	162	30	126	107	216
Total Cost	9,372	1966	1440	1496	280	1170	990	2030

TABLE 22

Combination Sprinkler and Pipe Distribution System

Annual Operation and Maintenance (Thousand Dinars)

Item	Total	Sector A	B	C	D	E
Wells						
Structures	1.3	0.5	0.2	0.2	0.2	0.2
Equipment	3.4	1.2	0.6	0.6	0.6	0.4
Reservoirs						
Structures	1.7	0.2	0.3	0.3	0.4	0.5
Pipelines						
Pipe	32.8	7.4	4.4	5.2	8.6	7.2
Appurtenances	5.0	1.1	0.7	0.7	1.3	1.2
Turnouts, meters, outlets						
Equipment	4.1	0.4	0.4	1.2	0.8	1.3
River Pump Station						
Structures	3.8	0.6	0.5	0.8	0.8	1.1
Equipment	17.6	2.1	1.8	3.0	4.9	5.8
Booster Pump Station						
Structures	1.7	0.1	0.1	1.0	0.3	0.2
Equipment	19.1	1.0	0.2	14.6	2.1	1.2
Transmission Lines						
Structures	1.2	0.3	0.2	0.4	0.2	0.1
Surface Drains						
Drains & structures	1.1	0.2	0.1	0.3	0.2	0.3
Roads						
Roads & Bridges	5.1	1.0	0.8	1.0	1.3	1.0
Total	97.9	16.1	10.3	29.3	21.7	20.5

TABLE 23

Combination Sprinkler and Pipe Distribution System

Replacement Costs (in thousand Dinars)

Item	Life Years	Total	Sector A	B	C	D	E
Wells							
Casing	20	79	30	24	15	5	5
Equipment	10	191	50	59	56	13	13
Pump Stations							
Equipment	20	653	65	50	351	85	101
Pipelines							
Equipment	20	331	73	44	51	85	78
Turnouts, meters, Outlets							
Equipment	10	168	21	22	25	37	63
Drains							
Subsurface drains	30	214	30	24	64	40	56
Roads							
Structures	30	57	11	8	12	15	11
Reservoirs							
Structures	30	20	3	3	3	4	7

Table 24

Market Prices for Agricultural Production

CROP	PRICE IN D/TON
Wheat - Hard	66 1/
- Soft	60
Barley	45
Sugarbeets	12 2/
Tobacco	358 3/
Sunflower	350 4/
Vetch/ Oats	35
Alfalfa	10
Berseem	10
Horse Beans	185
Chickpeas	100
Artichokes	53
Tomato	24
Pepper	150
Potato	86
Melon	79
Watermelon	40
Olives	70
Oranges	80
Apples, Pears	150

1/ Government Office of Cereals
2/ At Beja; transportation costs included in cost of production
3/ Government Tobacco Office
4/ Government Office of Oils

TABLE 25
CROP YIELDS

CROP	YIELD PER HECTARE IN TONS		
	Present	Future	
		Without Project	With Project
Oranges	36	39	40
Apples, Pears	20	26	30
Artichokes	-	-	25
Tomato	20	22	30
Pepper	6	7	10
Early Potato	11	15	18
Late Potato	7	8	10
Melon	8	10	12
Watermelon	10	15	20
Green beans	1.5	2	3
Summer Onions	20	22	25
Winter Onions	12	13	15
Radishes	2.5	3	3
Green Peas	2.5	2.6	3
Turnips	5	6	8
Carrots	5	8	10
Cauliflower	20	25	30
Sugarbeets	-	-	38
Tobacco	1	1.5	2.8
Sunflower	1.5	2	2.5
Berseem	40	75	82
Alfalfa	42	60	84
Vetch/Oats	7.5	9	12
Corn Forage	70	90	100
Sorzo Forage	60	70	85
Horse Beans	25	28	34
Hard Wheat	0.9	1.2	3.5
Soft Wheat	1.0	1.5	4
Barley	1.1	1.5	4
Chickpeas	0.6	0.7	1

Table 26

Crop Production Costs
In Dinars per Hectare

CROP	PRESENT	FUTURE With Project	FUTURE Without Project
Wheat	40	50	80
Barley	40	50	60
Vetch/Oats	81	90	100
Chickpeas	73	73	90
Legumes 1/	97	108	120
Industrial Crops 2/	162	180	200
Forage 3/	65	72	80
Truck Crops 4/	162 5/	180 5/	300
Fruit Trees 6/	146	162	180
Sugarbeets	-	-	210
Artichokes	-	-	320
Berseem	65	72	80

1/ Based on horse beans
2/ Based on tobacco
3/ Based on berseem
4/ Based on tomatoes and Watermelon plus Winter Beans
5/ Excludes winter vegetable crop
6/ Based on Pears

Table 27

Seed and Plant Costs

Crop	Quantity Required per hectare	Cost in Dinars per unit
Hard Wheat	1.2 q	8.5
Soft Wheat	1.2 q	7.6
Barley	1.5 q	4.6
Sugarbeet	.12 q	60.0
Tobacco	31,250 plants	no charge
Vetch/Oats	1 q	11.0
Sunflower	0.1	35
Berseem	0.2	50
Horse beans	0.8	21
Chickpeas	0.8 q	15
Artichokes	12,000 plants	0.037
Tomatoes	15,000 plants	0.0015
Peppers	15,000 plants	0.003
Pears	1,250 plants	0.35
Watermelon	0.04	650

Table 28

Official Prices for Fertilizer and Pesticides

(in dinars)

Item	Unit	Cost	Export Price	Import Price
Ammonium Nitrate	q	5.3		9.8 (1974) 2/
Superphosphate 45%	q	3.6	8.0 (1974) 1/ 10.9 (1975)	
Superphosphate 16%	q	1.9		
Potash	q	3.3		5.1 (1974) 3/
Potassium Sulphate	q	11.5		
Manure	T	1.05		
Aldrex	kg	0.3		
Phosdrine	litre	2.4		
Parathion 1%	kg	0.12		
Dithane 45	kg	1.7		
2 - 4 - D	kg	0.78		
Tiphon	kg	0.18		
Pelt 44	kg	1.2		
Karatane	kg	0.15		

1/ Price for phosphate fertilizer

2/ Price for nitrogen fertilizer

3/ Price for potash

Table 29

Contract Rates for Agricultural Operations

Operation	Rate in Dinars per hectare 1/
Plowing	4.0
Disking	3.0
Spread Fertilizer	2.0
Harrowing	3.0
Seeding	2.0
Rolling	2.0
Furrowing	1.5
Cutting (green forage)	2.0
Baling	100 millimes per bale

1/ Includes machine and operator

	COCEMO Rates in Dinars per hour
Tractor with Plow	1.8
with Disc	1.7
with Seed Drill	1.8
Combine	6.0
Corn Picker	10.0

TABLE 30

CASH FLOW FOR RECOMMENDED IRRIGATION SYSTEM (in 1000 D)

YEAR	COSTS					FUTURE BENEFITS BY SECTOR					PRESENT BENEFITS	NET 1/ BENEFIT	CASH FLOW
	Capital Cost	O,M & R	Energy Costs	Extension Costs	Total Cost	A	B	C	D	E			
1	1295	-	-	-	1295	-	96*	70*	55*	1*	310	(88)	(1383)
2	1594	8	2	10	1614	40	-	75*	55*	1*	321	(150)	(1764)
3	1625	21	6	20	1672	130	30	-	56*	1*	335	(118)	(1790)
4	1997	38	15	30	2080	190	100	(158)	-	2*	351	(217)	(2297)
5	2050	61	23	40	2174	260	150	145	50	-	365	240	(1934)
6	669	77	34	50	830	326	200	245	200	(250)	381	721	(109)
7		88	39	50	177	"	246	490	290	12	395	969	792
8		88	41	50	179	"	"	716	390	52	411	1319	1140
9		88	"	"	179	"	"	857	481	272	428	1754	1575
10		88	"	"	179	"	"	1142	"	460	443	2212	2033
11		152	"	"	243	"	"	1283	"	635	460	2511	2268
12		159	"	"	250	"	"	"	"	989	474	2851	2601
13		161	"	"	252	"	"	"	"	1164	491	3009	2757
14		138	"	"	229	"	"	"	"	"	506	2994	2765
15		164	"	"	255	"	"	"	"	"	522	2978	2723
16		88	"	"	179	"	"	"	"	"	539	2961	2782
17		88	"	"	179	"	"	"	"	"	554	2946	2767
18		88	"	"	179	"	"	"	"	"	568	2932	2753
19		88	"	"	179	"	"	"	"	"	583	2917	2738
20		88	"	"	179	"	"	"	"	"	594	2906	2727
21		310	"	"	401	"	"	"	"	"	"	"	2505
22		261	"	"	352	"	"	"	"	"	"	"	2554
23		466	"	"	557	"	"	"	"	"	"	"	2549
24		288	"	"	379	"	"	"	"	"	"	"	2527
25		319	"	"	410	"	"	"	"	"	"	"	2496

( ) = negative value
* Present Benefits
1/ Future Benefits less Present Benefits

TABLE 3C (continued)

CASH FLOW FOR RECOMMENDED IRRIGATION SYSTEM (in 1000 D)

YEAR	Capital Cost	O,M & R	Energy Costs	Extension Costs	Total Cost	FUTURE BENEFITS BY SECTOR A	B	C	D	E	PRESENT BENEFITS	NET BENEFIT	CASH FLOW
26-30		88	41	50	179	326	246	1283	481	1164	594	2906	2727
31		196	"	"	287	"	"	"	"	"	"	"	2619
32		194	"	"	285	"	"	"	"	"	"	"	2621
33		230	"	"	321	"	"	"	"	"	"	"	2585
34		197	"	"	288	"	"	"	"	"	"	"	2618
35		233	"	"	329	"	"	"	"	"	"	"	2577
36-40		88	"	"	179	"	"	"	"	"	"	"	2727
41		310	"	"	401	"	"	"	"	"	"	"	2505
42		261	"	"	352	"	"	"	"	"	"	"	2554
43		466	"	"	557	"	"	"	"	"	"	"	2549
44		288	"	"	379	"	"	"	"	"	"	"	2527
45		319	"	"	410	"	"	"	"	"	"	"	2496
46-50		88	"	"	179	"	"	"	"	"	"	"	2727

TABLE 31

Farm Plan for Financial Analysis

Farm Plan	Sector	Crop	Area in Hectares
1	C, E	Fruit trees	1.25
2	A	Sugarbeets	1.75
		Berseem	0.9
		Legumes	1.35
		Wheat	1.00
			5.00
3	B	Sugarbeets	1.7
		Berseem	0.6
		Legumes	1.3
		Wheat	1.4
			5.0
4	D	Sugarbeets	0.7
		Berseem	2.5
		Legume	0.8
		Wheat	1.0
			5.0
5	C	Artichoke	0.49
		Vegetable	0.45
		Berseem	0.31
			1.25
5a	C	Legumes	1.0
		Wheat	5.0
			6.0
6	E	Vegetable	0.1
		Berseem	1.9
			2.0

TABLE 32

Returns Available for Repayment of Project Costs

Farm Plan	Farm Size Ha.	Sector	Gross Return Dinars	Cost Dinars	Net Return Dinars	Net Return Dinars/Ha.
Orchard						
1	1.25	C, E	3,750	1,029	2,721	2,176
2	5.0	A	2,617	1,503	1,114	223
3	5.0	B	2,409	1,491	918	184
4	5.0	D	3,104	1,348	1,756	351
5	1.25	C	1,578	1,068	510	408
5a	6.0	C	1,789	1,289	499	83
6	2.0	E	1,708	963	745	372

TABLE 33

Cash Flow for the Financial Analysis (in 1000 Dirars)

Year	Capital Cost	Replace-ment Cost	Extension Cost	Total Cost	Net Returns A	B	C	D	E	Total	Cash Flow
1	1311		-	1311	-					-	(1311)
2	1615		10	1625	-	-				-	(1625)
3	1664		20	1684	28	-	-			28	(1656)
4	2032		30	2062	66	14	-	-		80	(1982)
5	2073		40	2113	144	41	-	-	-	185	(1928)
6	677		50	727	172	100	27	69	-	368	(359)
7			50	50	172	117	183	137	-	609	559
8			50	50	172	117	218	258	26	791	741
9			50	50	172	117	309	321	155	1074	1024
10			50	50	172	117	595	321	104	1309	1259
11		69	50	119	172	117	731	321	217	1558	1439
12		76	50	126	172	117	731	321	572	1913	1787
13		139	50	189	172	117	731	321	740	2081	1892
14		52	50	102	172	117	731	321	740	2081	1979
15		78	50	128	172	117	731	321	740	2081	1953
16			50	50	223	117	731	321	740	2132	2082
17			50	50	223	163	731	321	740	2178	2128
18			50	50	223	163	845	321	740	2292	2272
19			50	50	223	163	845	369	740	2340	2290
20			50	50	223	163	845	369	888	2488	2438
21		241	50	291	223	163	845	369	888	2488	2197
22		186	50	236	223	163	845	369	888	2488	2252
23		325	50	375	223	163	845	369	888	2488	2113
24		229	50	279	223	163	845	369	888	2488	2209
25		250	50	300	223	163	845	369	888	2488	2188
26-30			50	50	223	163	845	369	888	2488	2438
31		113	50	163	223	163	845	369	888	2488	2325
32		111	50	161	223	163	845	369	888	2488	2327

TABLE 33 (continued)

Cash Flow for the Financial Analysis (in 1000 Dinars)

Year	Capital Cost	Replace-ment Cost	Extension Cost	Total Cost	A	B	C	D	E	Total	Cash Flow
33	220	220	50	270	223	163	845	369	888	2488	2218
34		111	50	161	223	163	845	369	888	2488	2327
35		152	50	202	223	163	845	369	888	2488	2286
36-40			50	50	223	163	845	369	888	2488	2438
41		241	50	291	223	163	845	369	888	2488	2197
42		186	50	236	223	163	845	369	888	2488	2252
43		325	50	375	223	163	845	369	888	2488	2113
44		229	50	279	223	163	845	369	888	2488	2209
45		250	50	300	223	163	845	369	888	2488	2188
46-50			50	50	223	163	845	369	888	2488	2438

( ) negative cash flow

PLATE 6

Earth Canal Distribution System

Construction Schedule

Item	Const. Cost	Years after start of construction							Future Years
		-1	1	2	3	4	5	6	
Tranche A	1 297		885	412					
Tranche B	791			545	246				
Tranche C	1 463				1018	445			
Tranche D	1 288					885	403		
Tranche E	1 484						1 024	460	
River Pump Station	572				359	222			
Subsurface Drains	210								210
Design & Engineering	849	100	130	150	150	140	130	49	
Total Cost	7 954	100	1 015	1 107	1 764	1 692	1 557	509	210

Costs in 1000 Dinars.

PLATE 7

Earth Canal Distribution System

Schedule of Construction Activities

Activity	Quantity	Years after start of construction							Future Years
		-1	1	2	3	4	5	6	
Design and Engineering									
Roads and Surface drains	470 km								
Drill Wells	7 ea								
Equip. Wells	19 ea								
Pumping Plants	6 ea								
Pipelines	40 km								
Reservoirs	6 ea								
Primary canals	57 km								
Secondary canals	3 850 ha								
Land levelling	3 850 ha								
Transmission lines	28 km								
Subsurface drains	4 400 ha								

PLATE 8

Combination Sprinkler-Pipe Distribution System

Contractor Schedule

Item	Const. Cost	Years after start of sonstruction							Future Years
		-1	1	2	3	4	5	6	
Tranche A	1626		1084	542					
Tranche B	1177			785	392				
Tranche C	1385				923	462			
Tranche D	1785					1190	595		
Tranche E	1608						1072	536	
River Pump Station	572				382	190			
Subsurface Drains	214								214
Design and Engineering	1005	100	160	175	170	160	160	80	
Total Cost	9372	100	1244	1884	1675	1812	1827	616	214

Note: Costs in 1000 Dinars.

PLATE 9

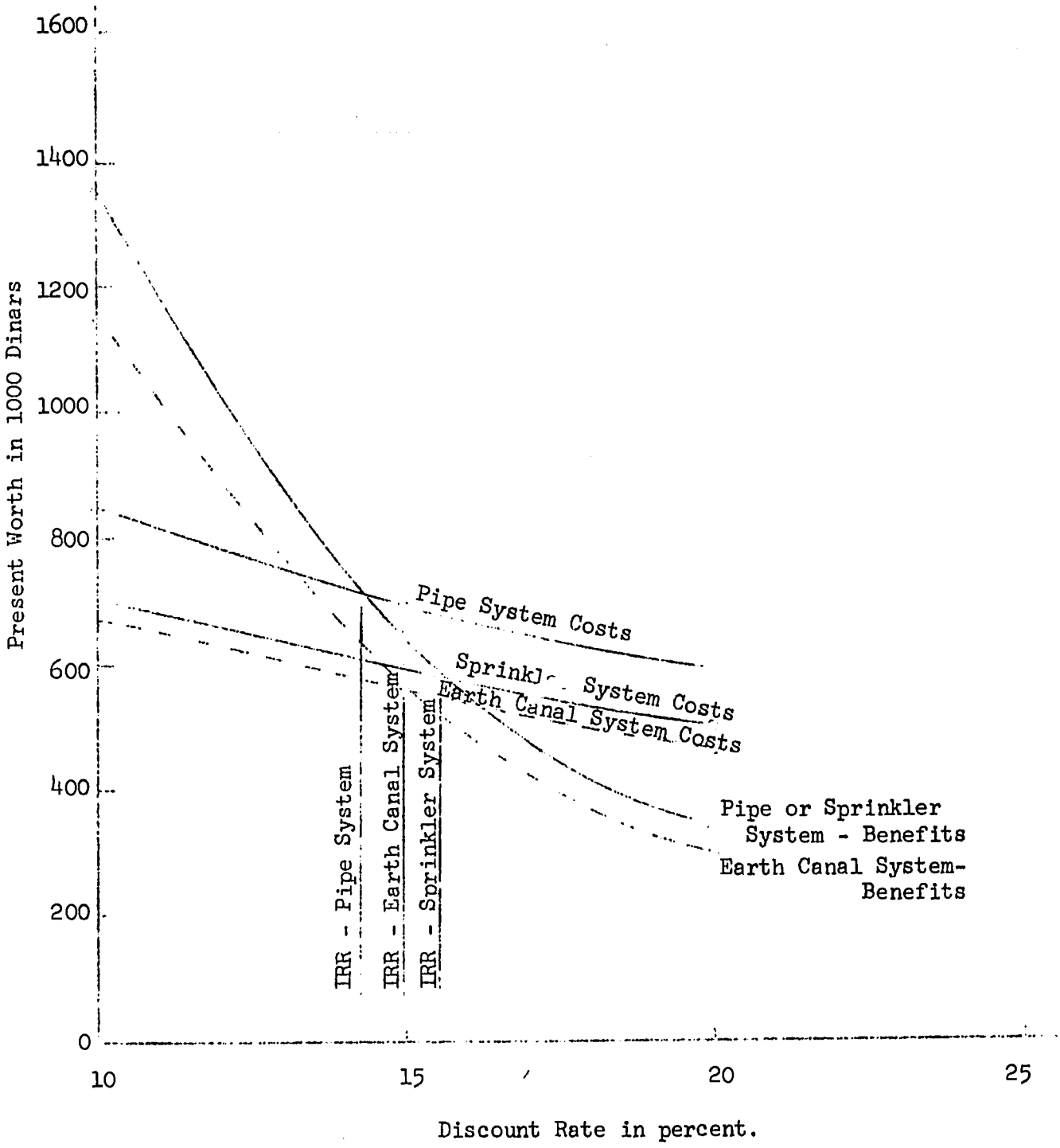
Combination Sprinkler-Pipe Distribution System

Schedule of Construction Activities

Activity	Quantity	Years after start of construction							Future Years
		-1	1	2	3	4	5	6	
Design and Engineering	-								
Roads and Surface Drains	470 km								
Drill Wells	7 ea								
Equip. Wells	19 ea								
Pumping Plants	9 ea								
Pipelines	250								
Reservoirs	30 ea								
Transmission Lines	28 km								
Subsurface Drains	4600 ha								

PLATE 10

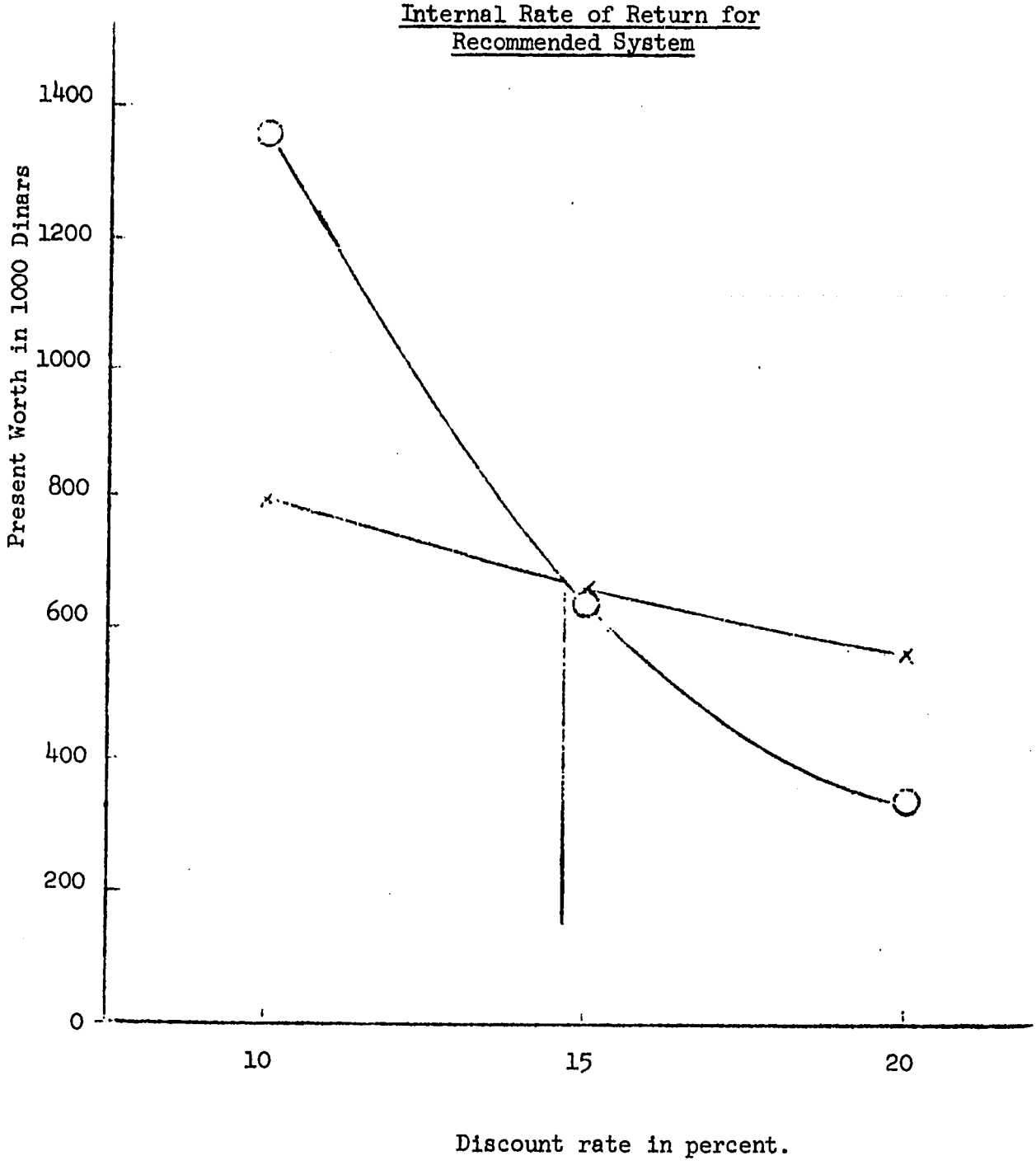
Economic Selection of Irrigation System



Note: 5-year development period in each sector.

PLATE 11

Internal Rate of Return for Recommended System



Note: 5-year development period for each sector

B/C at 10 % = 1.7