AG:DP/JOR/71/525
Terminal Report

DEVELOPMENT AND USE OF GROUNDWATER RESOURCES OF EAST JORDAN

JORDAN

PROJECT FINDINGS AND RECOMMENDATIONS

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS ROME, 1975

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DEVELOPMENT AND USE OF GROUNDWATER RESOURCES OF EAST JORDAN

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Report prepared for
the Government of Jordan
by
the Food and Agriculture Organization of the United Nations
acting as executing agency for
the United Nations Development Programme

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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1. INTRODUCTION

1.1 PROJECT BACKGROUND

The basic agricultural problem in Jordan is the shortage of rain-fed arable land which is a result of the rainfall pattern. More than 90 percent of the area receives a mean annual rainfall of less than 200 mm which is insufficient for high agricultural production. Thus, irrigation is the only method for agricultural development of most of the arable land and within the project area groundwater is the most reliable water resource.

The hydrogeology of East Jordan was studied under phase I of the present project, 'Investigation of the Sandstone Aquifers of East Jordan' - JOR/9 (FAO 1969, 1970). The studies indicated the Amman-Wadi Sir aquifer system as the most important groundwater resource of East Jordan. A large part of this resource is as yet unexploited and there is much scope for new development for irrigation.

Before the termination of the JOR/9 project the Government submitted a request to the United Nations Development Programme (UNDP) for further assistance in the development and use for irrigation of the identified groundwater resources. The request was approved at the Eleventh (14-29 January 1971) session of the UNDP Governing Council and the phase II project, entitled Development and Use of Groundwater Resources of East Jordan (JOR/71/525), was set up. The Food and Agriculture Organization of the United Nations (FAO) was appointed as the executing agency for UNDP, while the Natural Resources Authority (NRA) was designated as the cooperating agency for the Government.

The Project Document (phase II) was signed on behalf of the Government of Jordan, the United Nations Development Programme and the Food and Agriculture Organization of the United Nations on 30 December 1971.

The total financial arrangements amounted originally to a UNDP contribution of US$ 613 400 and a government contribution in kind of JD 93 661 plus the equivalent of US$ 53 000 towards local UNDP costs 1/.

1/ US$ 1 = JD 0.316 as at 1.11.74.

1.2 OBJECTIVES

The broad objective of the project (phase II) was to assist the Government in the development of the groundwater and land resources which had been identified by the JOR/9 project (phase I). More specifically, the terms of reference called for:

(a) testing of aquifers in order to check the estimates of quantities of groundwater available under production pumping conditions in the pilot development areas;

(b) evaluating the land resources for future development and finding the appropriate solutions for specific soil reclamation problems (leaching of saline soils, correction of alkaline soils, establishment of good drainage conditions);

(c) carrying out agronomic studies and experimentation to determine the most suitable cropping pattern, plant varieties and agricultural practices;

(d) testing of different methods of irrigation in the pilot development areas, and experimentation on plant water requirement and irrigation principles in order to assure the best use of the limited and expensive water available;

(e) preparing of preliminary and final designs of irrigation schemes in new development areas;

(f) supervising the construction and operation of irrigation schemes which might be implemented during the period of the project;

(g) carrying out agro-economic studies on farmers' price/cost incentives for the recommended cropping pattern and varieties, availability of production equipment and inputs, credit, potential markets and marketing facilities;

(h) training of farmers in modern methods and techniques of irrigated agriculture;

(i) preparing of feasibility reports suitable for loan application to international financing institutions;

(j) coordinating the actions of the various agencies concerned with the development of irrigated agriculture in the project area;

(k) preparing an overall Government Plan for large-scale development of land and water resources in East Jordan.

1.3 IMPLEMENTATION

1.3.1 General administration

The project became operational on 16 January 1972 - although preliminary operations had started on 21 January 1971 with the arrival of the Project Manager - and activities were completed on 30 June 1974. Project headquarters was established at Amman. The international staff recruited by FAO and the counterpart staff are listed in Appendix 1. Appendix 2 gives details of fellowships and in-service training, while Appendix 3 lists the equipment supplied.

It was originally planned that the project would last for three years, that is until the end of 1974.

1.3.2 Organization and results

Upon request of the Government, a UNDP/FAO Review Mission visited the project in April 1973. The Mission recommended that 'most of the activities of the present phase of the project should be progressively transferred to the Government in such a way that by January 1974 UNDP/FAO assistance to the basic investigations would be mainly advisory services and guidance'.

Following the above recommendation, the programme was adjusted for termination of field activities by the end of December 1973. As a result of the shortening of the duration of the project, the objectives were not met in all respects and there were changes in emphasis. Thus, most of the agronomic, soil reclamation, irrigation and water requirements field trials were not completed due to the limited time and the project was not always able to use field data in the design of irrigation schemes and in the preparation of the overall irrigation plan. The supervision of the construction of new irrigation schemes was limited to one scheme which was the only one implemented during the life of the project.

The project made considerable efforts to train counterpart staff in all its activities but again the time available was not sufficient for completion of this training.

The project was, however, able to attain all its objectives in the design of irrigation schemes, in agro-economic studies, and in the preparation of feasibility reports suitable for loan application.

These activities culminated in the major achievement of the project - the preparation of the Medium Term Plan for Development of Groundwater Irrigation in East Jordan. In fact, all investigations and studies over the period since 1965 when the first phase started were aimed to produce such a plan which lays the basis for overall irrigation development in East Jordan.

1.3.3 Reports

In the time available it was possible to prepare two Technical Reports only for formal transmission to the Government: Agronomic Experimental Studies and Development of Crop Production (No.1); and Medium Term Plan for Development of Groundwater Irrigation in East Jordan (No.2).

Seven Technical Papers were prepared and were handed informally to the Government. Seventeen Working Papers were produced for internal use of the project staff. All these papers record detailed technical data and provide training material for counterpart staff. In addition, consultants' reports in specialized fields were transmitted to the Government.

Appendix 4 gives a complete list of documentation.

2. FINDINGS, RESULTS AND CONCLUSIONS

2.1 GROUNDWATER MANAGEMENT

2.1.1 General

The work of groundwater management was carried out by the Hydrology Section of the NRA, and a hydrogeologist of this agency was assigned to the project as liaison officer. The programme was prepared and its implementation supervised by the project. The data collection consisted of monitoring of water levels, recording water withdrawals and systematic water quality sampling in areas where groundwater was exploited.

The Electric-Analog Model of the Amman-Wadi Sir aquifer in the Shaubak-Ras en Naqb area which was initiated during phase I, was completed (Appendix 4 (33)). Three digital models were constructed and operated for the Wadi Dhuleil, Qatrana and 'Azraq areas (Appendix 4, (41-44)). An appraisal of the aquifer response to production pumping was made and a water availability map of the Amman-Wadi Sir system was prepared (Map 1).

2.1.2 Hydrogeology of the Amman-Wadi Sir Aquifer system

Under phase 1 (JOR/9), ten aquifer systems were recognized, their spatial distribution defined and their potential for development assessed. Studies showed the Amman-Wadi Sir system as the most important groundwater resource of East Jordan in terms of recharge, reservoir capacity and quantity of water that is economically available for irrigated agriculture. A large part of this water resource is as yet unexploited and there is much scope for new development for irrigation (FAO 1969, 1970).

The Amman-Wadi Sir aquifer system outcrops in an extensive area of the Highlands, on the western edge of the Plateau, and along the top of the Ras en Naqb escarpment. It is present at depth beneath much of the Plateau and extends beneath the basalts of the Dhuleil-Mafraq area. The system is confined in large areas of the Plateau and in some parts of the Highlands.

Carbonate rocks, principally limestone and dolomite, are the predominant aquifer material. Silicified limestone, joined chert, sandstone and sand are also present. The system becomes increasingly sandy south-eastwards into the Jafr basin.

The maximum recorded thickness of the system is about 350 m in the Azraq basin. In the Highlands and the western part of the Plateau the total thickness ranges from 200 to 250 m, but this may be locally reduced by erosion in the outcrop area. There is a marked thinning of the system eastwards towards Bayir. Saturated thicknesses range from the total thickness in area where the system is artesian to nil at the edge of saturation in some parts of the Highlands.

Much of the outcrop in the Highlands is in areas of relatively high rainfall, whereas outcrop areas on the Plateau are located in areas of low rainfall. In most of the Plateau and in some parts of the Highlands the system is overlain by sediments of low permeability which essentially prevent recharge by vertical percolation.

The main source of recharge is rainfall on the outcrop area. Some water is transferred to the system from the basalt aquifer of the Dhuleil-Mafraq area. The contribution from this source probably totals 20 to 30 MCM/annum. The mean annual recharge to the system is estimated at 350 MCM/annum but the quantity of recharge is extremely variable from year to year. However, the reservoir capacity of the system is so large that inter-annual variations in the quantity of recharge do not normally cause marked water level changes. About two-thirds of the recharge appears as springs and base flows in wadis which drain to the Jordan Valley or directly to the Dead Sea. The balance discharges eastwards or westwards as sub-surface flow. It is estimated that about 90 percent of the total recharge discharges westwards to the Jordan rift and essentially all this water forms part of the balance of the Dead Sea basin.

The distribution of mean annual recharge has been estimated according to the main recharge areas. These correspond to the major mountain blocks of the Highlands with the one exception of the recharge contributed by sub-surface flow from the basalt aquifer of the Dhuleil-Mafraq area. Table 1 shows the estimated quantities of recharge, as well as the estimated amount of water flowing from each area to the Dead Sea basin.

Table 1

ESTIMATED RECHARGE DISTRIBUTION OF THE AMMAN-WADI SIR AQUIFER SYSTEM

Recharge area	Average annual recharge (MCM)	Discharge to Dead Sea basin (MCM)
Ajlun	110	110
Amman	78	72
Mazar	84	84
Tafila	23	17
Shaubak-Ras en Naqb	18	2
Underflow from Dhuleil-Mafraq area	30	30
TOTAL	343	315

The reservoir capacity of the system cannot be estimated with any degree of accuracy. Nevertheless, the dead storage obviously represents an immense quantity of water which could support a policy of long-term depletion on a relatively large scale.

Distribution of permeability within the system ranges from less than 0.01 to more than 100 m/day. In general, low permeability zones occur near the crests of the recharge mounds and there is an increase in permeability down the gradient. High permeability zones are normally present in areas of groundwater flow convergence. Transmissivity is a function of permeability and of aquifer thickness and the latter is extremely variable in the structurally complex and highly eroded area in the Highlands.

The total salinity of the water ranges from 300 to over 2 500 ppm. In the areas west of a line from Mafraq to Ma'an, the concentration of dissolved solids rarely exceeds 1 000 ppm and is usually considerably less. In general, these waters can be used for irrigation of the available suitable soils. They present a low sodium hazard and a medium to high salinity hazard according to US Salinity Laboratory standards. The total dissolved solids exceed 1 000 ppm in large parts of the Azraq and Jafr basins.

2.1.3 Present water use

Spring discharges and the base flows in the rift side wadis which are maintained by groundwater from the Amman-Wadi Sir system have been traditionally utilized, mainly for irrigation. However, most of this water emerges at too low an elevation to be mobilized for use in the Highlands or on the Plateau.

Several of the major discharges to the Jordan Valley have now been regulated by storage structures. These include the dams on the Wadis Ziglab, Shueib and Kafrein. A storage structure is under construction on the Wadi Zerqa. Work on a major storage structure on the Yarmouk River has been suspended since 1967 due to the political situation. A plan to divert base flow from the Wadi Mujib to the southern Ghors is under consideration for financing and some studies have been made for regulation of the Wadi Hasa. All this water is being or will be used in the rift zone of the Dead Sea basin.

Only a small proportion of the water resource of the Amman-Wadi Sir system is presently used within the Highlands and Plateau. Gross extraction by pumping probably does not exceed 70 MCM/annum and net extraction could be about half that amount. Most of the pumping from the system is concentrated in the Amman-Zerqa Valley and in the Wadi Dhuleil area.

Current gross extraction from the system in the Amman-Zerqa Valley totals about 30 MCM/annum. The net extraction is probably less than 15 MCM/annum, but return flows from domestic, industrial and agricultural uses cause deterioration in the quality of the water. Most of the water extracted is used for domestic supplies and the balance for agriculture and small industries. Demands for irrigation are not expected to increase due to land limitations and Government controls on new extraction. On the other hand, a large population is concentrated in the valley and there is an increasing demand for domestic and industrial supplies. The water pumped for Amman is about 18 MCM/annum of which about 13 MCM/annum is extracted from the Amman-Wadi Sir system. The forecast requirement for Amman by the year 2002 is 84 MCM/annum which exceeds the total rechargeable resource in the area between the Wadis Zerqa and Mujib.

Gross withdrawals from the system in 1972 in the Wadi Dhuleil area totalled about 22 MCM. Net extraction is estimated to have been 16 MCM. Approximately 2 MCM were exported from the area to supply the Irbid pipeline which provides domestic water to the northern districts. The balance was used for agriculture. Gross extraction increased by about 15 percent in 1973. A model study has shown that the 1972 rate of pumping probably exceeded the safe yield in this area and that the net long-term extraction should not exceed 10-12 MCM/annum (see Appendix 4 (41, 44)).

Several wells in the vicinity of Sama in the upper Yarmouk Valley to the north of Mafraq are pumped for irrigation. Gross extraction is of the order of 1 to 2 MCM/annum. Small irrigation developments near Karak and Shaubak in the Highlands and at Qatrana, Abyad, Tell Burma and Arja which have been constructed or are being implemented, demand a gross extraction of about 7 MCM/annum. There is a limited demand for the Hasa phosphate industry. The balance of the extraction by pumping is mainly for domestic supplies and does not exceed 3 MCM/annum.

2.1.4 Water availability for irrigation

2.1.4.1 General discussion

The Ajlun-Irbid area receives an average annual recharge of about 110 MCM but water levels generally exceed 200 m below surface. Since the maximum economic pumping depth for irrigated field crops cannot exceed 150 m, even with high discharges, little of this water can be economically intercepted within the area.

Water discharges from the basal aquifer to the Amman-Wadi Sir system in the upper Yarmouk Valley. Acceptable pumping levels and well yields are associated with good soils in the vicinity of Sama to the north of Mafraq. The area of relatively shallow water level is, however, limited by the topography. Some irrigation from wells has already been started by the private sector in this area and public investment does not appear justified.

As present extraction in the Wadi Dhuleil area probably exceeds the safe yield, additional development of irrigation cannot be recommended in this area.

The average annual recharge to the system in the Madaba-Amman-Zerqa area is about 78 MCM. About 35 MCM flow northwards through the Amman-Zerqa Valley to the upper Wadi Zerqa and an equal amount flows southwards to the Wadis Zerqa Main and Mujib. Some 2 MCM discharge westward to the Wadi Sir springs and about 6 MCM flow eastward to the Azraq basin. The spring discharge at Wadi Sir is fully utilized for domestic supplies and irrigation. Net pumpage in the Amman Zerqa Valley totals about 15 MCM/annum but most of this is probably replaced by induced recharge from storm run-off. Little of the water flowing south to the Mujib basin or east to the Azraq basin is used. Nevertheless, in view of the forecast demand for Amman, it is considered that all the available groundwater of the Madaba-Amman Zerqa area should be reserved for future domestic supplies in the area. Additional development of irrigated agriculture cannot be recommended.

A water availability map (Map 1) was prepared for the area underlain by the Amman-Wadi Sir system to the south of Amman-Azraq. The map delimits areas where certain characteristics of the system such as depth to water level, well productivity, well construction cost and water quality could be limiting. It indicates the distribution of recharge as a guide to the quantity of water which might be extracted on a safe yield basis. The map is not a substitute for detailed hydrogeological appraisal of any particular area, nor does it relate the availability of water to land.

2.1.4.2 Constraints on development

It would appear that the areas of potential development are located to the south of a line Mujib-Azraq. The rechargeable resources in this region are about 125 MCM/annum and the reservoir capacity is very large. However, there are several constraints on the development of this water. In fact, assuming that suitable land is available, the following general criteria must be met if use of groundwater for irrigation is to be economically feasible:

(a) Pumping depth must not be excessive.

(b) Well productivity must be adequate.

(c) Well construction costs must be acceptable.

(d) The rechargeable resource must be sufficient to sustain the development, or the reservoir capacity must be large enough to permit a long-term depletion programme.

(e) The quality of the water must be suitable for irrigation.

The above criteria do not have absolute values but fall within a range depending on other criteria. The profitability of any development must be assessed according to the conditions particular to the area.

The constraints on the development of the water of the Amman-Wadi Sir aquifer taken into account in the preparation of the water availability map are discussed below:

(a) Depth to water level limitations

Depth from land surface to water level was contoured by comparing the land surface contours with the interpretation of the regional piezometry of the system. The land surface contours of the available 1:250 000 map of Jordan are at 25 m intervals. The piezometric map of JOR/9 Technical

Report 2 (FAO, 1970 b) shows water level contours at 50 m intervals. Therefore the depth to water level contours are of limited accuracy, particularly in areas of rugged topography or where well control is sparse. The areas delimited within the mapped contour intervals do not take account of localized areas of high or low elevation.

Depth from land surface to water level is contoured at 50 m intervals up to the limit of 150 m. This limit was selected because it is considered that pump-lifts required to develop groundwater in areas where static water levels are in excess of 150 m depth would generally be unacceptable for irrigation under the prevailing economic conditions. The map shows that water levels are generally less than 150 m below surface in a limited area in the vicinity of Jizah-Dabah, an extensive area extending south from Siwaqa to near Uneiza, some areas to the east of Karak and Tafila, an extensive area in the mountains between Shaubak and Ras en Naqb, and in large areas of the Jafr and Azraq basins. Areas with water level less than 100 m below surface have a similar but rather more restricted distribution. Areas with water levels at less than 50 m depth occur in the Azraq basin, in the vicinity of Hasa, to the south of Jurf al Darawish and in the Shaubak-Ras en Naqb area. Flowing artesian wells may be located in the central parts of the Azraq basin and in some localities in the Shaubak-Ras en Naqb area. It is assumed that the available groundwater resource in the area between the Wadis Zerqa and Mujib is to be reserved for future domestic supplies in the Amman region.

It is concluded that the areas where water is available and depth to water is not limiting to development of irrigation are located in the Highlands, on the western edge of the Plateau to the south of Siwaqa, and in the Azraq and Jafr basins.

(b) Well productivity limitations

The productivity of a well reflects the mean permeability of the section penetrated by the well. It is considered that well yields cannot fall appreciably below 100 m^3/h for field crop irrigation and about 50 m^3/h for irrigation of fruit, and remain economic under the conditions which pertain in most of the area 1/.
Areas are recognized on the water availability map where permeability

1/ See Medium Term Plan for Development of Groundwater Irrigation in East Jordan. Figures 2 and 3.

combined with aquifer thickness could limit well productivity to below an acceptable discharge. In the areas delimited, specific capacities would normally be considerably lower than about 3 $m^3/h/m$ in wells penetrating 100 m of saturated section at discharge of 100 m^3/h, i.e. the drawdown for 100 m^3/h discharge would exceed 33 m. The aquifer thickness limitations cannot be indicated on a map of this scale. Reference should be made to detailed geological maps to estimate the saturated thickness available at any particular locality. However, limited saturated thickness is common only near the edge of the escarpment and the deeply eroded side wadis where considerations other than well productivity preclude development of irrigation.

The map shows that well productivity limitations reduce the area to the east of Karak, where depth to water is not limiting, to a relatively small area in the vicinity of Ghuweir, eliminate the possibility of development in the Tafila region, and exclude parts of the shallow water areas between Shaubak and Ras en Naqb, and to the south of Husseiniya. Well productivity in parts of the Azraq and Jafr basin could be limiting. The extensive area of relatively shallow depth to water extending southwards from Siwaqa to Husseiniya is little affected by permeability limitations.

(c) Well construction cost limitations

The Amman-Wadi Sir system becomes increasingly sandy south-westwards into the Jafr basin. Beds of uncemented sand are common in this area and the carbonate sections are relatively thin. The sands are normally fine and well graded. Construction of wells in these sediments involves the use of expensive screens and setting carefully graded sand packs. Wells up to 400 m deep will be required. Thus, well construction costs in the south-eastern part of the Jafr basin will be very high and would probably preclude economic development of the water for irrigation. The area where the lithology of the system may be a constraint to development is indicated in Map 1.

Wells over 500 m deep will be required to tap the Amman-Wadi Sir system in a large part of the Azraq basin. Well construction costs will be more than double those in potential production areas in the Highlands and in the western part of the Plateau. It is doubtful whether such costs would be economically acceptable. The area where well construction cost, due to well depth, may be limiting, is indicated on Map 1.

(d) Water quality limitations

The areas where total dissolved solids in the waters of the Amman-Wadi Sir system exceed 1 000 ppm are indicated on Map 1. These include most of the central and eastern parts of the Azraq basin and the south-eastern half of Jafr basin. Water quality deteriorates rapidly in both these areas. Total salinities of up to 1 700 mm have been observed in the Azraq basin and up to 2 650 ppm in the Jafr basin.

With the exception of the Dabah area, the concentration of dissolved solids in the water in the Highlands and along the western edge of the Plateau is less than 1 000 ppm. In a large part of the Highlands total salinities are below 500 ppm.

(e) Water quantity limitations

The order of magnitude and regional distribution of recharge within the area have been estimated and the regional pattern of groundwater movement is known. The total mean annual recharge is about 125 MCM. It is estimated that about two-thirds of the recharge occurs in the mountainous block between the Wadis Mujib and Hasa. The reservoir capacity of the system has not been estimated but is obviously very large.

The quantity of the water which can be recovered on either a safe yield or controlled depletion basis is known for only limited areas. Analog model studies of the Shaubak-Ras en Naqb area indicate that it would be possible to extract up to 15 MCM/annum in this region without incurring unacceptable water level declines (Appendix 4 (33)). A digital model of the Qatrana area indicates that gross extraction of 8.5 MCM/annum in the vicinity of the existing pilot development would result in stabilized declines of less than 10 m (Appendix 4 (42)). Forecasts of aquifer response to pumping from elsewhere in the system are lacking.

Taking into consideration the above constraints on the development of the Amman-Wadi Sir aquifer, a medium term plan was prepared on the basis of gross extraction equivalent to the estimated recharge. The planned distribution of extraction is in accord with the recharge and groundwater flow pattern. As this rate of extraction will involve an essentially unknown amount of reservoir depletion, the planned development is phased to allow periodic appraisal of aquifer response to extraction.

2.2 SOIL SURVEY AND SOIL RECLAMATION STUDIES

2.2.1 General

Within the project area, water is the limiting factor for irrigation development. Therefore, the land resources described in this report are confined to those areas where there appear to be no general hydrogeological constraints to economic development of groundwater for irrigation.

Soil and land classification studies were initiated during phase I of the project (FAO, 1972b). During phase II, soil studies were continued by the Soil Section of the NRA collaboration with the Research Department of the Ministry of Agriculture. Detailed soil surveys were undertaken on 10 000 dunums 1/ and semi-detailed surveys on 22 000 dunums. The project advised on specific soil reclamation problems and assisted the Government to prepare a programme of soil reclamation trials (Appendix 4 (34)). This programme is now partially underway but no final results have yet been obtained.

2.2.2 Description of land resources

The areas in East Jordan where no major hydrogeological constraints exist for irrigation development are:

(a) The area in the vicinity of Ghuweir and Adir to the east of Karak.

(b) The area of the Highlands between Shaubak and Ras en Naqb.

(c) The area of the Desert Plateau extending southwards from near Siwaqa to the vicinity of Husseiniya and lying mainly to the east of the Amman-Aqaba highway.

The area near Ghuweir and Adir has an undulating topography and the elevation ranges from 900 to 1 000 m.

The areas between Shaubak and Ras en Naqb are located in the mountains and foothills of the Highlands and rise to heights of 1 300 to 1 600 m. The topography is frequently rough and broken and large expanses of level land are rare.

The area between Siwaqa and Husseiniya is a gently dissected plateau formed from flat-lying mainly calcareous sediments. The altitudes range from 1 050 m in the southern part to about 750 m in the north.

1/ 1 Jordan dunum = 0.1 hectare.

In the Ghuweir-Adir and Highland areas agricultural lands normally occur on the shallower slopes and in the valley bottom. Most of these lands are cultivated with winter cereals though there is risk of failure due to the variability of the rainfall. Some tree crops and vegetables are also grown in the wetter areas but productivity is generally low.

In the Desert Plateau the rainfall supports only sparse grazing which is used by nomadic herds of goats, sheep and camels. The natural vegetation is overgrazed and in some areas has been destroyed by ploughing. Some winter cereals (mainly barley) are grown in small patches along the wadi beds but yields are low and the failure risk is very high.

2.2.3 Soil and land class surveys

The land classification system used is based on that proposed by the U.S. Department of the Interior (1953). Certain modifications of the system were made to suit local conditions.

A gross area of about 140 000 dunums was surveyed in detail, semi-detail, or at reconnaissance level. The surveys are described in FAO (1972b) and in working papers and reports of the Soil Section of NRA. The areas selected for survey were chosen on the basis of a preliminary assessment of the available land and water resources, and represent only a small proportion of the areas in which groundwater development is generally feasible, particularly in the Plateau region. Additional surveys will be necessary for further irrigation development but preliminary reconnaissance shows that the necessary areas of irrigable land are available. The surveys provide a sample of the type of irrigable land to be found in the areas. The results of the surveys completed to date are summarized in Table 2. It should be noted that the lands are classified according to their existing conditions and that the table does not indicate the classification to which the lands could be improved by proper irrigation management.

Even with preliminary soil reconnaissance a large part of the land surveyed has to be written-off as unsuitable for irrigation and included as class 6 land. Nearly 45 percent of the surveyed lands are included in class 4. Class 3 or better lands represent about 30 percent of the surveyed areas.

The important constraints to land development for irrigation in the Ghuweir-Adir and Highlands areas are slope and limited depth of soil. The soils may be initially saline and/or alkaline in the drier parts of the Shaubak-Ras en Naqb area, but the drainage is generally good and these defects may be removed by leaching.

Table 2

SUMMARY OF SOIL AND LAND CLASS SURVEYS

Locality	Type of survey	Gross area surveyed (dunums)	Land Classification (dunums)				
			1	2	3	4	6
Ghuweir area							
Ghuweir-Adir	Semi-detailed	8 950	1 000	3 000	2 750	1 950	250
Sub-total		8 950	1 000	3 000	2 750	1 950	250
Highlands							
W. Arja	Detailed	6 070	-	2 410	1 570	2 090	-
Udruh	Detailed	5 070	-	-	3 120	370	1 580
Abu Lisan	Detailed	1 860	-	990	660	50	160
Qurein	Detailed	9 000	-	520	2 150	6 260	70
Shaubak	Detailed	10 000	-	1 280	800	2 560	5 360
W. Wuheida	Detailed	2 050	-	46	537	1 317	150
Uweina	Detailed	12 000	-	-	-	5 530	6 470
Abu Makhtoub 1/	Reconnaissance	27 500	1 450	2 300	10 750	13 000	-
Sub-total		73 550	1 450	7 546	19 587	31 177	13 790
Desert Flateau							
Siwaqa	Detailed	4 300	-	-	-	3 200	1 100
Qatrana	Detailed	10 000	-	960	2 840	5 850	350
Sultani	Detailed	17 250	-	240	1 340	11 270	4 400
Abyad 1/	Semi-detailed	13 000	-	-	2 750	4 300	5 950
Tell Burma	Semi-detailed	16 150	-	-	500	6 300	9 350
Sub-total		60 700	-	1 200	7 430	30 920	21 150
GRAND TOTAL		143 200	2 450	11 746	29 767	64 047	35 190

1/ Detailed surveys have been completed of over 3 000 dunums.

The reclaimable lands in the Siwaqa-Husseiniya area may have slope and thickness defects. They normally contain soluble salts in excess of the tolerance of crops and may contain exchangeable sodium. Experience in the pilot developments at Qatrana, Abyad and Arja shows that salinity/alkalinity problems may be solved by leaching.

Drainage problems are not anticipated as the majority of the soils are underlain by a thick layer of gravel, and in many cases drain to a water table at considerable depth.

2.2.4 Soil reclamation studies and trials

The majority of soils in the Desert Plateau areas are saline and a great part of them are alkaline. Preliminary leaching trials and the experience gained from the operational schemes showed that the salt content of these soils and the alkalinity are quickly reduced to a low level by leaching. Additional trials were conducted to confirm the above conclusion and to establish an economic leaching procedure, both with and without soil amendments. These trials included:

(a) leaching and gypsum trial at Wadi Abyad;

(b) sub-soiling trial at Qatrana;

(c) study on irrigation and leaching requirements in the desert schemes.

The gypsum trials showed that gypsum application had little or no effect on accelerating the reclamation process. It was observed that the growth of sorghum in the sub-soiled plots was better than in the control plots. Leaching using a reasonable amount of water and cropping with a salt tolerant crop such as barley is the most adequate and economical way for reclamation of the Plateau soils.

The results of the studies are described in detail in a project Working Paper (Appendix 4 (22)).

2.3 AGRONOMIC STUDIES AND TRIALS

2.3.1 General

The agricultural sector in Jordan contributes about 20 percent of the Gross National Product, employs about 40 percent of the labour force and provides about 50 percent of the export revenues. However, the country imports JD 3.23 million worth of agricultural crop products and the total imports of food commodities equal

JD 18 million. There is therefore great interest in and need for intensification as well as diversification of crop production.

The annual cropped area in the East Bank is 3.5 to 4 million dunums, which may be broken down as follows:

Cropped area in East Bank

Area (millions of dunums)	Crops
2.5 – 3.0	Cereals, mainly wheat
0.4	Other field crops, mainly lentils
0.3	Vegetables, mainly tomato
0.3	Tree crops, mainly olives and vines
3.5 – 4.0	Total cropped area

The yields of all rainfed crops fluctuate within a wide range reflecting the variability of the rainfall. Yields may vary between good and bad rainfall years by several hundred percent.

The irrigated area in the East Bank is about 175 000 dunums, of which about 150 000 dunums are in the Jordan Valley and South Ghors. There are some 25 000 dunums of irrigated land in the Highlands and on the western edge of the Desert Plateau. Of this total, some 20 000 dunums are irrigated from pumped wells and the balance from springs and base flows in wadis.

Production in the Jordan Valley and South Ghors consists mainly of vegetables produced in the period November–June. Fruits, mainly citrus and banana, and some cereals are also grown. Irrigated agricultural production in the Highlands and Desert Plateau is mainly of vegetables with some field crops including fodder. The vegetables are produced during the period July–October.

A plan is being implemented in the Jordan Valley whereby the irrigable area will be increased to 200 000 dunums by 1975. A proposal for irrigation of 60 000 dunums in the South Ghors is under consideration. Irrigation of 80 000 dunums in the Highlands and Desert Plateau is proposed in the Medium Term Plan for Development of Groundwater Irrigation in East Jordan, prepared by the project.

2.3.2 Description of agronomic activities

The objective of the agronomic studies and trials was to determine the most suitable crop plants/varieties and their cultural requirements in the new groundwater irrigation development areas of East Jordan. The studies were designed to systematically organize the crop production work through:

(a) Collection of the extensive varietal seed material of cultivated field crops and vegetables;

(b) Organizing field tests on the promising varieties of the most successful crops;

(c) Initiating fertilizer, irrigation, water-use and cultural method studies on the promising crop varieties identified;

(d) Devising suitable cropping patterns capable of giving high returns to the farmers;

(e) Initiating cropping work in Qatrana and the other operational irrigation schemes.

Failure of the mud-flat soils to allow a good germination of the crops, particularly during the summer season, has proved a great stumbling block to efficient crop culture. This difficulty was overcome in the trials at least for some crops by sowing on ridges after furrow irrigation.

A particular effort was made to obtain the required seed from outside the country. Seeds, with particular emphasis on wheat, barley, maize, sorghum, alfalfa and vegetables, were grown in test plots to determine the most promising varieties. A programme for local seed production and improvement was initiated, and seeds of alfalfa, berseem, maize and other crops have been produced in sizable quantities for the first time in the country.

The project provided technical assistance to the Government for the cropping of the newly implemented schemes at Qatrana, Abyad and Ghuweir. A number of crop rotations were studied, and the most promising was put into practice on the Qatrana pilot scheme.

In addition to the crop trials, lamb fattening trials were held at Qatrana to find out whether lamb fattening could be a profitable way of consuming fodders produced in the desert irrigation schemes.

The field trials and observations conducted at Qatrana, Wadi Dhuleil, Shaubak, Dier Alla and other experimental farms are reported in Technical Report 1.

2.3.3 Results and conclusions

It was found that improved agronomic technologies developed in some European countries and the western United States could prove useful after suitable modifications for use in East Jordan. Though sufficient progress has been made in the identification of promising crop/varieties and their cultural requirements, details still remain to be completed and additional trials should be undertaken by experienced workers. Crops such as alfalfa, some forages and other crops, particularly those that can withstand severe winters and profitably make use of the winter precipitation (wheat, barley, oats, rapes) can be very successful. High value and high yielding crops could permit of the use of frequent costly irrigations required for their successful production.

2.3.3.1 General conclusions on various crops

The main conclusions from the agronomic studies and trials on various crops are summarized below:

(a) Wheat

Immediate scope for increasing wheat production in Jordan lies in the use of fertilizers and superior seeds combined with good agronomy in the irrigated areas. Yields up to 500 kg/dunum were obtained in some experimental plots.

For obtaining high yields from the groundwater irrigated areas in the hills of East Jordan, semi-winter and winter-durums and bread-wheats with high yields and vitreously hard grain are required. Tests with the superior varieties identified such as Capeitti (Capelli x Itie), Aningas and Hard 331 x 156, should be repeated. For December-January sowings, Sonalika, Zambesi, Mexipak and Potam varieties can be grown. A number of wheat varieties have given superior yields at Shaubak and should be retested.

(b) Maize

Experimental sowings throughout Jordan have indicated that maize can be successfully grown with possible yields of 700 kg/dunum or more under good farm management conditions. Bulk quantities of seeds of three synthetic varieties have been multiplied or obtained in the country. Varietal testing work as well as irrigation and fertilizer requirement studies should be intensified.

(c) Alfalfa

Alfalfa is the most successful forage and hay crop of East Jordan under irrigation. The following suggestions are made regarding its improvement:

- The varieties in use are good but improvement is possible by selecting more winter-hardy, high-yielding, disease (rust) and insect pest (e.g. aphids) resistant varieties.
- Observations made at Qatrana indicated that Certified Haydon, Moapan 69, Saranac, Jit (from Iraq), Sonora 70, Medicago gigante polypase, M. maemmana, are the better varieties in cold resistance. Field trials for forage and seed-yields should be conducted.
- Fertilizer trials (particularly phosphorus) should be started with California Common, Certified Haydon and Moapan 69.
- Possibilities of local seed production have been demonstrated at Qatrana and line sowing was done at Ghuweir (50 dunums) for the purpose. This work should be expanded and local seed production increased.

(d) Sunflower

Preliminary studies on oil-seeds have indicated the possibilities of successful cultivation of sunflower. Under good management, the crop is capable of giving high seed yields (150-200 kg/dunum) that contain a high percentage of oil (40 to 45 percent) of good quality. In addition, the crop is hardy with comparatively moderate irrigation requirement.

(e) Soybean

Soybean can be successfully grown in Jordan under irrigation but its water requirements are expected to be high. Preliminary information on promising varieties and cultural requirements has been collected but more work is needed.

(f) Rapes

Preliminary studies of rapes and mustards have revealed their possible usefulness under the climates of East Jordan as oil-seeds and forage crops. More research on this category of crop plants is required.

(g) Tomato

Tomato is an important vegetable crop capable of giving very high yields (2-3 t/dunum) under good management. Preliminary varietal testing work was initiated at Qatrana in order to identify the best varieties from among the confusingly large number on sale. This work should be continued to organize local seed production.

(h) Onions and garlic

Onion and garlic crops were observed to be eminently suited for cultivation in Jordan and can make a successful use of water and of temperature conditions prevailing in the hilly and Plateau areas, by giving high yields (2-4 t/dunum). Their production in the country should be increased as an import substitute.

(i) Melons

Melons of good quality can be produced under irrigation with high yields (1.3-2.0 t/dunum). Since melons can be exported to adjoining countries in large quantities at attractive prices, the expansion of this crop, particularly sweet melon, is advisable.

(j) Sugar beet

Under good management conditions, it has been shown possible to produce enough summer raised roots to yield about one ton of processed sugar per dunum. A feasibility study has shown that sugar production based on winter beet production under irrigation in the Jordan valley and by rainfall in the Highlands would be viable (Agrar-und Hydrotechnik, 1974).

(k) Cotton

Observations on raising American cotton (Syrian variety) at Qatrana were encouraging. With more work on choice of suitable varieties, good agronomic handling and pest control measures, it should be possible to raise the crop successfully and profitably under irrigation. Trials should be continued.

(l) Oats

Oats grow successfully in Jordan and can produce high yields of forage during the scarcity months of autumn as well as early summer. Varieties that are suited to both forage as well as porridge grain manufacture have been identified. The seeds increased should be utilized in production and the testing work that was done only for one season should be continued.

(m) Fodder maize and sudax

Fodder maize and sudax have been observed to grow fast and give high yields (estimated at over 4 t/dunum) under good management during the summer. Varietal testing should be extended with the available multiplied seeds.

(n) Forage legumes and grasses

Observations on forage legumes and grasses grown in the hills and the Plateau areas of East Jordan have shown the possibility of successful utilization of some for pasture as well as for irrigated meadows. Promising species are Sweet Clovers, Narobonne and other vetches, some Medic, and to some extent, Red Clover, Berseem (Trifolium) and Italian clovers. Twoomba Canary Grass, Smilo Grass, Rye Grasses and Ryes (both annual as well as perennial), Rhodes Grass and to some extent, Orchard Grass also showed promise as did rapes (Brassica spp) and Eruca spp.

Some of the identified species and varieties can be used in planting grass plus legume mixtures. Further investigation on the suitability of these crops to the conditions of East Jordan should be continued.

(o) Green manures

In the two years of preliminary work useful information was obtained about the most promising green manure crops. Sweet Clovers offer the best chance of success, followed by Narobonne and other vetches and cowpeas. Broad beans have limited value in the winter low temperature areas.

2.3.3.2 Cropping pattern in the Desert Plateau schemes

Work during 1972 and 1973 confirmed the possibility of growing the following crops in the Desert Plateau under irrigation:

Cereals: wheat, barley, oats, maize and sorghum.

Grain legumes: soybean, cowpeas, field beans.

Oil-seeds: sunflower, soybean, safflower.

Vegetables: tomatoes, onions, cauliflowers, broadbeans, melons.

Forage crops: alfalfa, sudax, sorghum.

Other crops: cotton, sugar beet.

Taking into consideration the existing marketing conditions, the water consumption and other economic aspects, the following cropping pattern is recommended for the new irrigated areas:

Crop	%
Alfalfa	40
Wheat followed by maize	40
Vegetables (winter and summer)	20

2.3.3.3 Fruit production in the Highlands

A 12-year old orchard of approximately 100 dunums at Shaubak Government Farm in the Highlands was studied in regard to the success of different species of fruit trees and varieties, diseases and disease control and expected yields. It was concluded that:

- From the point of view of the ecological conditions, the development of fruit tree culture in irrigated Highland areas is possible and advisable.
- Climatic conditions (cold winter, low rainfall during the blooming and mild summer temperatures) are favourable to regular growth and yield, to good quality and to long storage life of fruits.
- Apple is the most suitable fruit crop in deep soils with sufficient infiltration rate, and which contain less that 50 percent calcium carbonate.
- Prune and plum culture is possible in heavy and calcareous, deep soils.
- In locations less exposed to late spring frosts, apricot culture is suitable.
- In the less deep and/or calcareous soils grape culture is advisable.

Based on the above observations and on the particular climatic and soil conditions of each of the development areas in the Highlands, the following recommendations are made:

(a) Shaubak, Abu Lisan and Abu Makhtoub areas

In the deep soils and where $CaCO_3$ is relatively low, apple, apricot, plum, cherry and peach are recommended. In the less deep soils and where $CaCO_3$ is high, grapes are recommended.

(b) Udruh and Qurein areas

These areas are warmer than Shaubak and the rainfall is lower. Only the deep soils are suitable for prune, apple and apricot. The rest of the land is recommended for grapes.

(c) Wuheida area

The climate is arid and relatively warm. Fruit trees (apple and apricot) are recommended only in the deep soils where salinity is not a limiting factor. The rest of the area should be planted with annual crops for some years till the soils are completely reclaimed and then planted with fruit trees and grapes.

The following varieties are particularly well adapted to the climatic conditions of the Highlands:

Apples: Golden Delicious, Rome Beauty, Starking Delicious.
Pears: Doctor Enjot, Coscia, William, Spadona, Abate Fetel, Decana del Comizio.
Apricots: Caninos, Cafona, Rouge de Roussillon.
Plums and Prunes: Formosa, Burbank Shiro, Santa Rosa, Stanley, Sugar Prune.
Peaches: Cardinal, Collins, June Gold, Dixired, Red Cap.
Grapes: Regina dei Vigneti, Italia, Regina Afouz-Ali, Regina Nera.

2.3.3.4 Seed production

Jordan spends a large amount of foreign exchange annually for the purchase of crop and vegetable seeds and other planting material of horticultural use (fruit tree nursery plants). The variability and dryness of the climate in Jordan are favourable factors for local seed production.

The seed production, certification and distribution work should be properly organized as early as possible. Progressive farmers should be given incentives and training in order to develop the sound seed production that is basic to any attempts at agricultural development.

2.3.3.5 Lamb fattening trials

The lamb fattening trials were held at Qatrana in 1972 and 1973. In both years, the lambs were obtained on loan from the settler-trainees at the Qatrana scheme. An enclosure adequate for 300 lambs was constructed, but it was possible to obtain only 60 lambs in 1972 and 144 lambs in 1973. Three variations of a barley-alfalfa hay ration were fed in 1972; in 1973 the rations were exclusively alfalfa, either baled hay or wilted. An attempt to establish a control of lambs retained on desert grazing was unsuccessful.

The results of this trials are described in a project technical paper (Appendix 4 (8)). No sound conclusions can be drawn but it is recommended that the lamb fattening experiments should continue.

2.4 CROP WATER REQUIREMENT AND TESTING OF IRRIGATION METHODS

2.4.1 General

Water is scarce and expensive in East Jordan and profitable irrigation entails a careful use of the available water. This could be attained by determining through field trials the water requirements of the different crops and by selecting the best irrigation method, taking into account the local conditions and the fact that inexperienced farmers will be settled in the new irrigation schemes.

Activities aimed to introduce modern research techniques and to establish sound field trials to obtain preliminary results during the shortened life of the project; it was thus possible to obtain some information on the water requirements of the main crops. It was fortunate that a number of schemes became operational during the project, making it possible to test and compare different irrigation methods in practice.

Details of the work can be found in a project consultant report (Appendix 4 (47)).

2.4.2 Agro-climatological data

Two agrometeorological stations were established at Qatrana, the first late in 1970, outside the irrigation development area on bare dry soil, and the second in mid-1972, within an irrigated alfalfa field some 300 m from the previous station.

A large difference in the evaporation rates was found between the two meteorological stations. Peak rates of 13 to 14.4 mm/day were recorded over the dry bare soil, whereas over the irrigated field, peak figures were of the order of 8 to 9.2 mm/day. Evaporation rate from a Class A in an alfalfa field was about 64 percent that of a Class A in the dry bare soil surrounding. Further measurements are necessary to check and adjust this relationship as well as all the derived figures on crop water use.

The yearly evaporative demand over the irrigated perimeter of Qatrana would be of the order of 2 000 mm instead of 3 150 mm measured at the dry soil station. For most crops at full soil cover and under no water stress, the peak monthly water use rates would be practically between the rates of the sunken pan (Colorado) and Class A pan, i.e. between 7 and 9 mm/day. A minimum of three years measurements are still needed to get improved figures.

2.4.3 Soils

Soils at Qatrana are silty loams to clay loams. The average field capacity is 23 percent and the permanent wilting point 13.5 percent. The bulk density is from 1.31 to 1.51 for the surface 30 cm layer and 1.56 to 1.69 for the deeper layers. The water available to a depth of one metre is around 150 mm. The infiltration rate is between 4.5 and 5 mm/hour. These soil properties affect irrigation intervals as well as water uniformity distribution, storage and application efficiencies.

2.4.4 Desert Plateau irrigation schemes - crop water use and irrigation requirement

2.4.4.1 Crop water use

Four drainage lysimeters (4 m^2 in area and 1.5 m in depth) were installed early in 1972 after a period of land reclamation and levelling. A moisture neutron probe, a number of tensiometers, Bouyoucos blocs and meter and sprinkler irrigation equipment were introduced. Sixtyfour plots (36 m^2 each) were supplied through portable pipes with measured amounts of water from a calibrated reservoir.

The results obtained on crop water use are summarized below.

(a) Alfalfa

The 1972 data on alfalfa water use (one year old crop) are of limited use due to poor and heterogeneous stand and small percent soil cover. With spot reseeding and additional care, the stand and growth were greatly improved and the 1973 data refer to a good crop reaching 60 to 70 cm height before cutting, with a complete soil cover. The lysimeter yield, from nine cuttings, was 89 t/ha of fresh weight. The water use or evapotranspiration of alfalfa (ET-Alfalfa) was first estimated from Class A rates in the alfalfa field using monthly ratios (ET/Class A) established in Lebanon. The net water requirement of alfalfa would be around 1 550 mm. The value actually measured was 1 430 mm with missing data for January and February and only 44 mm rainfall in 1973. Peak monthly rates of 7.0 to 7.5 mm/day occur in July with 6.5 to 7.0 mm/day for June and August and 5.0 to 6.0 mm/day for May and September. These figures were measured on the lysimeters and confirmed by using established ET/Class A ratios.

A field plot experiment conducted in 1973 with total water applications ranging between 1 110 to 1 475 mm failed, however, to show significant differences in yields. Irrigation scheduling based on tensiometer readings and depletion levels was not properly followed. It is essential to repeat the experiment for water optimization studies. Due to the calcareous nature of the soil, the addition of phosphate or other fertilizer should be adequate to prevent fertility level from becoming a limiting factor.

(b) Wheat

In 1973, two lysimeters plus their buffer areas and 32 field plots were under Mexipak wheat. A preliminary conclusion could be made that for good grain yield (5 to 6 t/ha) the water use of wheat is of the order of 650 mm. More trials are needed to assess the proper peak monthly rates. Wheat yield increased almost linearly with increasing water application up to the lysimeter levels.

(c) Maize (after wheat)

The maize was planted late (22 July) and this delayed the vegetation and the peak water use. Frost occurred in November and damaged the plants. Complete analysis of the experimental data was not possible.

It is estimated that at Qatrana maize as a second crop (i.e. after wheat) would need from 550 to 600 mm of water. Results from the field plots are only indicative and the experiment should be repeated and improved. They tend, however, to confirm the figure of 550 mm and that the peak monthly rate of 6 mm/day would occur in September.

(d) Tomato

Based on two years of experimentation at Qatrana, on lysimeter and in field plots, it was found that the water use of a high yielding tomato crop at Qatrana is of the order of 900 mm. It is characteristic that the highest yield was obtained with the largest total amount of water used. Further work is necessary to determine the monthly water use peak rates.

2.4.4.2 Irrigation requirement for the selected cropping pattern

Irrigation requirement for the selected cropping pattern in the Desert Plateau was estimated using the field and agrometeorological data from Qatrana. Monthly ratios of crop water use to Class A pan evaporation established in Lebanon were used whenever possible after comparison and analysis of individual values obtained at Qatrana. Precision may be expected only after two additional years of continued crop water use experiments. The water needs are given in Table 3 for a cropping pattern with 43% alfalfa, 43% wheat followed by maize and 14% winter and summer vegetables.

The data suggest that the annual gross irrigation requirement for the selected cropping pattern in the Desert Plateau is 1960 mm and that two peak rates of demand occur: in May with 240 mm (7.7 mm/day) and in August with 278.7 mm (9 mm/day). These figures are indicative and the ongoing field experiments are intended to improve them. The design of irrigation schemes in the Desert Plateau was based on an annual gross demand of 1 550 mm and a peak demand of 7.5 mm/day, figures that are considerably lower than those given above. Thus, the water stress treatments suggested for alfalfa (July-August) are important and experimentation should continue in this direction.

2.4.5 Highland irrigation schemes - water use of orchards

An irrigation trial was initiated in 1972 on apple trees at Shaubak. The trees are not uniform either genetically or with respect to their age or growth. Two sites were selected and access tubes were installed in a regular grid pattern for soil moisture determination. In addition, some tensiometers were placed at 50 and 100 cm depths. The neutron probe was not used and the tensiometers were neither sufficient nor adequately used or checked. Only ovendrying moisture determinations were made. Two irrigation treatments were used: (a) prescheduled irrigation based on Class A pan, and (b) traditional irrigation as practised previously in the orchard.

Table 3

IRRIGATION REQUIREMENT FOR THE SELECTED CROPPING PATTERN IN THE DESERT PLATEAU SCHEMES

Month	Wheat + Maize (43%)		Alfalfa (43%)		Vegetables (14%)		Total water use (mm)		Effective rainfall	Gross irrigation requirement
	Water mm	Weighed	Water mm	Weighed	Water mm	Weighed	Net	Gross (effic.0.70)	mm	mm
January	50	21.5	50	21.5	50	7.0	50.0	71.5	16	55.5
February	90	38.7	70	30.1	65	9.2	78.0	111.5	16	95.5
March	125	53.8	110	47.3	95	13.3	114.4	163.6	12	151.6
April	170	73.1	135	58.1	109	15.3	146.5	209.5	-	209.5
May	175	75.2	175	75.2	80	17.5	167.9	240.1	-	240.1
June	(100)	42.9	190	81.7	(110)	15.4	140.0	200.2	-	200.2
July	85	36.6	230	98.9	150	21.0	156.5	223.8	-	223.8
August	170	73.1	215	92.4	210	29.4	194.9	278.7	-	278.7
September	180	77.4	190	81.7	150	21.0	180.1	257.5	-	257.5
October	100	43.0	150	64.5	90	12.6	120.1	171.7	-	171.7
November	-	-	65	28.0	-	-	28.0	40.0	4	36.0
December	45	19.4	40	17.2	-	-	36.6	52.4	13	39.4
Total		555		697		162	1 413	2 020	61	1 959

<u>Note</u>: Calculations for vegetables were based on garlic (winter vegetable) and tomato (summer vegetable).

Treatments were applied along six tree rows (three rows per treatment) across ten varieties each represented by three to nine trees. Due to lack of water or inadequate irrigation during the previous years the development of the Shaubak apple orchard is below normal. The average projected area of the tree canopy is between 7 and 8 m^2, the soil cover being between 25 and 35 percent.

Preliminary results indicate that the total water use for a full grown vigorous orchard at Shaubak (soil cover $\geqslant$85%) would be equal to 0.60 Class A value (i.e. some 975 mm for 1973). Annual rainfall would contribute from 100 to 200 mm. With individual basin and controlled irrigation, efficiency could be high. For young orchards achieving only partial soil cover (30% for example), it could be assumed that most of the moisture extraction is taking place from the area under the tree canopy (plus some 25% maximum additional area outside it, i.e. from 1.25 times the projected canopy area). This is especially true with small basins (localized water applications around each tree) and under low rainfall, which is the case of Shaubak. Thus the irrigation requirement for the Shaubak orchard with 30 percent soil cover would be around 300 mm. This figure should be confirmed before being accepted as final.

2.4.6 Testing of irrigation methods

A series of field trials was carried out to evaluate different methods of irrigation and to select the most economical and adaptable to local conditions. The main objective was to find out the different irrigation parameters and to determine the irrigation efficiency for each method. Systematic tests were limited to sprinkler and basin irrigation. Border and furrow irrigation methods were broadly tested but no efficiency trials were carried out due to the lack of time. However, detailed experimental programmes have been prepared and handed over to the counterpart irrigation agronomists for implementation. A programme for a drip irrigation experiment was also prepared.

2.4.6.1 Sprinkler irrigation tests

Detailed records of wind velocity and direction started at Qatrana in 1970 and at Udruh in 1971 with the installation of two wind recorders and the use of totalizer anemometers. Analysis of the wind data led to the conclusion that night time sprinkling is essential and that the total average daily sprinkling period is about 14 hours. The predominant direction of wind (when velocity is higher than 4 m/sec) is W and NW.

A number of sprinkler tests were carried out during the 1972 summer in a 2.5 ha alfalfa field at Qatrana. It was concluded that with single nozzle sprinklers, the best results were obtained with a 12 m x 18 m spacing, 3/16 in nozzle and 2.5 atmospheres nozzle pressure. The irrigation efficiency was estimated to be about 75 percent under wind velocities below 4 m/sec. The work was continued at Wadi Abyad Pilot Project during the winter 1972/73. The results obtained are discussed below:

(a) Water losses (L)

$$L(\%) = \frac{d-m}{d} \times 100$$

Where: d = average depth of water calculated from the discharges of the sprinklers (theoretical application);

m = actual application, i.e. mean depth of water of all catching cans.

For normal climatic and operational conditions (appropriate nozzle size and pressure) the water losses ranged between 10-17 percent. It was found that water losses are almost linearly related to wind velocity with value of 4 percent losses for each meter per second wind velocity.

(b) Uniformity coefficient (C.U.)

$$C.U. = 100 \left[1.0 - \frac{\sum (m - x)}{n.m} \right]$$

Where: m = mean depth of water of all catching cans;

$\sum(m-x)$ = sum of deviations, in absolute values of depth of water of each can from the mean m;

n = number of cans

High C.U. values (89%) were obtained with Wright Rain Perfect, two-nozzles, 27.5° sprinklers with 4.5 mm range nozzle and 2.3 mm spreader nozzle when wind velocities were below 2 m/sec. C.U. 78% was obtained with velocities between 2.9 and 4.2 m/sec. With high wind (>7 m/sec) the C.U. dropped below 60%. The following linear relation was found between C.U. and wind velocity (in the range 1.0 - 7.7. m/sec):

$$C.U. = 95.7 - 4.91\ V, \quad \text{with } V = \text{wind velocity in m/sec.}$$

(c) Pattern efficiency (P.E.)

$$\text{P.E.} = \frac{100 \times \text{depth of lowest 25\% of all cans}}{\text{mean depth of all cans}}$$

Satisfactory pattern efficiencies were obtained at Wadi Abyad from the sprinkler irrigation described above when 83.5% of wind velocities were below 2 m/sec. With wind between 3 to 4 m/sec, the P.E. fell to 68% and decreased to 44% at 7 m/sec.

The above considerations on water losses, uniformity coefficients, pattern efficiencies and prevailing wind conditions confirm the conclusion that night sprinkling is essential and that the normal sprinkling period should be from 18.00 till 08.00 h. Estimated spray losses (Frost and Schwalen nomograph) were of minor importance (3-5%)under low to moderate wind and reached 8.5% under windy conditions (7 m/sec).

(d) Overall efficiency

Recalling that the overall efficiency for the sprinkler scheme could be defined as:

$$e = e_1 + e_2 + e_3$$

with e_1 = ratio of the amount effectively stored in the root-zone to the amount delivered to surface of the area to be irrigated;

e_2 = ratio of the amount delivered into the surface of the area to be irrigated to the total discharge of the sprinklers over that area;

e_3 = ratio of the amount delivered to the area to be irrigated to the amount delivered at the head of the scheme;

the overall sprinkler efficiency under controlled irrigation would be between 70 and 75 percent.

2.4.6.2 Basin irrigation tests

Experiments were carried out in four alfalfa basins at Qatrana during the years 1972 and 1973. The size of the basins varied from 1 260 to 1 530 m^2, which is about the average for the project (100-200 m long, 12 m wide). Flow discharge into the basins measured by a Cipoletti weir varied between 30 to 70 m^3/hour; water applications were between 54 and 92 mm.

Soil moisture was determined by ovendrying before and three days after irrigation at 12 predetermined sites (four equidistant points along the basin with three equidistant points across the width). The soil has a relatively low infiltration rate (4.5 to 5 mm/h). No systematic difference was found in the depth of water applied to different parts of the basin. Application and storage efficiencies therefore were calculated on the assumption that individual observations of depths of water are equally representative and form a normal distribution. The desired application depth for each irrigation was defined as the amount of water applied to 80 percent of the basin area, assuming that under-irrigation is tolerated in 20 percent of the area.

The distribution efficiency was calculated from the expression:

$$C.U. = 100 \left[1 - \frac{\sum (m-x)}{m.n} \right]$$

previously defined under sprinkler tests (2.4.7.1).

The water application efficiency was defined as the ratio of the desired application depth (water stored in the rootzone) to the actual depth applied. The water storage efficiency was defined as the ratio of water stored in the rootzone to the water needed in the rootzone.

The following results were obtained:

(a) The uniformity distribution (C.U.) was high in all trials and in both years. The well-levelled basins selected, and the low soil infiltration rate at Qatrana and the flow rates adopted, all tend to justify these high values.

(b) The storage efficiencies were very high (about 95%) in both years and application efficiencies were high (between 60 and 85%). Only minor deep percolation losses are to be expected under controlled irrigation with low infiltration rates, relatively small water application depth, and a three week irrigation interval. In 1973, the alfalfa was two years old with a deeper root system, so growth and uniformity were greater and moisture extraction was more uniform and deeper.

It is concluded that under good conditions (low infiltration rates, controlled irrigation, good land levelling, etc.) the overall irrigation efficiency for basins should be 65 percent.

2.4.6.3 Border, furrow and drip irrigation

No results are as yet available on the border, furrow and drip irrigation methods.

Ten borders 175 m long, 10 to 15 m wide with 0.2, 0.4 and 0.6 percent slopes have been constructed at Qatrana and are now under a wheat crop. Trials on irrigation efficiency are expected to start in summer 1974.

A drip irrigation site has been selected at Al-Hussein Station. Water is available at an acceptable pressure (reservoir). Fruit trees, mainly peaches, are uniform. The proposed irrigation experiment comprises three irrigation treatments (drip, individual basin and control-unirrigated) in three replicates (three rows of 9 to 10 trees each with three varieties). A minimum of three uniform trees per variety is suggested and three levels of fertilizer application in order to optimize or maximize yield with respect to water input.

2.5 DESIGN OF IRRIGATION SCHEMES

2.5.1 General

The design of irrigation schemes was an important project activity. The main task was to provide the Government with the final design of new schemes for implementation through bilateral aid financing and to train Jordanian counterparts in the design work.

The project was able to produce final designs, contract documents and drawings for six irrigation schemes as well as preliminary designs for seven schemes. The design of several irrigation schemes provided more accurate data on the costs which have been used in the preparation of the overall Plan for Irrigation Development in East Jordan.

Several problems of a technical and economic nature, related to irrigation development, had to be solved before finalizing the design work. Because the data required for the analysis of these problems could best be acquired from analysis of particular schemes and because there was pressure from the Government for the design of certain schemes for which financing possibilities were in view, it was decided to work simultaneously in the design and in solving problems common to all or several schemes. However, this decision entailed frequent revisions of the design work.

To accelerate design work, a topographical map of scale 1:2 500, covering an area of 22 000 dunums, was prepared through a local sub-contractor.

2.5.2 Problems related to irrigation development

The following technical problems related to the design of irrigation schemes were examined in detail and have been the subject of special working and technical papers (see Appendix 4B and C).

2.5.2.1 Choice of plant for deepwell pumping

There is no high tension supply in any of the area suggested for irrigation development. National grid power could be a possibility for the future but the load would have to justify the extension. Bearing in mind the possibility of national grid power in the future, the following alternative power supplies were considered:

(a) A central power station for all, or for several, of the proposed schemes.

(b) Individual scheme power stations.

(c) Diesel direct-drive for pumping.

The above three solutions were examined in detail by the project (see Appendix 4 (35, 49)) 1/ and the following conclusions were reached:

- In Highland schemes the choice of power supply is relatively straightforward A central power station, which cannot be envisaged until there are about 25 wells, is appreciably more costly than either of the other alternatives. Diesel direct-drive is cheaper than power stations for individual schemes up to about 10 wells. In the Shaubak-Ras en Naqb area, the number of wells in any individual scheme does not exceed the above figure, even at full development. Diesel direct-drive power should therefore be used in these schemes. The sole qualification to this conclusion relates to areas like Shaubak, where the surface discharge head is important. In such cases, a detailed comparison must be made between diesel direct-drive and a power station for the particular scheme. In the Ghuweir and Adir areas, the distance between the areas is more than 3 km so that two power stations would be required with low voltage transmission.

1/ A full discussion of the power alternatives is given in Medium Term Plan for Development of Groundwater Irrigation in East Jordan.

In each area, the number of wells will be from 7 to 14, depending on average discharge of 200 or 100 m^3/hour. There will therefore be similar costs of diesel direct-drive and scheme power stations, with the difference increasingly in favour of the latter beyond 10 wells. In these circumstances, scheme stations are to be preferred in view of the relative ease of an eventual switch-over to supply from the national grid.

- In the Desert Plateau schemes, the choice of power supply is more complex. Where one operator can handle a well pump and a booster pump, diesel direct-drive is the cheapest solution. But the significance of staff costs is such that, where a separate operator is required for both the well and the booster pump, diesel direct-drive is the most costly solution as soon as there are three or more wells. In the majority of cases the distances between well and booster pumps will require an operator for each, and all schemes will have three or more wells. Scheme electric power will therefore usually be cheaper than diesel direct-drive. Of the two electric alternatives, the central power station cannot be envisaged until there are about 18 wells. And even at that point, a power station for each of four individual schemes of five wells will still give lower unit power costs than a central power station serving the 20 wells. The rate of decline in unit costs of a central power station with more than 18 wells has not been examined, but it will certainly be slow. Bearing in mind the possibility of national grid power in the future, it appears that power stations for individual schemes are to be preferred over central power stations serving several schemes.

The above discussion has been limited to power supplies for irrigation. In the Desert Plateau area, the other demands are small, except for the phosphate mine. In Highland areas, however, there are demands for domestic use, some light industry, and domestic water. It has been shown that the irrigation demand alone is not sufficient to justify a central power supply. But if that demand were taken together with other existing and foreseeable demands, there might be a sufficient load to justify a central power supply, probably based in Ma'an.

2.5.2.2 Optimum discharge of wells

The determination of the discharge of wells in any irrigation scheme is of particular importance since it has an effect on the pumping cost per cubic metre of water. It is evident that by increasing the discharge of a well an increase of the pumping lift (due to the increase of the drawdown) will occur and consequently an increase of the operation cost. On the other hand, high yield wells mean that less wells are needed for the irrigation of the same area and consequently reduced capital cost.

The determination of the optimum discharge of a particular well, i.e. the discharge which gives the lowest cost per cubic metre of water, was made by using linear relations for capital cost/power and annual cost/power and with the following variants:

(a) depth of well;
(b) depth to static water level;
(c) specific capacity of well;
(d) time of pump operation per year.

The following three formulas were developed by which the optimum discharge of a well can be approximately determined:

- Case of a shaft pump equipped with a diesel direct drive engine:

$$Q_{opt} = \sqrt{\frac{(1\,332D + 980d + 25.45T + 707\,500)\;60\;SC}{1.94T + 600}}$$

- Case of an electric submersible pump powered be an individual diesel generator:

$$Q_{opt} = \sqrt{\frac{(1\,332D + 980d + 20.7T + 629\,000)\;75\;SC}{2.64T + 1\,350}}$$

- Case of a number of wells equipped with electrical submersible pumps, powered by a central diesel generator:

$$Q_{opt} = \sqrt{\frac{(1\,332D + 980d + 9.6T + 271\,000)\;75\;SC}{2.4T + 1\,308}}$$

Where:

Q_{opt} = optimum discharge of well in m^3/h

D = total depth of well in m

d = depth to water table in m, plus 3 m for friction losses in the well

T = time of pumping per year in hours

SC = specific capacity of well in $m^3/h/m$

Several assumptions and simplifications were made in the development of the above formulas, the most important being the linear relation of the drawdown to the discharge which is true only over a relatively small range of discharges. Thus the optimum discharge determined from the above formulae has only an indicative value and a more accurate calculation should be made for each particular case on the basis of the actual characteristics of the well.

2.5.2.3 Choice of reservoirs

Due to the wind conditions in the Desert Plateau, sprinkler irrigation can only be applied with a high efficiency (0.70-0.75) at night between 18.00 - 08.00 h. Similarly, in the Highlands, contour-furrow irrigation can be applied only during the daylight, i.e. a maximum of 14 hours a day. With a peak irrigation application day of 14 hours, there is a choice to be made between:

(a) pumping at a given rate to a storage reservoir for the highest number of hours per day;

(b) pumping at a higher rate to a balancing reservoir for 14 hours per day to provide the same quantity of water as in (a).

It must be assumed that the well characteristics will allow the choice to be made. The actual case of provision of 6 hours storage (i.e. pumping from the well for 20 h/day) has been examined in detail. The conclusions are:

- there is little cost difference between the two alternatives for Highland schemes;
- the cost differences in the Desert Plateau schemes relate to well characteristics and each case must be examined individually;
- there are non-cost advantages to storage reservoirs which may be summed up as overall operation flexibility.

It is considered that storage reservoirs are desirable for both Desert Plateau and Highland schemes.

There is a choice in the type of storage reservoir. In practice the choice is between concrete reservoirs or butyl-lined earth reservoirs. It was found that concrete reservoirs are less costly up to capacities of about 2 000 m^3 and are also easier to construct. It is considered that concrete reservoirs are to be preferred for most of the irrigation schemes.

2.5.2.4 Choice of conveyance system and irrigation method

(a) Discussion

The choice between conveyance systems of canals or buried pipes was examined. Water losses and management problems of earth canals combine to eliminate this system. For small discharges, the capital costs of concrete-lined canals are almost similar to those for buried asbestos cement pipes but the annual costs of the former are higher.

For the Desert Plateau schemes the border strip method of irrigation was compared to basins. The capital costs of both methods are similar. Annual costs of border strip might be lower than for basins, but higher skills would be involved, an important consideration when the settlers are inexperienced.

The choice from the above methods is therefore a combination of buried pipes and levelled basins. This method was compared with sprinkler irrigation. The comparison shows that the direct costs (amortization, maintenance and supervision) of sprinkler irrigation are always higher than buried pipes and basins, but the latter involve higher labour requirements. The indirect costs (land losses, irrigation efficiency, farm machinery efficiency, elimination of night work, and delays in completion of construction) of sprinkler irrigation are less than buried pipes and basins. Taking account of both direct and indirect costs, sprinkler irrigation costs are slightly lower than basins for Desert Plateau schemes but much higher for Highland schemes. The labour inputs for sprinkler irrigation are lower for both Desert Plateau and Highland schemes.

The cost and labour comparisons are summarized in Table 4.

Table 4

COMPARISON OF COSTS AND LABOUR INPUTS FOR SPRINKLER AND BASIN IRRIGATION SYSTEMS

	Desert Plateau schemes		Highland schemes	
	basin	sprinkler	basin	sprinkler
Initial capital (JD/dun)	42.0	42.0	36.0	45.0
Direct costs (JD/dun/yr)	5.7	7.6	4.7	7.3
Indirect costs (JD/dun/yr)	15.1	11.0	4.2	3.3
Labour (man-h /dun/yr)	18.0	10.0	52.0	7.0

In conclusion, sprinkler irrigation is preferred for all Desert Plateau schemes and contour basin irrigation is preferred for all the Highland schemes.

(b) Recommendations

Based on field trials carried out by the project and the experience gained from the operational schemes the following recommendations are made:

(i) Sprinkler irrigation - Desert Plateau schemes

- Rate of application: 6 - 6.5 mm/h (in average 6.3 mm/h)
- Spacing of sprinklers: 12 x 18 m
- Discharge of sprinklers: 1.36 m^3/h
- Wetted radius: 14 - 14.5 m
- Sprinkler nozzles: one nozzle 4.76 mm diam.
- Operation pressure: 2.5 atm on average
- Diameter and length of laterals: 75 mm (3 in) diam. and 198 m length. The total length (net) of the irrigated strip will be 204 m
- Number of sprinklers on each lateral: 17
- Discharge of each lateral: 23 m^3/h
- Area served by each lateral: 3 670 m^2 or 3.67 dunums
- Risers: 0.60 m for normal crops, 1.50 m for maize and sorghum
- Pressure regulators: Where the topography is uneven the use of individual pressure regulators is recommended to be installed at each sprinkler
- Required pressure at the hydrants: 3 atm.
- Hydrants: Diameter of riser pipe 75 mm (3 in). Hydrants will be placed at intervals of 54 m
- Auxilliary line: An auxilliary line of 18 m length and 75 mm diameter will be used to serve three positions of the lateral from each hydrant.

(ii) Surface irrigation - Highland schemes

- The suggested method is the contour-furrow with individual basins for fruit trees and contour-furrow for grapes
- Orchard valves will be placed at 50 m intervals on the buried secondary pipelines. The recommended length of furrows is 100 m but in some cases up to 130 m is acceptable.

- Small individual basins will be constructed around each tree. The size of the basins will be gradually increased with the growth of the trees. Contour furrows will be constructed midway between the rows of trees at intervals of 4 to 6 m. Water will be conveyed from the furrows to the basins through plastic syphons or by opening the earth bank.
- Discharge unit of the orchard valves will range between 20 to 40 m^3. Water will be diverted from the valves to the furrows through portable quick coupling pipes.
- For grapes it is suggested that two contour furrows be constructed between the lines of grapes. By using plastic pipes the discharge unit will be divided into four to six furrows to reduce the stream in each furrow and avoid the risk of erosion.

2.5.2.5 Layout of pipelines

Some principles have been established for the layout of pipelines by comparing the capital and annual costs for different layout solutions. Because of the many assumptions made, these principles should be considered only as guidelines.

The principles are the following:

(a) Desert schemes

- When the slope is zero or negligible the most economical layout solution is to have four parallel pipelines for each well, distant 414 m, two from one side of the well and two from the other side.
- When the slope is more than 0.6 percent, two or three parallel pipelines following the slope and distant 414 m should be used.
- The recommended length of pipelines is between 500 and 1 000 m.

(b) Highland schemes

- When the slope is 2 percent or more, the most economical layout solution is to have four parallel pipelines for each well following the slope and distant 206 m.
- The recommended length of pipelines is approximately 1 000 m.

2.5.2.6 Selection of diameter of pipelines

The selection of the diameter of pipelines should be based on the comparison between cost of pipeline and capitalized cost of energy for friction losses in the pipeline.

On the basis of the assumptions made for the desert and highland schemes, detailed tables have been prepared giving the economical diameter of pipeline for different discharges and longitudinal slopes (Appendix 4 (23)).

2.5.3 Preliminary design of irrigation schemes

The preliminary designs for seven irrigation schemes, prepared by the project, cover a net irrigated area of approximately 25 000 dunums. The purpose of these designs was to determine the irrigable area of each scheme, to examine the different solutions and select the most economical to determine the best location of wells from the engineering point of view, and to estimate the approximate cost. For the preparation of the preliminary designs the following data were used:

- topographical map of scale not less than 1:10 000;
- soil reconnaissance or semi-detailed soil survey of the same scale;
- all available information on the hydrogeology of the area.

The schemes for which preliminary design was prepared are shown in Table 5. For some of these schemes final designs were prepared later and changes were made in the design concept in accordance with the conclusions of the general studies.

2.5.4 Final design of irrigation schemes

The project produced final designs for six irrigation schemes for immediate implementation. The schemes cover a total net irrigable area of approximately 11 900 dunums.

Work on these designs gave to the project staff the opportunity to examine in detail and compare all the possible technical solutions and to acquire precise data about the cost of the schemes, used later in the preparation of the "Medium Term Plan for Development of Groundwater Irrigation in East Jordan". For the counterparts, the "model final designs" will be of great use in future work. The designs are accompanied by all the drawings and contract documents including technical specifications and bid schedules.

Table 5

IRRIGATION SCHEMES FOR WHICH A PRELIMINARY DESIGN WAS PREPARED BY THE PROJECT

No.	Scheme	Location	Net irrigable area (dunum)	Existing wells		Additional required wells		Suggested irrigation method	Suggested water distribution system	Construction cost (JD)
				No.	Total discharge (m^3/h)	No.	Total discharge (m^3/h)			
1	Siwaqa 1/	Desert Plateau	2 700	2	420	2	530	Borders and furrows	Open concrete canals	200 000
2	Wuheida 1/	Highlands	2 000	3	670	–	–	Contour basins	Buried pipelines	150 000
3	Shaubak 1/	Highlands	3 620	3	800	1	250	Contour furrows	Buried pipelines	250 000
4	Udruh	Highlands	3 100	2	400	2	500	Contour furrows	Buried pipelines	230 000
5	Qurein	Highlands	8 000	2	400	10	2 000	Contour furrows	Buried pipelines	640 000
6	Abu Makhtub	Highlands	2 100	2	600	–	–	Contour furrows	Buried pipelines	174 000
7	Qatrana Extension 1	Desert Plateau	3 300	2	400	3	600	Basins	Buried pipelines	320 000
	TOTAL		24 820	16	3 690	18	3 880			1 964 000

1/ Schemes for which final design was prepared later.

Table 6

IRRIGATION SCHEMES FOR WHICH FINAL DESIGN WAS PREPARED BY THE PROJECT

No.	Scheme	Location	Net Irrigable area (dunum)	Existing Wells No.	Existing Wells Total discharge (m^3/h)	Suggested pumping plant	Suggested irrigation method	Suggested water distribution system
1	Siwaqa	Desert Plateau	2 700	4	1 025	Central generator 1 050 kW	Sprinkler	Buried pipelines
2-3	Sultani (Central and East)	Desert Plateau	2 725	4	1 060	Central generator 900 kW	Sprinkler	Buried pipelines
4	Abu Lisan	Highlands	1 170	2	400	Diesel direct-drive shaft pumps	Contour furrows	Buried pipelines
5	Wuheida	Highlands	1 710	2	570	Diesel direct-drive shaft pumps	Contour furrows	Buried pipelines
6	Shaubak	Highlands	3 600	4	1 000	Central generator 250 kW	Contour furrows	Buried pipelines
	TOTAL		11 905	16	4 055			

For the preparation of final designs the following data were used:

- Topographical map of scale 1:2 500 with contour intervals 1 m.
- Detailed soil survey and land classification of the same scale.
- Testing data of wells (all the required wells for the irrigation of the scheme were drilled and tested before the preparation of the final design).
- All the available information on the hydrogeological conditions of the area.
- All the available information on the agro-economic and socio-economic conditions of the area.
- The results of all studies and field trials carried by the project.

All the schemes for which a final design was prepared (Table 6), have been included in the 3-year Government Plan for implementation; the required funds are estimated at JD 2.07 million (Table 7).

Table 7

FUNDS REQUIRED FOR IMPLEMENTATION OF THE IRRIGATION SCHEMES INCLUDED IN THE 3-YEAR GOVERNMENT PLAN

No.	Scheme	Net area (dunum)	Total funds required (JD)			
			Construction 1/	On farm development	Initial operations	Total
1	Abu Lisan	1 170	92 000	50 000	68 000	210 000
2	Wuheida	1 710	108 000	76 000	107 000	291 000
3	Shaubak	3 600 2/	325 000 2/	155 000 2/	216 000	696 000
4	Sultani Central	2 725	238 000	68 000	108 000	414 000
5	Sultani East					
6	Siwaqa	2 700	281 000 3/	68 000	110 000	459 000
	TOTAL	11 905	1 044 000	417 000	609 000	2 070 000

1/ Excluding sunk costs (already spent).

2/ Approximate figures (final design not yet completed).

3/ Including spare generator to be shared with Sultani scheme.

The above table shows that the project gave the possibility to the Government for an immediate investment of about JD 2 millions. Additional long term investment possibilities are given by the Medium Term Plan for Development of Groundwater Irrigation in East Jordan (see 2.9).

2.6 SUPERVISION OF CONSTRUCTION AND OPERATION OF IRRIGATION SCHEMES

2.6.1 General

The project provided technical advice and assistance to the Government in the construction and operation of new irrigation schemes. This activity gave the opportunity to the project staff to evaluate in practice the different technical solutions, to check the cost estimates and to improve the design work.

Of the schemes designed by the project, only the Qatrana South was implemented during Phase II. Technical assistance was provided by the project during the construction phase and later during the land preparation phase. Some complementary works for the existing Qatrana pilot scheme were designed and their construction supervised.

2.6.2 Construction of Qatrana South scheme

The Qatrana South scheme, with a net irrigated area of 700 dunums, is an extension of the Qatrana North pilot scheme implemented during Phase I. Except for minor changes in the water distribution system, the same design principles were applied in the two schemes. Two wells of a total discharge of 240 m^3/h equipped with diesel drive vertical shaft turbine pumps are used for the irrigation of the scheme. The distribution system consists of buried asbestos pipes to which alfalfa valves were installed at 25 m intervals. Basin irrigation is applied, the basins being of 100-130 m length and 12 m width, the same dimensions as Qatrana North.

The construction of the civil works and the supply and installation of pumps were done through local contractors under the supervision of the Irrigation Department of NRA, on the basis of the design prepared by the project. During the construction period the project provided assistance in supervising the work and in adjusting the design to the field data.

The land preparation (land levelling, construction of basins) was done by the Engineering Department of the Ministry of Agriculture on the basis of a levelling plan prepared by the project. Six tractors and land levelling equipment were provided by the project for this work.

The construction of the scheme was completed in early 1974 and at the time of writing (June 1974) the basins are being prepared for cropping.

2.6.3 Supervision of the operation of irrigation schemes

In addition to the Qatrana North pilot scheme, three irrigation schemes on the Desert Plateau, implemented and financed by British Aid, became operational during phase II: Wadi Abyad of 500 net irrigated dunums, Ghuweir of 500 net irrigated dunums and Tell Burma of 1 000 net irrigated dunums. Although the project was not directly involved in the implementation of these schemes, technical assistance was provided to the Government by the project staff in solving operational problems. Again the experienced gained was used in improving the design work and the cost estimates.

2.6.4 Supplementary works at Qatrana North pilot scheme

After two years of operation of the Qatrana North scheme a detailed study was carried out by the project to evaluate the different elements of the scheme and to make suggestions for improvement. Supplementary works were designed and constructed under project supervision and as a result a better water control and flood protection has been obtained.

The construction of concrete open canals for experimental purposes at Qatrana gave the opportunity to obtain accurate data of their cost and to compare them to the buried pipes. It was concluded that for small discharges of 100-150 m^3/h there is no significant difference in capital cost between concrete open canal and buried asbestos pipes but the maintenance cost of the former is higher. This cost comparison and the fact that buried pipelines present several advantages for water management led to the conclusion that buried pipelines should be chosen in all the schemes suggested for irrigation development.

2.7 AGRO-ECONOMIC AND SOCIO-ECONOMIC STUDIES

2.7.1 General

The primary purpose of the agro-economic studies was to obtain the information required to assess the feasibility of the proposed irrigation development schemes. The studies were consequently oriented to obtain and analyse data on (a) yields, costs and prices of the main crops and livestock; (b) costs of pumping and delivery of water; (c) potential markets and marketing facilities; (d) socio-economic conditions of settlers. An estimate of the nomadic and semi-nomadic populations in East Jordan was also compiled. The agro-economic studies carried out under phase I of the project were 'farm management' orientated. These data laid the basis for feasibility reports for individual irrigation schemes suitable for loan applications to international financing institutions (2.8). The Medium Term Plan for Development of Groundwater Irrigation in East Jordan is the synthesis of all the technical, agro-economic and socio-economic studies carried out by the project (2.9).

Previous agro-economic studies under phase I of the project are given in JOR 9 Technical Report 3 (FAO, 1972a).

2.7.2 Data on main crops and livestock

Data on yields, costs and prices of the main crop and livestock possibilities were assembled and analysed. The improvement in basic data was a continuing process as field work progressed and as more information was obtained from neighbouring countries. Major revisions in basic assumptions are summarized in working papers. Improvements in the data and their analysis have been incorporated into the assessments of individual schemes. Particular efforts were made in devising sound farm machinery cost estimates. The most serious deficiency in basic data lies in the technical coefficients of lamb fattening and seasonal meat price movements.

For the Desert schemes, the finally established crop costs and major inputs are given in Table 8 and the gross and net revenues in Table 9.

Table 8

CROP COSTS AND MAJOR INPUTS FOR DESERT SCHEMES

Item		Wheat	Maize	Alfalfa	Tomato	Onion
Supplies	(JD/dunum)	2.68	4.14	0.50	10.46	7.30
Machinery except harvest	"	1.67	1.07	0.40	0.81	0.75
Stand establishment	"	-	-	2.04	-	-
Harvest	"	0.71	1.02	4.27	-	-
Cost except labour and water	"	5.06	6.23	7.21	11.27	8.05
Labour (man/hour/dunum)		8	25	16	132	122
Water (m^3/dunum)		694	710	1 791	856	384

Table 9

GROSS AND NET REVENUES FOR DESERT SCHEMES

Item	Wheat	Maize	Alfalfa	Tomato	Onion
Normal yield (kg/dunum)	450	700	1 750	2 400	2 000
Gross revenue (JD/dunum)	18.0	23.5	29.8	43.2	36.0
Crop costs except labour (JD/dunum)	9.2	10.5	17.9	16.4	10.4
Net revenue (JD/dunum)	9.7	13.0	11.0	26.8	25.5

For the Highland schemes, apples and grapes are mainly recommended with inter-row potatoes in the first two years. Because of the complexity of the problem, the economics of Highland schemes have been examined only on the basis of internal rate of return, taking into account the total annual costs (including scheme costs) of a 'model scheme' for the whole life of the plantations. For both apples and grapes, farm-gate price estimates are JD 40/t and yields at full production 2 t/dunum.

2.7.3 Cost of pumping and delivery of water

Data on costs of pumping and delivery of water were assembled and analysed, and records of existing operational schemes were examined in detail. It became necessary to examine in depth three fundamental technical choices:

(a) the method of irrigation, which reduces to a choice between levelled basins and sprinkler irrigation;

(b) the system of power for pumping which, in practice, involves a choice between diesel direct-drive vertical shaft pumps and diesel generator electric driven submersible pumps;

(c) the size and type of reservoirs.

This involved detailed study of existing examples of the various possibilities and, for (a) and (b), lengthy correspondence with manufacturers.

Many cases were examined in both Desert Plateau and Highland areas. It was possible to establish the cost of water pumping as a function of the discharge of wells, lift pumping and time of annual pump operation. The average cost of water pumping, at the outlet of the pumps, was calculated as 6 fils/m^3. This cost was used in the economic analysis of the schemes.

2.7.4 Potential markets and marketing facilities

Potential markets, marketing facilities and marketing charges were determined. There is a wealth of basic statistics in the country, but they contain many contradictions and have not been fully exploited by government agencies concerned with marketing. Accordingly, commodity balances were drawn up for many commodities, and the available data on products of particular relevance to groundwater schemes were carefully scrutinized. Frequently, this involved going back to the original unprocessed data. Conclusions are summarized below.

2.7.4.1 Highland schemes

Among the several species of fruit trees that can grow in the Highland schemes, apple and grape are predominant from the marketing point of view, both in terms of total annual consumption and the scope for import substitution. The actual domestic consumption is estimated at 20 000 t for apple and 8 500 t for grapes, while the present domestic production is 2 000 t and 7 500 t respectively. By 1985 the consumption is estimated to increase, as a result of population growth and increase in per caput income, to 43 000 t for apple and 18 000 t for grapes. The new irrigated areas required to eliminate fruit imports by 1985 are estimated at some 30 000 dunums (Table 10).

Table 10

IRRIGATED AREA REQUIRED TO ELIMINATE FRUIT IMPORTS BY 1985

Fruit	Present domestic demand (tons)	Domestic demand in 1985 (tons)	Present domestic production (tons)	Additional production required (tons)	Assumed irrigated yield (tons/dunum)	Required irrigated area (dunum)
Pear	1 100	2 100	300	1 800	1.7	1 100
Peach	1 000	2 100	600	1 500	1.2	1 300
Plum	1 500	3 200	2 000	1 200	1.1	1 100
Apricot	1 200	2 600	800	1 800	1.0	1 000
Apple	20 000	43 000	2 000	41 000	2.0	20 000
Grapes	8 500	18 000	7 500	10 500	2.0	5 250
TOTAL						29 750

There would be no likelihood of increased domestic fruit production from elsewhere in the country to compete with proposed production from the Highland irrigation schemes. It should, however, be possible to export apples from the Highland schemes to Saudi Arabia, and the market should reach some 10 000 t by 1985.

It therefore appears that the fruit production programme in Highland schemes should put the maximum possible area to apple, and the most appropriate other fruits in the areas unsuitable for apple.

On the basis of 'prices most often recorded' in the Amman wholesale market, it is concluded that the on-farm harvest price for apples will be JD 40/t. It is also considered that the on-farm price for late grapes will be JD 40/t.

2.7.4.2 Desert Plateau schemes

Current investments in irrigation in the Jordan Valley are planned not only to increase the output and quality of winter vegetables, but also to develop a more effective rotation and to include potato and maize in the cropping pattern. Whereas irrigated products in the Jordan Valley and the Desert Plateau area have previously been seasonally complementary, they will in the future be increasingly competitive.

The people likely to be recruited to groundwater irrigation schemes in the Desert Plateau area have considerable experience in sheep production. This provides a simple but powerful argument for giving priority to the production possibilities of these animals. Dairy and egg production could be competitive but would require specialized management.

Thus a process of elimination of possible import substitutes leaves for the Desert Plateau schemes cereals, fodder and some vegetables. Wheat and barley could both be produced in the area but while they have similar production costs, barley produces lower yields and at a lower price.

(i) Wheat and sorghum

Even if there were a substantial increase in irrigated wheat production, the country would remain a net importer of wheat. The on-farm price of hard wheat grain has been held at about JD 32/t by government intervention in the market by the sale of imported wheat at less than world price levels. It is proposed that whereas the 'financial' value of soft wheat grain is JD 30/t on-farm, the 'economic' value of soft wheat grain is JD 36/t.

The market for maize grain in mainly for poultry feed. The almost wholly imported supplies have arrived into-mill at about JD 28/t (bagged) in recent years. Due to government intervention in the market, and despite large increases in world price, the into-mill price has remained virtually unchanged. The volume of imports of maize is about 25 000 t/year. This is equivalent to about 40 000 irrigated dunums. It seems probable that the country will remain a net importer of maize for a long time, and the world parity cost of JD 33.5/t on-farm is taken for economic analysis.

The market for sorghum grain is the same as for maize and the market value of the crop is similar.

(ii) Fodder and lamb fattening

The basic idea of fodder production is to fatten lambs which would be taken off the rangelands in March-April. The seasonality of lamb fattening suggests that the feed producing activities should have a similar seasonality. The most obvious choice of fodder is alfalfa. In addition, there is scope for direct sale of fodder in competition with existing feeds. The total volume of animal feeds consumed is over 100 000 t, of which barley and vetch are about 50 000 t. The total production of alfalfa from the proposed Desert Plateau irrigation development would be about 40 000 t.

Information on meat prices shows that, in a normal year, the price of meat does not fall at the period when the lambs are being slaughtered. This is believed to reflect a consumer preference for young spring lambs. Under present production conditions, purchase of lambs for fattening would tend to increase the unit price of meat in the spring above the selling price after fattening. Investigations have shown that the numbers of young lambs available could be considerably increased by prophylaxis and this could reduce the spring price. In drought years the price of spring lamb falls considerably below the average price of meat, and fattening would have higher profitability than in the normal years. The value of alfalfa for fattening lambs is estimated at JD 21/t, and the value if sold as baled hay at JD 17/t.

Production of other fodders, including sorghum, sudan grass and oats is being investigated but it seems unlikely that they will prove more appropriate to lamb fattening than alfalfa. They would cause considerable increases in peak machinery and labour requirements if substituted in a cropping pattern for alfalfa.

(iii) Vegetables

Price and volume series of vegetables were obtained from records of the Amman wholesale market. With the exception of tomato, the volume traded per month of any item rarely exceeds 1 000 t. The Amman wholesale market is considered to handle 60-70 percent of the total trade in the East Bank. Prices generally fall severely from the beginning to the peak of the season, but tomato is again an exception. For each of the vegetables examined, wholesale prices show a pronounced upward trend over the period 1966-73 despite clear upward trends in the volumes traded during this period.

Imports are significant only for tomato and onion. For most of the other vegetables, Jordan is a net exporter. Future export possibilities are not good other than for winter tomatoes which can only be produced in the Jordan Valley.

Vegetable production from groundwater irrigation schemes must be approached with caution. The country is already self-sufficient in most items and the only substantial export possibilities are in winter. The volumes of domestic demand are not large in terms of production under irrigation. Seasonally high prices would be eliminated by relatively small volumes of production. Tomato and onion are the only vegetables for which there is a limited scope for production. Farm gate prices for both crops are taken as JD 18/t.

(iv) Conclusion

It is concluded that in the Desert Plateau schemes there is scope for production of alfalfa, wheat and maize and limited scope for production of tomato and onion.

2.7.5 Estimate of the nomadic and semi-nomadic population

Government policy, expressed officially, is that settlers on future desert irrigation schemes must be drawn from the bedouin population with traditional rights to the proposed irrigation areas. It was considered useful to estimate the nomadic and semi-nomadic population in East Jordan who might wish to be settled in such schemes. The estimate was based mainly on the population census of 1952 and 1961 and on a partial census conducted in 1967.

Taking into account recent modifications (e.g. nomadic people serving in the army, increasing tendency to abandon nomadism), the best estimate of the nomadic population at the end of 1971 is 60 000 of whom only 20 000 might be classified as pure nomadic. At seven persons per family, this population represents about 8 500 families. A part of this population may wish to continue nomadic pastoralism, which will presumably become more profitable as the number of people exploiting the desert rangelands decreases. Therefore it is concluded that the number of people who would wish to settle on irrigated farms does not exceed 50 000 people or 7 000 families. With an average farm unit of 25 dunums per family, an irrigated area of 175 000 dunums will be needed for the settlement of all the nomadic population in Jordan.

2.7.6 Socio-economic surveys

Three socio-economic surveys were conducted by the project in collaboration with the United Nations Economic and Social Office, Beirut, in the operational Plateau irrigation schemes of Qatrana, Wadi Dhuleil and Jafr. The objective was to understand better the past and present social and economic conditions of the bedouin settlers and evaluate objectively their potentialities for development. The studies also provided basic information to help the officials in charge to plan a more effective educational and training programme.

The data were collected by interviews with the settlers using questionnaires prepared in consultation with several government agencies. The chief interviewer/writer was recruited from the American University of Beirut. Additional information was provided by personal observations and individual talks with the project personnel. Several local staff participated in the interviewing teams.

(a) Qatrana

The Qatrana survey was conducted in April 1972 by interviewing 31 of 32 settlers.

- All respondents wanted to work their farm-units themselves and preferred to grow vegetables and alfalfa for sheep. The majority seemed to favour establishment of a cooperative.
- The majority expressed interest in building a house at the scheme or in the village if they were given a government loan.
- Respondents' dependency on the Government is strong and their expectation of it high. Therefore it is necessary that the real objectives and goals of the Government for projects such as

that of Qatrana, be clearly defined. If the goal is to develop irrigated farming with the least expenditure and with the greatest assurance of success, the Government may need to turn over the farm-units to people who have sufficient experience in irrigated farming and who are less dependent on government help and support to keep the project going. If the objective, however, is to help settle the bedouins and improve their standard of living, the Government must accept that this will imply longer, possibly continuing, support.

(b) Wadi Dhuleil

The survey at Wadi Dhuleil was conducted in May 1973 by interviewing 23 sharecroppers and 17 settlers.

- If the type of development envisaged by the Government in the Wadi Dhuleil Project is aimed at achieving a main goal of government policy, namely, the settlement of as many nomads as possible, it may be concluded that the Project under the present system will not contribute, at least in the short run, to the accomplishment of such a goal. Almost all units are operated and cultivated by tenants. In the long run, however, the present owner-tenant arrangement could contribute to the eventual settlement of the bedouin landowners who live in tents near the Project area. Their frequent contacts with and visits to the tenants could help increase their knowledge, or the knowledge of their children, of irrigated farming and might eventually motivate them to operate and cultivate their own farms.

- If, on the other hand, the Government encourages the existing owner-tenant arrangements and considers this approach to be less costly, while still contributing to the improvement of both bedouins and tenants, the authorities still need to take certain measures to help maximize the returns of the two groups. It is evident from the survey that the returns from the agricultural units are low due, inter alia, to the exploitation of the dealer. The tenants are fully dependent on the dealer to receive, on credit, whatever farm inputs they need during the season. No services are being provided to tenants by government departments to reduce their dependence on the dealer. The establishment of an agricultural cooperative in the Project may help reduce such dependence and contribute to increase of their income.

(c) Al Jafr

The survey at Al Jafr was conducted in April 1973 by interviewing 23 of the 26 settlers who moved into the Project and lived in housing units there.

- The survey revealed that the majority of the settlers still need training. The present level of productivity is low and can be increased by using larger quantities of fertilizers and by a better control of plant diseases. The extension agents in the project can play a significant role in improving agricultural practices.

- It seems that the settlers are becoming less dependent on the Project authorities. They are now paying for their own seeds, fertilizers, chemical sprays, boxes used for marketing and transportation. However, they still require government assistance for the supply of machinery and other farm equipment. If the Government decides to withdraw from the Project, the settlers have agreed to form a cooperative.

- To help strengthen the cooperative at its early stages of development and to enhance self-reliance among settlers, the Government can devise a system whereby the costs of farm inputs and services, provided free to settlers, are introduced and added to the cooperative capital.

- The Project is still affected by the way agricultural units have been distributed and from the envy existing between settlers and other people living in the nearby area. When distributing agricultural units to prospective settlers, the principle of working in the Project to gain experience in irrigated farming must be adhered to by the selection committee. Furthermore, the committee should take into account certain selection criteria, such as devotion to work, willingness to be more independent and to join a cooperative, age, size of family, level of income and education before the settlers are selected.

2.8 FEASIBILITY REPORTS

2.8.1 General

Feasibility reports suitable for loan applications to international financing institutions were prepared for the six irrigation schemes for which final engineering designs were completed. Throughout, the analyses were done in terms of internal rates of return. Cost benefit ratios were not used since there is no generally accepted discount rate.

Farm size, farm budgets, repayment capacity and credits were examined in detail for two 'model' schemes, one representative of the Highland schemes and the other of the Desert schemes. It ultimately became possible to express internal economic rates of return as a function of well discharge and total dynamic head; this was an important contribution to the selection of future areas for groundwater irrigation.

A useful role was played in securing British aid finance for Abu Lisan and Wuheida schemes.

2.8.2 Model Highland Scheme - Abu Lisan

A detailed study of the Abu Lisan scheme showed that the internal economic return with economic input prices is about 22 percent over 25 years, the estimated life of the trees and vines. The sensitivity of this result was examined with respect to a 10 percent fall in output prices and the rate falls to 20 percent. The effect of non-zero opportunity costs of land and of labour of those settlers who had not previously farmed in the Abu Lisan area was also examined. The opportunity cost variants considered were:

I	JD 2 080/year	Net revenue of land before reclamation (zero cost of outside labour of settlers)
II	JD 5 780/year	Net revenue of land plus cost of outside labour of settlers before reclamation, taken at JD 100/family/year (JD 100 x 37 families)
III	JD 9 480/year	Net revenue of land plus cost of outside labour of settlers before reclamation, taken at JD 200/family/year (JD 200 x 37 families).

For the two levels of output prices examined, the rates of return are:

Sensitivity of Highland Rates of Return

Output price variant	Opportunity cost variant		
	I	II	III
		(percent)	
I	22.1	20.4	18.7
II	20.0	18.1	16.5

The only recurrent inputs to which taxes or subsidies apply are fuel and oil. With financial rather than economic fuel and oil prices, each of the above rates is reduced by about one absolute percentage point, e.g. from 20 to 19 percent. If no inter-row potatoes are grown in year 2, the rates also fall by about one absolute percentage point, i.e. the omission of potato net revenue in year 2 is as important as the substitution of financial for economic fuel and oil prices throughout the life of the scheme.

Taking Abu Lisan as reasonably representative of Highland schemes, the basic data may be modified to permit calculation of rates of return for any combination of well discharge (Q) and total dynamic head (TDH) which can serve as a guide to the selection of irrigation areas. Four cases were examined for discharges (Q) of 165 and 55 m^3/hour and total dynamic head (TDH) of 55 and 180 m. These TDH's are the initial levels but the rate of return calculations also take account of long-term regional drawdowns of 30 m between years 2 and 15, and a further 30 m from year 16 to the end of the scheme life. It appears that even with ostensibly poor wells, the internal economic return will still be acceptable. In effect, this implies that wherever water can be found, and apples grown, investment in groundwater irrigation will be economically feasible. The returns from stone fruits have not been explicitly examined but will be of similar magnitudes, subject to the market limits.

2.8.3 Model Desert scheme - Sultani

A detailed study of the Sultani scheme showed that the internal economic return is about 15 percent over 30 years. The sensitivity of this result was examined with respect to financial output prices, and the rate falls to 12 percent. The effect of non-zero opportunity costs of labour was also examined. The opportunity cost variants considered were:

I	: Zero	:	No opportunity cost for land and labour
II	: JD 10 600/year	:	Cost of labour of settlers before reclamation, taken as JD 100/family/year (JD 100 x 106 families)
III	: JD 21 200/year	:	Cost of labour of settlers before reclamation, taken as JD 200/family/year (JD 200 x 106 families)

Sensitivity of Desert Plateau Rates of Return

Output price variant	Opportunity cost variant		
	I	II	III
		(percent)	
I	15.4	12.9	9.4
II	12.2	8.9	4.8

Using Sultani data, the internal economic return as a function of well discharge (Q) and total dynamic head (TDH) can be calculated as for Highland schemes. The minimum acceptable rate of return is taken to be 12 percent. It appears that the minimum acceptable combinations of Q and TDH are:

$Q = 256\ m^3/h \quad H = 160\ m$

$Q = 100\ m^3/h \quad H = 120\ m$

$Q = 50\ m^3/h \quad H = 80\ m$.

All the Desert Plateau schemes examined fall within these limits. The TDH cited here includes long-term regional drawdown.

2.8.4 Farm income and financial arrangements

Highland fruit schemes have high rates of return so that, even after paying all costs, farmers on units of a manageable size will receive average net annual incomes of well over JD 300. In view of the delay until year 6 before annual revenues exceed all costs in the following year, the net funding required is high; for the first six years, total funding at Abu Lisan amounts to about JD 350/family. It is proposed that a 25 dunum farm size be adopted and that the repayment schedule be based on 'pessimistic revenues', i.e. reasonable revenue less 20 percent. On this basis, all repayments can be made by the end of year 20.

Desert Plateau schemes have acceptable economic rates of return but some financial subsidy is required, even with the maximum manageable size of 44 dunums. In view of acquired experience, it is proposed that a 25 dunum farm size be adopted and that government provide all funds required in project years 1 to 3; each scheme will be self-financing thereafter. The apparent subsidy involved is JD 3 400/family, but the effective subsidy is only JD 1 700/family.

2.9 MEDIUM TERM PLAN FOR DEVELOPMENT OF GROUNDWATER IRRIGATION IN EAST JORDAN

The Medium Term Plan for Development of Groundwater Irrigation in East Jordan is the major achievement of the project. In fact, all the investigations and studies carried out during the two phases of the project aimed at the preparation of this Plan which gives the possibilities to the Government to go ahead with the overall irrigation development in East Jordan.

The Plan contains all the elements for the preparation of a feasibility report for the development of about 81 000 dunums of irrigated land distributed in the Western Highlands and Desert Plateau between Amman and the Ras en Naqb escarpment. It is considered that activities should be implemented in two phases over about 10 years. The funds required are estimated to be JD 12.2 million.

The Plan provides for 90 percent use of the rechargeable water resources in the Amman-Wadi Sir aquifer system. The first phase can start immediately. After a few years' pumping, when the aquifer response to large withdrawals is known more accurately, the second phase can be defined in more detail.

The Plan is produced in such a way as to provide the elements for loan application to international financing institutions. It includes an implementation programme comprising soil surveying and mapping, well drilling, design, construction and financing.

2.9.1 General

The Plan proposes development of about 81 000 dunums of irrigated land distributed in 15 areas in the Western Highlands and the Desert Plateau between Amman and the Ras en Naqb escarpment, within the Amman-Wadi Sir aquifer system. Some 27 000 dunums of the planned development are in the Highlands and will be based on fruit production. On the Desert Plateau, production of fodder, cereals and some vegetables is suggested.

Phase 1 development would total about 31 000 dunums of which 4 900 dunums have been implemented. It is considered that, if finance is made available, Phase 1 could be implemented in four to five years and the entire Plan could be completed in ten years. Five of the proposed Phase 1 schemes, totalling 11 900 dunums, are included in the Government's current three-year plan.

Final designs have been completed for six Phase 1 schemes totalling 12 800 dunums. In addition, preliminary designs are available for four schemes totalling 8 300 dunums to be implemented during Phase 1.

The Desert Plateau schemes which are based on field crops will be irrigated by sprinklers and the power requirements will be provided by diesel electric generators. The fruit schemes in the Highlands will be irrigated by piped water to individual tree basins in the case of trees, or to contour furrows in the case of grapes. The water will usually be pumped by diesel driven, vertical shaft turbine pumps.

Of the estimated required JD 12.2 million, some JD 6.4 million will be for construction of irrigation systems, JD 2.1 million for on-farm development, and JD 3.6 million for credit and subsidies (Table 12).

The fruit schemes will be profitable with internal rates of return of about 20 percent. The field crop schemes are more marginal but internal rates of return should not fall below 10 percent. Marketing the produce should present no serious problems since all production is destined for the domestic market.

The entire development is planned for public investment, and operation and maintenance of the water supply and distribution systems will remain the responsibility of Government. Farm mechanization required for the field crop schemes will be provided by a form of government-operated cooperatives.

All investments in the Highland fruit schemes will be fully recoverable and the farmers will attain freehold ownership of the land. The Plateau field crop production schemes will require initial unrecoverable subsidy from Government, and ownership of land will remain with the public sector though the farmers will have security of tenure.

2.9.2 Land, water and human resources

2.9.2.1 The land resources

The land resources discussed below relate to areas where there appear to be no general hydrogeological constraints to economic development of groundwater for irrigation. The areas are:

(a) a relatively limited area of about 40 km^2 in the vicinity of Ghuwair to the east of Karak;

(b) an extensive area of about 500 km^2 in the Highlands between Shaubak and Ras en Naqb;

(c) an extensive area of over 3 000 km^2 extending southwards from near Siwaqa to the vicinity of Husseiniya and lying mainly to the east of the Amman-Aqaba highway.

The areas near Ghuwair and between Shaubak and Ras en Naqb are located in the mountains and foothills of the Western Highlands. The area between Siwaqa and Husseiniya forms part of the Desert Plateau. Large expanses of level land are rare in the Highland areas. The Desert Plateau region is less dissected and the general topography is undulating with occasional scarps and localized blocks of hills. The rocks underlying virtually all the areas are calcareous.

A gross area of about 140 000 dunums has been surveyed in detail, semi-detail, or at reconnaissance level (see Table 2). Additional surveys will be necessary but preliminary reconnaissance shows that the required areas of irrigable land are available.

The important constraints to land development for irrigation in the Highlands areas are slope and limited thickness of soil. The reclaimable lands in the Siwaqa-Husseiniya area may also have slope and thickness defects. The soils of the drier areas may be initially saline and/or alkaline, but the drainage is generally good and these defects may be removed by leaching.

2.9.2.2 The water resource

The areas of potential groundwater development are located to the south of a line through Mujib-Azraq because of a combination of hydrogeological constraints or because the groundwaters to the north of that line are fully utilized or are earmarked for domestic and industrial supplies, mainly in the Amman-Zerqa area. Hydrogeological constraints discussed under section 2.1.4 further restrict the areas of potential groundwater development to those listed in the previous section (see Map 1).

The rechargeable resource in the region of the proposed development area is estimated to average 125 MCM/annum and the reservoir capacity is very large. The aquifer response to extraction on either a safe yield or controlled depletion basis is known for only limited areas. Nonetheless it is considered feasible to plan on the basis of a gross extraction equivalent to the estimated recharge. The planned distribution of extraction is in accord with the recharge and groundwater flow pattern. The development is phased to allow periodic assessment of aquifer response to extraction. Water quality should not present problems to the development as the total dissolved solids are always less than 1 000 ppm and in many cases less than 500 ppm.

2.9.2.3 The human resource

Most of the settlers on the Desert Plateau schemes will be of nomadic background and will be recruited from a present population of at least 30 000 people. Assuming farm units of 25 dunums, the desert schemes will require 2 120 farmer/settlers who will have some 15 000 dependants. The Highland areas are already settled and the present population from which the development could draw is about 20 000. The Highland developments require 1 080 farmers with approximately 7 500 dependants.

The work experience of the people of the Desert Plateau is fairly diverse. All have knowledge of nomadic husbandry, many have been in the army, a number have worked as labourers on the roads or railway and some have worked as labour on irrigated farms. Only a small proportion are literate. The large majority of the population of the Highland areas has experience in rainfed agriculture and in husbandry of sheep and goats. Education standards are higher among these settled people than among the Plateau nomads.

All unsettled land is nominally held by the state but the bedouin tribes enjoy traditional rights for pasture and cultivation. Any development on the Desert Plateau with therefore have to be to the advantage of the local tribes and will require their full cooperation. The main land ownership pattern in the settled areas of the Highlands is 'Miri' or restricted land ownership where land owners have the right to use the land but not to abuse it. This land may be inherited. The Government has certain legal rights to repossess Miri land. The tenure pattern is one of part owner-operation and part sharecropping.

Development of groundwater irrigation in the Highlands will necessitate expropriation of scheme lands. This process is legally possible under Natural Resources Law No. 12 of 1968. Redistribution of land after development is covered by Natural Resources Law No. 30 of 1970.

2.9.3 Elements of the Plan and required finance

The areas to be developed are listed in Table 11 together with their water requirements. The main criterion for the allocation between Phases 1 and 2 is the present knowledge of the aquifer system characteristics in any area. Phase 1 schemes are rationally distributed throughout the development region and will use, in conjunction with existing schemes, about one third of the total rechargeable water resource. Phase 2 schemes will increase water use to 90 percent of the rechargeable resource.

Table 11

MEDIUM TERM PLAN FOR DEVELOPMENT OF GROUNDWATER IRRIGATION IN EAST JORDAN:

PLANNED LAND AND WATER USE (areas in dunums)

Scheme	Area implemented or under implementation	Area proposed under		Total area	Required water MCM/annum
		Phase 1	Phase 2		
DESERT PLATEAU					
Siwaqa	-	2 700	-	2 700	4.2
Qatrana	1 700	3 300	10 000	15 000	23.3
Sultani	-	2 700	12 300	15 000	23.3
Abyad	500	1 500	3 000	5 000	7.8
Hasa	-	-	10 000	10 000	15.5
Tell Burma	1 000	1 500	1 500	4 000	6.2
Arja	1 200	900	-	2 100	3.3
Sub-total	4 400	12 600	36 800	53 800	83.6
HIGHLANDS					
Shaubak	-	3 600	-	3 600	2.5
Abu Makhtub	-	2 100	1 900	4 000	2.8
Udruh	-	1 500	1 600	3 100	2.8
Wuheida	-	1 700	-	1 700	1.5
Qurein	-	1 400	2 600	4 000	3.0
Abu Lisan	-	1 200	-	1 200	0.9
Ghuwair-Adir	500	2 000	4 500	7 000	6.7
Other areas	-	-	2 500	2 500	1.9
Sub-total	500	13 500	13 100	27 100	22.1
GRAND TOTAL	4 900	26 100	49 900	80 900	105.7

(Note: The total annual water requirement of Phase 1 is 37 MCM).

Table 12 shows the areas proposed for irrigation development and the required funds. The average cost of Highland schemes is JD 174 per dunum of which land acquisition represents 6 percent. The average cost of Desert Plateau schemes is JD 152 per dunum and the present land value is taken as nil.

2.9.4 Feasibility of the development

The Highland schemes are based on fruit production as an import substitute. They have high rates of return in both economic and financial terms. Internal rates of return will be around 20 percent. Return to farmers will be high so that, even after paying all costs, units of manageable size will provide net annual incomes of well over JD 300. It is considered that all repayments on a 25 dunum farm can be made by the end of year 20.

Desert Plateau schemes have acceptable economic rates of return but some financial subsidy is required. It is proposed that the Government should provide all funds required to a 25 dunum holding for the first three years after which they will become self-financing.

2.9.5 Organization and management requirements

Government organizational arrangements should be made to ensure proper implementation of the plan. The irrigation development suggested is planned for public investment. Government will assume entire responsibility for the design, construction and on-farm development of the schemes. The operation and maintenance of the water supply and distribution systems, soil reclamation, cropping and training of farmers will remain the responsibility of Government during the development period.

The success of the proposed plan depends basically on efficient coordination of the activities of the different agencies involved. At present, separate divisions of the NRA are responsible for soil survey, groundwater investigations, well construction, design and construction of irrigation schemes and operation and maintenance of pumps and irrigation networks. Several departments within the Ministry of Agriculture have interests in the agricultural activities relating to irrigated farming including soil reclamation and land levelling, on-farm development, cropping, training of farmers and scheme management. Finance for development is provided through the National Planning Council. It is envisaged that the Cooperative Organization will perform an ever increasing role as development proceeds.

Table 12

MEDIUM-TERM PLAN FOR DEVELOPMENT OF GROUNDWATER IRRIGATION IN EAST JORDAN: AREA, PHASING AND FUNDING

Scheme	Net area in dunum				Required Funds (JD '000)			
	Implemented or under implementation	Proposed under Phase 1	Proposed under Phase 2	Total area	Construction	On-farm development	Credit and subsidies	Total
A. DESERT PLATEAU								
1. Siwaqa	-	2 700	-	2 700	243	62	108	413
2. Qatrana	1 700	3 300	10 000	15 000	1 197	306	532	2 035
3. Sultani	-	2 700	12 300	15 000	1 350	345	600	2 295
4. Abyad	500	1 500	3 000	5 000	405	103	180	688
5. Hasa	-	-	10 000	10 000	900	230	400	1 530
6. Tell Burma	1 000	1 500	1 500	4 000	270	69	120	459
7. Arja	1 200	900	-	2 100	81	21	36	138
Sub-total	4 400	12 600	36 800	53 800	4 446	1 136	1 976	7 558
B. HIGHLANDS								
1. Shaubak	-	3 600	-	3 600	266	136	220	622
2. Abu Makhtoub	-	2 100	1 900	4 000	296	152	244	692
3. Udruh	-	1 500	1 600	3 100	230	118	189	537
4. Wuheida	-	1 700	-	1 700	126	65	104	295
5. Qurein	-	1 400	2 600	4 000	296	152	244	692
6. Abu Lisan	-	1 200	-	1 200	89	46	73	208
7. Ghuweir - Adir	500	2 000	4 500	7 000	481	247	397	1 125
8. Other areas	-	-	2 500	2 500	185	95	152	432
Sub-total	500	13 500	13 100	27 100	1 969	1 011	1 623	4 603
GRAND TOTAL	4 900	26 100	49 900	80 900	6 415	2 147	3 599	12 161

Although this division of responsibility is to some extent inevitable, greater coordination could be achieved if a mutually agreed programme, correctly budgetted and financed, were established.

The government agencies involved in the implementation of the plan are National Planning Council, NRA, Ministry of Agriculture and the Cooperative Organization. It is recommended that a permanent Coordinating Committee be formed from representatives of these agencies under the chairmanship of the National Planning Council. The Committee will be responsible for securing prompt performance by all agencies of the services and work which each has to provide to support the implementation of the plan and the management of the schemes, and for the allocation of the required funds.

It is also recommended the an Irrigation Development Unit be formed within the Ministry of Agriculture which will be responsible for:

- providing liaison with other agencies involved with the plan;
- land preparation;
- on-farm development of the new schemes;
- management of the schemes during the development period;
- settler training;
- carrying out field trials and studies relating to cropping patterns, crops and agricultural and irrigation techniques.

The unit will make provision for providing the schemes with all necessary equipment (tractors, farm machinery, transport, etc.), supplies (seeds, fertilizers, tools, tree planting material) and facilities (stores, staff housing, communications).

Good maintenance of pumps, power units and farm equipment is an important factor. It is recommended to establish a central workshop in one of the schemes and to make available mobile repair units for servicing all farm equipment. The standardization of equipment and the holding of an adequate supply of spare parts will facilitate maintenance.

Staff of all categories are available in Jordan. However, attention should be paid to recruiting the best qualified personnel. To attract well qualified staff to stay in the field, good living conditions, transportation facilities and a special field allowance should be provided.

A fellowship programme for practical (non-academic) training in farm management, water use, irrigation practices and design of irrigation schemes is required to improve the technical standard of the staff. Training of mechanics and tractor drivers should be organized at regular intervals.

2.10 TRAINING AND EXTENSION

In-service training was provided in most fields of the project's work to the counterpart hydrogeologists, design and irrigation engineers, agronomists and economists and to the field staff working in the operational irrigation schemes. In spite of some difficulties due to the insufficient number of counterparts and to changes of some of them, new ideas and techniques were introduced. Considerable experience was gained by counterpart engineers in the design of irrigation schemes and they are now capable of continuing the work, though guidance is still required. Agronomists were introduced to modern cultural techniques, seed production and field trials. Irrigation agronomists began to be familiar with the different methods of irrigation, including sprinkler, and the technique of water requirement trials. Economists were introduced to the economic appraisal of irrigation schemes and to the method of analysis by internal rate of return. A considerable contribution of the project to the training of counterpart staff was the production of several technical and working papers which provide guidance for future work. The design work prepared by the project can be considered as model design for future work.

Five fellowships were scheduled for training in the relevant disciplines in institutions outside the country. However, due to Government delay in nominating the candidates and to language difficulties, only three fellowships were finally awarded (Appendix 2). Seven Government officials participated in four seminars organized by FAO in different countries.

It is greatly in the interests of the Government not to lose the services of the trained personnel on conclusion of the project.

The project was not staffed with extension specialists to take direct action in this field. However, the staff provided their technical assistance when required, mainly in cultural techniques and irrigation application.

3. RECOMMENDATIONS

In assessing the results of the project and in considering the recommendations it is pertinent to remember that project field activities were curtailed by one year - this had a more adverse effect on the quality of results than on the quantity of the work. The project was however able to fulfil many of its objectives, while progress in other spheres of activity was proportional to the duration of the project.

Groundwater management activities proceeded in accordance with the planned programme and a considerable part of the objectives was reached.

The time available for the agronomic studies was limited. Most of the trials were carried out on newly reclaimed areas with salinity and alkalinity problems, badly levelled and with bad soil structure. Many of the trials failed because it was not possible to obtain good crop stands, as well as through lack of sufficient attention from local staff. In spite of these difficulties, some interesting results were obtained, mainly in wheat production.

Work on water requirement and irrigation efficiency was carried out under the responsibility of the project for only 18 months. Most of the time available was spent on preparatory work. It is regrettable that the Government decided to take over this activity before the establishment of all field experiments and without giving the project sufficient time to reach final conclusions. As a result, the project was not able to use field data for the crop water requirements and most of the design work was based on water requirements calculated through special formulas.

Design of irrigation schemes was a most successful activity and in spite of the shortened duration, the project was able to produce preliminary designs for 25 000 dunums and final design for 11 900 dunums, in respect of the 30 000 dunums and 3 000 dunums set out in the Plan of Operation. Technical and Working Papers produced by the project examine in detail problems related to the design work in such a manner as to provide guidance to the counterparts.

Most of the objectives of the agro-economic studies were attained. It should however be mentioned that the feasibility studies were based on yield and water use estimates because of the limited data available from field trials.

The Medium Term Plan for Development of Groundwater Irrigation in East Jordan, for a total area of 80 000 dunums, provides the Government with an investment possibility estimated at over JD 12 million and can be considered a major project achievement.

Considerable progress was made in training counterpart staff in all activities, and for the first time the Design Section of the NRA was able to produce final designs for irrigation schemes.

3.1 ORGANIZATIONAL RECOMMENDATIONS

If the implementation of the suggested Medium Term Plan for Development of Groundwater Irrigation in East Jordan becomes government policy, organizational arrangements should be made to ensure proper implementation.

3.1.1 Formation of a Coordination Committee

It is recommended that a permanent Coordination Committee be formed comprising representatives of the National Planning Council, the NRA, the Ministry of Agriculture and the Cooperative Organization. The Committee will be responsible for securing prompt performance by all agencies of the services and work they are to provide in the implementation of the Plan and the management of the schemes, and for the allocation of the required funds.

3.1.2 Formation of an Irrigation Development Unit

It is recommended that an Irrigation Development Unit be formed within the Ministry of Agriculture to be responsible for providing liaison with other agencies involved with the Plan, on-farm development of the new irrigation schemes, management of the schemes during the development period, carrying out field trials and studies related to, e.g., cropping pattern, varieties, agricultural techniques, initiated by the project, land preparation and preparation of the annual budgets for all these activities.

3.2 TECHNICAL RECOMMENDATIONS

Detailed technical recommendations are given in the various documents prepared by the project (Appendix 4). Some general technical recommendations are given below.

3.2.1 Groundwater management

It is considered that present knowledge of water resources availability is sufficient to make feasible the implementation of the Medium Term Plan for Development of Groundwater Irrigation in East Jordan on the basis of a gross water extraction equivalent to the estimated annual recharge. It is, however, recommended that development should be phased and new assessments of water availability should be made for each area in the light of new data obtained on aquifer response. Therefore the data collection programme to provide information on aquifer response to production pumping should be a continuous process. In some areas, digital models should be established after some years of pumping to assess the availability of water for further extension of the irrigation.

3.2.2 Agronomic studies

Agronomic work carried out during the two seasons available provided only preliminary results on the crop/varieties testing, use of fertilizers, cultural techniques and cropping patterns. Working-out of the details still remains to be completed and additional trials should be undertaken to obtain final conclusions.

3.2.3 Crop water requirements

The studies on crop water requirements initiated by the project have not been completed and only some preliminary results were obtained. It is essential that these studies should continue in order to provide final conclusions. Maximizing yields for some crops (e.g. alfalfa) entails very high water consumption which probably is not an economic practice. Therefore systematic water stress trials should be continued in order to assure the best use of the expensive water.

Jordan lacks experience in orchard irrigation, and attention should be paid to the experiments at Shaubak and to the drip irrigation experiment at El Hussein Station.

It is greatly appreciated that the Government, following a suggestion of the project, decided to establish a Water Requirement and Irrigation Section in the Irrigation Department of NRA, which will be responsible for the continuation of the above studies. This Section should be strengthened with one or two more agronomists and funds should be made available for equipment and supplies.

3.2.4 Design of irrigation schemes

The project provided design standards and cost estimates for irrigation schemes on the basis of the available data and cost-prices information. These estimates and standards should be periodically revised as new experience is gained through operation of the schemes and as new cost-prices information becomes available. In particular, designs may require review to take account of present energy costs.

Although considerable progress was made in training counterparts in the design work, it is considered that further UN assistance is required in this activity. It is recommended that the services of a UN Irrigation Engineer be provided for two years to assist the Government in the design and construction of new irrigation schemes.

The Design Section of NRA should be strengthened with the appointment of two or three young engineers who will receive in-service training in the design work during the assignment of the UN expert.

3.2.5 Agro-economic studies

The project established a methodology for agro-economic studies and provided several models of feasibility reports. These studies are of a continuous nature and collection of basic data and frequent revisions of basic assumptions are necessary.

Appendix 1

PROJECT STAFF

A. International Staff

Name	Country	Activity	Period of Work From	To
P. Economides	Greece	Project Manager	21. 1.71	30. 6.74
W. Genet	Netherlands	Irrigation Engineer	14.11.71	31.10.73
S.P. Kohli	India	Agronomist	16.12.71	31.12.73
O. Wahbi	Egypt	Agricultural Economist	27. 3.71	31. 7.71
D.R. Steeds	U.K.	Agricultural Economist	19.10.71	31.10.73
C. Petersen	Denmark	Irrigation Methods and Practice (Associate expert)	15.10.71	22. 6.73
C. Jurgens	Netherlands	Farm Management (Associate expert)	19.11.71	27. 9.73
P. van den Hoven	Netherlands	Design Engineer (Associate expert)	3.12.71	2. 9.73

Consultants

Name	Country	Activity
W. Barber	U.K.	Hydrogeology
P. Scharlacken	Belgium	Agricultural Engineering
C. van den Berg	Netherlands	Soil Reclamation
E. Reiss	Germany, Fed. Rep.	Power-Pumping
G. Hutchison	U.K.	Power-Pumping
A. Abukhaled	Lebanon	Water Requirements
S. Yacoub	Jordan	Sociology
J. Arrighi de Casanova	France	Irrigation Methods and Practice
S. Schembri	Italy	Animal Husbandry
D. Carr	U.K.	Computer Programmes
F. Lalatta	Italy	Horticulture

B. Senior Counterpart Staff

Najeeb Tleel	Project Co-Manager
Badr Hirzalla	Hydrogeologist - Liaison Officer
Mazhar Toughan	Hydrogeologist
Salem Ayoub	Design Engineer
Youssef Khalidi	Design Engineer
Abdallah Suheimat	Design Engineer

B. Senior Counterpart Staff (Cont'd)

Name	Activity
Marwan Rasheed	Design Engineer
Mohamed Hani	Irrigation Engineer
Fahed Abu Kamar	Irrigation Agronomist
Mohamed Hanbali	Irrigation Agronomist
Hani Rasheed	Irrigation Agronomist
Munir Fakhuri	Irrigation Agronomist
Bassam Nimri	Agronomist
Jemil Qheiwi	Agronomist
Akram Turk	Agronomist
Khalil Hamdoukh	Soil Surveyor
Rassem Anshassi	Soil Surveyor
Walid Abdel Rahman	Soil Surveyor
Ahmed Abu Sheikha	Agricultural Economist
Hisham El Haj Khalil	Agricultural Economist

Appendix 2

FELLOWSHIPS AND IN-SERVICE TRAINING

A. FELLOWSHIPS

Name	Subject	Duration (months)	Training Place	Country
Youssef Khalidi	Design, construction and specification of irrigation projects	9	Bureau of Reclamation, Denver, Colorado	U.S.A.
Mohamed Hanbali	Irrigation management	9	Bureau of Reclamation, Denver, Colorado	U.S.A.
Bassam Nemri	Water use	18	University of Arizona, Tucson	U.S.A.

B. IN-SERVICE TRAINING

During in-service training of counterparts, particular attention was paid to the following subjects:

Design of irrigation schemes:

Choice of power plant, choice of irrigation method, design principles, land levelling, technical specifications, cost estimates and contract documents.

Water requirements - irrigation efficiency trials:

Experimentation techniques, use of special equipment, interpretation of field data and presentation of results.

Agronomic studies and trials:

Agricultural and experimentation techniques, seed production and improvement, use of farm machinery, use of fertilizers, lamb fattening, interpretation of field data and presentation of results.

Agro-economic studies:

Internal rate of return, feasibility studies, socio-economic survey of settlers.

Appendix 3

MAJOR EQUIPMENT PROVIDED BY UNDP

Description	Make/model	No.
Station Wagon	Peugeot/404	2
Station Wagon	Land Rover/109	3
Caravan trailer	Hosking	1
Automatic level	Kern/GK 1-AC	2
Typewriter	Olivetti LL-32	2
Camera	Minolta/ALF	2
Still-Branstead	Fisher/9.026.2	1
Gnerator diesel	Honda/E-4000	1
Pump deepwell and diesel engine	Peerless/Caterpillar	1
Tractor-Bulldozer	Caterpillar/D-4	1
Tractor	Ford/4000	3
Tractor	Ford/5000	3
Sunshine recorder	Lambrecht	1
Wind-run indicator	Lambrecht/1440	2
Hydrograph	Lambrecht/250	1
Thermograph	Lambrecht/251	1
Sheller maize	Hippo/No. 4 A	1
Sprinkler Broadcaster	Massey-Ferguson/22	1
Thresher Nursery	Vogel	1
Heavy Duty toolbar	John Deer	1
Rotary cutter	Moorhouse	1

In addition, the following equipment of Phase I (JOR/9) was absorbed by the present Phase II:

Pick-up	Land Rover/88	3
Station Wagon	Land Rover/109	2
Calculating Machine	Facit/CAL-13	2
Calculating Machine	Contex/55	1
Typewriter	Olivetti/LL 32	2
Altimeter Barometric	Paulin/Palab	2
Stop Watches	Seiko	3
Copying Machine	Eskofot/Planocop	1
Conductivity bridge	Phillips	1
Balance analytical	Kolb	2
Balance analytical	ASE/Monapan	1
Balance analytical	ASE/Toppan	1
Oven	Fisher/Isotemp	1
Shaker-Sieve	Soiltest/CL-394B	1
pH meter	Beckman/9601	1
Spectrophotometer	Beckman/B	1
Measuring line	Eastco/Standard	1

Description	Make/Model	No.
Photometer flame	Hitachi/FPF-2	1
Conductivity meter	Industrial Instr./RB3-R104	1
Bath hydrometer jar	Soiltest/CL-278D	1
Stirrer	Soiltest/CL-273	1
Binocular	Yachica/8 x 40	6
Stereoscope mirror	Toko/II, 3x	1
Duplicating machine	Rex-Rotary/M4	1
Conductivity-pH meters	WTW/LF-54/pH-54	1
Harrow	Massey-Ferguson/831	1
Harrow	Massey-Ferguson/34	1
Moisture Meter Bouyokos	Soiltest/A-74	1
Extractor pressure membrane	Soilmoisture Equip. Corp.	1
Tool carrier	Massey-Ferguson/80	1
Planter	Massey-Ferguson/37	2
Plough	Massey-Ferguson/56-12	1
Plough-chisel	Massey-Ferguson/24-7	1
Plough mouldboard	Massey-Ferguson/30	1
Mower conditioner	New Holland/Haybune 444	1
Tractor	Massey-Ferguson/165	2
Drill multipurpose	Massey-Ferguson/34-7	1
Tiller	Massey-Ferguson/738	1
Trailer tipping	Massey-Ferguson/21	1
Ridger	Massey-Ferguson/728	1
Seeder-grass	Brillion/SSP60T	1
Wagon forage	Gehl/G806	1
Pulverizer soil	Brillion/LG168	1
Cultivator	Massey Ferguson/37	1
Smoother land	Eversman/3212 D	1
Leveller land	Eversman/TM1-10	2
Sprayer	Dorman	1
Neutron probe	Pitman/225	1
Baler	New Holland/276	1
Forage harvester	New Holland/717	1
Pumping unit	Volvo-Penta	1

Appendix 4

DOCUMENTS PREPARED DURING THE PROJECT

A. ABSTRACTS OF KEY TECHNICAL REPORTS

(1) FAO. Development and Use of Groundwater Resources of East Jordan, Jordan. Agronomic experimental studies and development of crop production, based on the work of S.P. Kohli.

ABSTRACT

The aim of the work reported which was carried out under the UNDP/FAO project was to supply basic information that would permit the initiation of crop production in the newly developing groundwater irrigated desert-climate areas of East Jordan. Little information was available regarding successful irrigated crop production work. During the short period of the field activities of the project, only preliminary testing of the ideas and materials developed was possible.

A vigorous effort was launched for collecting the seed material of various crop varieties from FAO sources as well as from many other countries through direct contacts. These seeds were grown at different centres in the country. Of the crops found most suitable for irrigated culture, the following may be listed: cereals: wheat, barley, oats, maize, sorghum; oil-seeds: sunflower, soybeans, safflower, rapes; vegetables: tomato, melons, cucumbers, onions, cauliflower; forage crops: alfalfa, sudax, sorghum; other crops: sugarbeet, cotton.

Crop improvement objectives were determined and varietal testing work on wheat, maize, oats, sorghum, barley, soybean, tomato, alfalfa and other crops was carried out during the two seasons available. The varieties showing promise on the basis of preliminary testing were identified and seed-increased for use in further varietal trials and observations.

Irrigation and fertilizer requirement studies on wheat made some progress while those on maize were initiated. Wheat yields of over 5 t/ha with 12 irrigations (about 700 mm water) were obtained. Fairly good yields (3-4 t/ha) were obtained by using moderate quantities of water (about 400 mm). This finding may be economically useful since the limiting factor in the desert areas is water and not land.

The natural soil fertility appears to be good. Nitrogenous fertilizers beyond 75 kg N/ha failed to show response on wheat crop.

(2) FAO. Development and Use of Groundwater Resources of East Jordan. Medium Term Plan for Development of Groundwater Irrigation in East Jordan.

ABSTRACT

This report, prepared during the UNDP/FAO project JOR/525 describes a plan for the development of irrigated agriculture based on groundwater to be obtained from the Amman-Wadi Sir aquifer system. It proposes development of about 80 000 dunums of irrigated land distributed in 15 areas in the Western Highlands and on the Plateau between Amman and the Ras en Naqb escarpment. Some 27 000 dunums of the planned development are in the Highlands and will be based on fruit production, mainly apples and grapes. The remaining 53 000 dunums are on the Desert Plateau where production of fodder, cereals, and some vegetables is proposed.

The plan envisages phased development because of uncertainties concerning the response of the aquifer system to production pumping. The proposed first phase development totals about 31 000 dunums of which 4 900 dunums are, or are being, implemented. It is considered that, if finance is made available, the first phase could be completed in four to five years and the entire plan could be implemented in about ten years. Five of the proposed first phase schemes totalling 12 000 dunums are included in the Government's current three-year plan.

Final designs have been prepared for the above five schemes. In addition, preliminary designs are available for five other schemes totalling 12 500 dunums. The plateau schemes which are based on field crops will be irrigated by sprinklers and the power requirements will be provided by diesel electric generators. The fruit schemes in the highlands will be irrigated by piped water to three individual basins and the water will usually be pumped by diesel direct drive, vertical shaft turbine pumps.

The funds required for the entire Plan for three types of activity - construction of irrigation systems, on farm-development and credit and subsidies are estimated to be JD 12.2 million. The fruit production schemes will be very profitable with internal rates of return of about 20 percent. The field crop schemes are more marginal but internal rates of return should not fall below 10 percent. Marketing the produce should present no serious problems since all the production is destined for domestic markets.

The entire development is planned for public investment. Operation and maintenance of the water supply and distribution systems will remain the responsibility of Government. Such farm mechanization as is required for the field crop schemes will be provided by a form of government-operated cooperatives. All investments in the Highland fruit producing schemes will be fully recovered and the farmers will attain freehold ownership of the land. The field crop production schemes will require initial unrecoverable subsidy from Government, and ownership of land will remain with the public sector though the farmers will have security of tenure.

B. TECHNICAL PAPERS HANDED INFORMALLY TO THE GOVERNMENT

(3)	No.	1	Choice of reservoirs. September 1973
(4)	"	2	Choice of irrigation method. September 1973
(5)	"	3	Choice of plant for deepwell pumping. September 1973
(6)	"	4	Feasibility report on a Highland scheme: Abu-Lisan. September 1973
(7)	"	5	Feasibility report on a Desert scheme: Sultani. September 1973
(8)	"	6	Results of lamb fattening trials. October 1973
(9)	"	7	Design standards and cost estimates for irrigation schemes. November 1973

C. WORKING PAPERS PREPARED FOR INTERNAL USE OF THE PROJECT

(10)	No.	1	Calculated water use in the proposed irrigation development areas. June 1972
(11)	"	2	Note on wind velocities, directions and wind-break data from Qatrana Pilot Area 1971. July 1972
(12)	"	3	Optimum discharge of wells in Qatrana Extension. October 1972
(13)	"	4	Irrigation efficiencies in basins. November 1972
(14)	"	5	Sprinkler irrigation efficiencies. November 1972
(15)	"	6	Pumping costs and optimum discharge from wells (diesel engine - shaft pump). November 1972
(16)	"	7	Pumping costs and optimum discharge from wells (electric submersible pumps). December 1972
(17)	"	8	Pumping cost and optimum discharge from wells (several electric submersible pumps powered by a central diesel generator). January 1973
(18)	"	9	Wind conditions and effect on sprinkler irrigation in the Desert Schemes. January 1973
(19)	"	10	Results of 1972 lamb fattening exercise at Qatrana. January 1973
(20)	"	11	Programme for irrigation of apple trees at Shaubak Experimental Station 1973. March 1973.
(21)	"	12	Irrigation and leaching requirement in the Desert Schemes. August 1973
(22)	"	13	Farm machinery costs in Desert Basin Schemes. March 1973
(23)	"	14	Selection of diameter of pipelines. October 1973
(24)	"	15	Experiment on water requirements of wheat at Qatrana. October 1973
(25)	"	16	Optimum layout of pipelines. November 1973
(26)	"	17	Results on efficiency trials on basin irrigation at Qatrana. December 1973.

D. CONSULTANTS' REPORTS

(27) Barber, W. Consultant Hydrogeologist. Consultant mission report. March 1971.

(28) Barber, W. Consultant Hydrogeologist. Consultant mission report. September 1971.

(29) Barber, W. Consultant Hydrogeologist. Consultant mission report. January 1972.

(30) Barber, W. Consultant Hydrogeologist. Consultant mission report. August 1972.

(31) Barber, W. Consultant Hydrogeologist. Consultant mission report. February 1973.

(32) P.B. Scharlaeken. Agricultural Engineer. Consultant mission report. January 1972.

(33) Bundesanstalt für Bodenforschung, Hannover. Electric analog studies of the Amman - Wadi Sir Aquifer in the Shaubak - Ras en Naqb area. February 1972.

(34) Dr. C. van den Berg. Consultant Soil Reclamation. Consultant mission report. March 1972.

(35) Lahmeyer International GMBH Power Consultants. Power sources. April 1972.

(36) J. Arrighi de Casanova. Consultant in Irrigation. Report on a consultant mission. May 1972.

(37) S. Yacoub. Consultant Sociologist. A socio-economic survey of the settler-candidates in the Qatrana irrigated farming pilot project in East Jordan. June 1972.

(38) A study of the Wadi Dhuleil irrigation project in East Jordan: preliminary investigation. December 1973.

(39) A social and economic evaluation of the Al-Jafr Bedouin settlement project in East Jordan.

(40) S. Schembri. Animal Husbandry Expert. Development of animal husbandry in Jordan. July 1972.

(41) Raikes and Partners. Digital model of the Wadi Dhuleil area of East Jordan. October 1972.

(42) Raikes and Partners. Digital model of the Qatrana well field area of East Jordan. October 1972.

(43) Raikes and Partners. Digital model of the shallow aquifer complex of the Azraq Basin, East Jordan. April 1973.

(44) Raikes and Partners. Digital model of the Wadi Dhuleil area of East Jordan. Supplementary Report 1973.

(45) D. Carr. Consultant on Computer Programmes. Report on the technical mission. November 1972.

(46) A. Abukhaled. Consultant in Water Use. Review of experimental work on crop water use and irrigation practices at Qatrana, Jordan. January 1973.

(47) A. Abukhaled. Consultant in Water Use, and M. Hanbali, Irrigation Specialist. Evaluation of data on crop water use and irrigation methods in Jordan. March 1974.

(48) F. Lalatta. Consultant Horticulturist. Fruit culture development in pilot areas of East Jordan. February 1973.

(49) Engineering and Power Development Consultant Limited. Power supplies for FAO groundwater project Southern Jordan. May 1973.

Appendix 5

REFERENCES

Agrar-und Hydrotechnik. Feasibility study on sugar beet cultivation and sugar
1974 production in Jordan.

FAO. Investigation of the Sandstone Aquifers of East Jordan, Jordan.
1969 Hydrogeology of the southern desert of Jordan, based on the work of J.W. Lloyd. Rome. LA:SF/JOR/9, Technical Report 1.

FAO. Investigation of the Sandstone Aquifers of East Jordan, Jordan.
1970 The hydrogeology of the Mesozoic-Cainozoic aquifers of the western highlands and plateau of East Jordan, based on the work of D.H. Parker. Rome. AGL:SF/JOR 9, Technical Report 2.

FAO. Investigation of the Sandstone Aquifers of East Jordan, Jordan. Rome.
1971 AGL:SF/JOR 9, Interim Report.

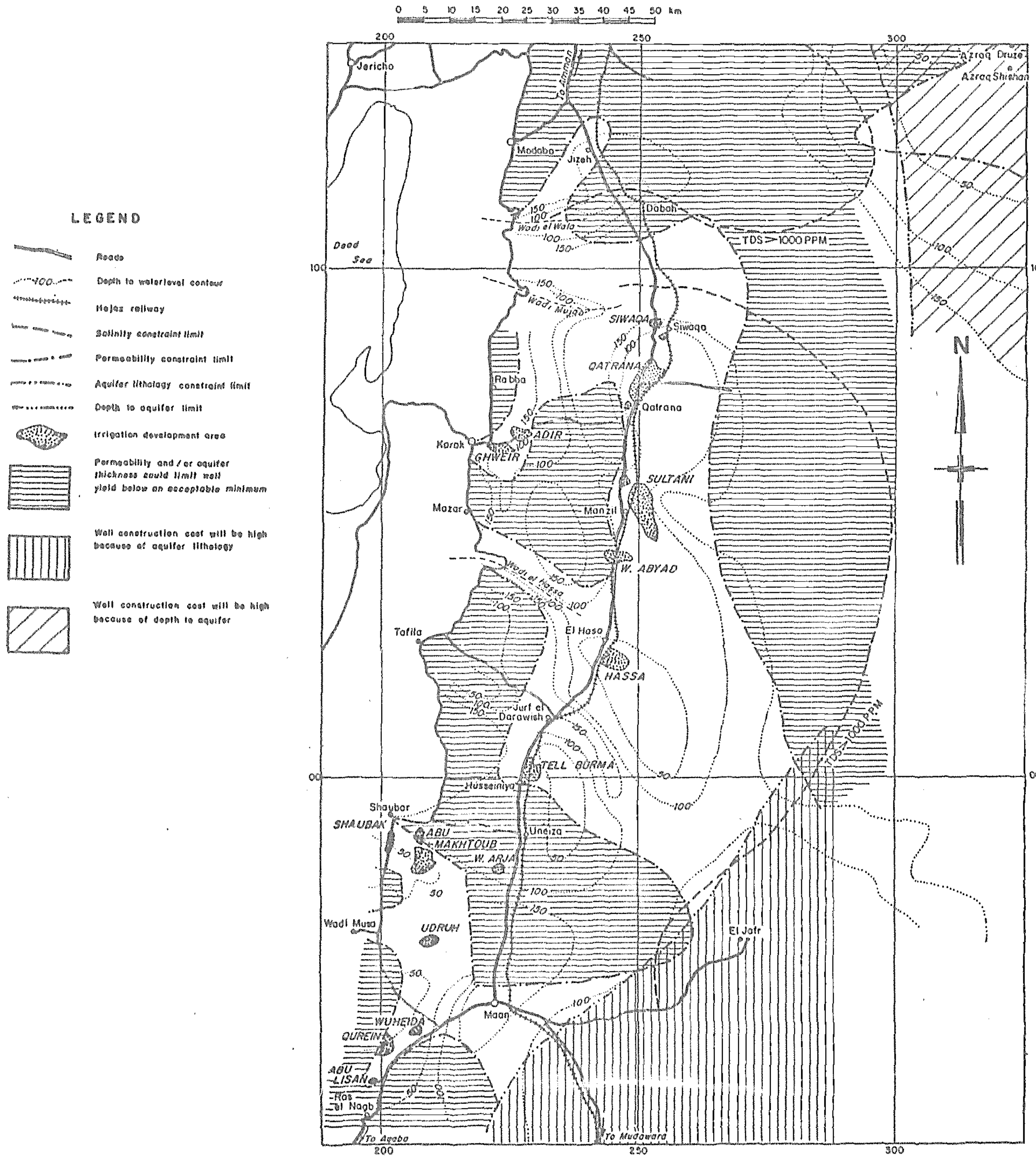
FAO. Investigation of the Sandstone Aquifers of East Jordan, Jordan. Agro-
1972a economic studies of irrigated farm production, based on the work of G.H. Ward. Rome. AGL:SF/JOR 9, Technical Report 3.

FAO. Investigation of the Sandstone Aquifers of East Jordan, Jordan. Soil
1972b studies and land classification of the agricultural development areas. AGL:SF/JOR 9, Technical Report 4.

US Department of the Interior. Bureau of Reclamation Manual, Vol. V, Part 2.
1953 Washington, D.C.

Map 1

EAST JORDAN WATER AVAILABILITY MAP AND LOCATION OF THE PROPOSED AREAS FOR DEVELOPMENT



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