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6TH
NEAR EAST - SOUTH ASIA REGIONAL IRRIGATION PRACTICES SEMINAR

AMMAN, JORDAN
1966

Foreword

The proceedings of the Sixth Near East-South Asia Irrigation Practices Seminar are reported in this volume. The seminar was co-sponsored by the Government of Jordan and the United States Department of State Agency for International Development, and was held in Amman, Jordan, from March 19 to March 30, 1966.

Fifteen nations of the NESA Region sent delegates to the seminar as follows: Afghanistan, Ceylon, Cyprus, Greece, India, Iran, Iraq, Jordan, Lebanon, Nepal, Pakistan, Saudi-Arabia, Syria, Turkey, and the United Arab Republic. Observers were present from the United Kingdom and the United Nations Food and Agriculture Organization (FAO).

The seminar series, sponsored by the United States Agency for International Development, had its beginning in Izmir, Turkey, in 1956, and has been held biennially since that time with meetings successively in Tehran, Iran; Lahore, Pakistan; Ankara, Turkey, and New Delhi, India.

Delegates to the seminar were appointed by their respective governments from officials having a major responsibility concerned with irrigation in their countries. The delegates dedicated their efforts in the seminar towards the task of finding solutions to the many problems concerned with irrigation practice, realizing that legal practices, institutional practices, social customs, and water delivery practices beyond the control of the irrigator have a profound effect upon the efficiency of water use under irrigation, but that the effect of all practices, including those of the irrigator, are integrated at the farms and fields being served. The seminar was effectively used by the delegates to study problems, exchange ideas, discuss mutual problems, and formulate plans for better use of the land and water resources of the NESA Region.

A. Alvin Bishop

USAID/Washington

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Sixth Near East-South Asia Regional Irrigation Practices Seminar

March 19-30, 1966

Amman, Jordan

Co-Sponsored by

The Government of Jordan, Host

and

U.S. Agency for International Development

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Farm Irrigation Adviser

Program

SIXTH NESA IRRIGATION PRACTICES SEMINAR

March 19-30, 1966

Amman, Jordan

Saturday, March 19

0800 *Registration of Delegates*

1000 *Inauguration*

Welcome Address by Dr. Najm ad-Din Dajani, Secretary General, Jordan Development Board

Welcome Address by Joseph C. Wheeler, Director, USAID/Jordan

Welcome Address by Dr. M. S. Fayyad, Head, Jordanian Delegation

Response by Mohamad El-Madany, Technical Advisor, Irrigation Ministry, United Arab Republic

Opening Remarks and Orientation by Dr. A. Alvin Bishop

1200 *Executive Committee Meeting*

Sunday, March 20

0800 Chairman, Dr. M. Fayyad, Jordan

Country Progress Reports by Afghanistan, Ceylon and Cyprus

1030 Chairman, Mohamad H. Parwana, Afghanistan

Country Progress Reports by Jordan, India and Iran

1230 Chairman, Thuraippah Thiruchittampalam, Ceylon

Country Progress Reports by Pakistan and Saudi Arabia

1630 *Executive Committee Meeting*

Monday, March 21

0800 Chairman, C.A.C. Konteatis, Cyprus

Country Progress Reports by Saudi Arabia, Syria and Turkey

1030 Chairman, D. B. Anand, India

Country Progress Reports by United Arab

Republic and Nepal

TECHNICAL SESSION: *Drainage and Salinity*

Some Drainage Problems and Drainage Reclamation in India

1230 Chairman, Asghar Azzarnia, Iran

TECHNICAL SESSION: *Drainage and Salinity* (continued)

Irrigation, Salinity and Drainage in Iraqi Delta, Iraq

The Problem of Waterlogging and Salinity, Pakistan

Tuesday, March 22

0900 Chairman, Nuri Hayali, Iraq

TECHNICAL SESSION: *Drainage and Salinity* (continued)

Drainage and Salinity Problems in Turkey and Maltepe Tile Drainage Project, Turkey

Evolution and Reclamation of Alkali Soils in UAR

TECHNICAL SESSION: *National Programs*

Organizational Responsibilities for Irrigation in India

Land Reform Problems, Iran

1120 Chairman, P. P. Gorkhaly, Nepal

TECHNICAL SESSION: *National Programs* (continued)

Financing Individual and Group Irrigation Projects in Jordan

National Programs for Improvement of Irrigated Agriculture in Turkey

The Control and Distribution of Irrigation Water in the United Arab Republic

TECHNICAL SESSION: *Farm Layout for Irrigated Agriculture*

Water-Use Improvement Project, Cyprus

Irrigation Development of the Khuzestan Region, Iran

2000 Dinner sponsored by Jordan Development Board

Wednesday, March 23

0800 Chairman, Muhammad H. Chaudhry, Pakistan

TECHNICAL SESSION: *Farm Layout for Irrigated Agriculture* (continued)

Farms Sizes, Considering Social and Economic Aspects in Irrigation Project Areas, Turkey

TECHNICAL SESSION: *Small Projects*

Rehabilitation of Bohlan Lateral, Helman Valley Project, Afghanistan

Problems in Planning an Irrigation Project in Cyprus

Water Development Projects in the Southern Desert of Jordan

1050 Chairman, Ayten Aydin, Turkey

TECHNICAL SESSION: *Small Projects* (continued)

Small Irrigation Project, Ghazvin Region, Iran

Development of Small Irrigation Projects and Cavak Irrigation Project, Turkey

Pumping Operation of Drainage Wells, UAR

TECHNICAL SESSION: *Technical Factors*

Water Budget of Shiraz Valley and Its Comparison to Water Requirement of Crops, Iran

1240 Chairman, Kimon Constantinidis, Greece

TECHNICAL SESSION: *Technical Factors* (continued)

Cropping Patterns and Irrigation Practices, Pakistan

Soil Moisture as a Function of Plant Growth, Pakistan

1630 *Executive Committee Meeting*

Thursday, March 24

0800 Chairman, Hashim Roumani, Syrian Arab Republic

Country Progress Report by Greece

TECHNICAL SESSION: *Technical Factors* (continued)

Technical Factors in Irrigation Practices, Turkey

TECHNICAL SESSION: *Research*

Evaluating Lands for Irrigation Commands, India

Evaluation of Sprinkler Method of Irrigation and Its Comparison to Furrow Method, Iran

1030 *Panel Meetings*

Friday, March 25

Field Trip to Jerusalem Area. Lunch sponsored by Jerusalem Municipality

Saturday, March 26

0800 Chairman Mohamad El-Madany, UAR

TECHNICAL SESSION: *Research* (continued)

Studies on the Use of Saline Groundwater for Irrigation, Pakistan

Studies on Irrigation Practices for Increased Production and Salinity Control, Pakistan

Irrigation Application Trials to Meet the Peak Needs of Crops During Short Supply Period, Pakistan

Measuring Devices for Farm Turnouts and Pipes, Turkey

Cartographic and Photographic Facilities for Soil and Water Development Projects in TOPRAKSU, Turkey

1030 *Panel Meetings*

2000 Dinner sponsored by USAID

Sunday, March 27

0800 Chairman, Dr. Sami Suna', Jordan

Country Progress (remarks only; no prepared report), Lebanon

TECHNICAL SESSION: *Education and Training*

Plans for Education and Training in Irrigation in Cyprus

How Research is Carried to the Cultivators in India

Selection of Technical Staff and On-the-Job Training, Iran

Organization of Irrigation in the Irrigation System of Greece

1030 *Panel Meetings*

1630 *Executive Committee Meeting*

Monday, March 28

0700 *Field Trip to the East Ghor*

Tuesday, March 29

0700 *Field Trip to the East Ghor*

Wednesday, March 30

0800 *Executive Committee Meeting*

1000 Chairman, Dr. Sami Suna', Jordan

TECHNICAL SESSION: *Panel Reports*

1230 *Closing Session*

Chairman, Dr. M. Fayyad, Jordan

Report of Executive Committee, Dr. Sami Suna'

General Business, including: Resolution by Syrian delegate; invitations by Cyprus and UAR for the Seventh Seminar.

Seminar Report, Dr. A. Alvin Bishop

Delegate Appraisal, D. B. Anand

Delegate Appraisal, Hashim Roumani

Observations by USAID, Emory M. Howard

Closing Address, Dr. Najm ad-Din Dajani

1400 *Adjourn*

CHAPTER I

OPENING SESSION

Chairman

DR. HANNA ODEH

Director of Planning and Research

Jordan Development Board

Welcome Address

by

DR. NAJM AD-DIN DAJANI

Secretary General, Jordan Development Board

Your Excellencies,

Gentlemen,

I have the honor of welcoming each of you on behalf of His Majesty the King, the Government and people of this country, on this occasion of inaugurating the Sixth Irrigation Seminar in Amman, the deliberations of which, I hope, will promote those of previous seminars.

The exchange of information in such seminars in reg rd to water distribution, irrigation techniques, plant requirements and other relevant subj:cts, is without doubt considered to be highly useful for purposes of economical development. This is especially true in countries which face drought problems and shortages in agricultural production, thereby preventing the attainment of self-sufficiency in foodstuffs, which problem is further accentuated by population pressure.

Jordan is a country that suffers from its limited cultivable area, which does not exceed seven percent of its total area. Moreover, the country lives under circumstances of a harsh struggle against nature. Drought seasons record fearful figures which defy all types of feasibility studies, and makes every drop of water valuable. In spite of these adverse natural circumstances, the people of Jordan enjoyed relative prosperity twenty years ago. However, the Palestine catastrophe did away with that state of affairs and created more severe conditions as a result of the influx of more than half a million refugees and the deprivation of the remaining part of Palestine of its most fertile plains, and its surface and underground waters. This situation resulted in over-population in a meager area, and led to a state of bitter strife in which all efforts were mobilized to utilize available resources to increase the cultivable area through exploration for underground water, and also to utilize surface waters, notwithstanding their scarcity, and flood waters through the construction of dams.

It is fortunate that our country has witnessed a general awakening movement which embraced all activities and was reinforced by domestic stability during the reign of His Majesty our beloved King Hussein. (May God preserve him.) In the twelve years that have elapsed since his accession, the country has achieved a state of overall prosperity that has brought enlightenment to all strata of the population. The Government system has grown steadily, coping with this prosperity and helping in its creation. Public services have been greatly strengthened and academic scholarships have played a significant role in providing the governmental system with such highly qualified and well trained employees as have enabled it to carry out its tasks toward the country's growth and development. Among the main concerns of the Government has been water. The Central Water Authority was established and undertook extensive exploration work throughout the Kingdom for underground water and constructed a number of dams in the desert. Another Authority, The East Ghor Canal Authority, was established to implement the first stage of the Major Yarmouk Scheme, in cooperation with US Agency for International Development, and has almost completed this work, thereby putting about 120 thousand dunums in the Ghor area under full irrigation. The Government also established a Regional Corporation to implement the Major Yarmouk Scheme, which aims at the irrigation of 517,000 dunums in Jordan Valley, in addition to execution of the Arab defensive project for the exploitation of Jordan River Tributaries water to save Arab Zor lands which were formerly irrigated by Jordan River water. These lands are now threatened by Israel's aggressive conversion of the River watercourse, thus increasing the salinity of water flowing in the old course, which renders these lands useless for irrigation. These Jordanian projects require the construction of dams at Makarin and Mukheibeh, and the utilization of storage waters to generate electric power. Our projects aim at the expansion of irrigated lands since it has been confirmed beyond any doubt that our dependence on rainfall water is impossible and that, on the other hand, an area of more than 160,000 acres can be cultivated if water is made available.

It is therefore obvious that we cannot relinquish our rights in any drop of water which others would like to deprive us of, because to us water means life. The cultivation of the above area would undoubtedly strengthen our defense against harsh natural circumstance, and would prevent the conversion of our most fertile lands into deserts that would increase our already heavy burdens. The cultivation of such lands would increase our production and thus mitigate the problems of over-population. It would play an important role in our balance of payments and provide opportunities for the exportation of vegetables and other horticultural products to Near East and other markets, since the Ghor area enjoys such enormous exportation opportunities in wintry seasons as cannot be available to adjacent countries.

It is with great pleasure that I mention with appreciation the close cooperation between the Ministries of Agriculture and National Economy, Jordan Development Board, the Central Water Authority, the East Ghor Canal Authority, the Ministry of Interior for Municipal and Rural Affairs, the Ministry of Social Affairs, the Agricultural Credit Corporation, the US Agency for International Development in Jordan, and of friendly states in all fields of economic and social development, agricultural extension and land reclamation for irrigation purposes. All these agencies work in full cooperative coordination and deep understanding for the realization of all that leads to the prosperity of this country.

Gentlemen, the afore-said statement explains why we are particularly glad to have this seminar held in Jordan. We have been confident that the participation of this large number of friendly nations' representatives in the seminar, on such high technical, scientific and practical levels, will create a sublime scientific atmosphere radiant with goodness and yielding beneficial information. Through it most useful and easily applied methods will be generalized among farmers, on whose behalf I express thanks to you in the name of the Government and a most sincere welcome to every one of you, with wishes for your happy stay in this country, which is honored by your presence.

Gentlemen, the rapid increase of world population imposes on the whole world the necessity to think of its destiny and of hungry mouths that daily increase in number. Thoughts should be focused on supporting academic and practical efforts for utilizing available possibilities aimed at the expansion of cultivable areas, and of productive capacity, and organizing methods of water usage. Such efforts should prevent waste or negligence in water resources. They should bridge the gaps in existing legislation, that we might more fully benefit from storage waters for power generation, which constitutes the basis of all industrial development in the world. The world has also to strengthen its efforts for the promotion of peace, paying heed to the fact that were armament expenditures directed toward peaceful purposes it should, by itself, secure the strongest defense against the calamities of starvation, sickness and unemployment.

Gentlemen, this seminar actually represents a community of international importance, whose history is intertwined. The relationships of its people with each other are historically and inseparably interwoven. The standards of its peoples are similar. The objectives of its rulers are similar, in their endeavor to develop the region and spread welfare and prosperity among its people by overcoming poverty, disease, unemployment and under-development. This necessitates sincere cooperation among our states, based on principles of good neighborhood, complete and fraternal understanding within the limits of justice, mutual interests and work for the good of humanity at large, including our peoples.

In conclusion, I extend best wishes for the seminar and all participants, thanking them for all the troubles they have incurred in their travel to this place, and wishing them a happy stay in our country, hopefully expecting that they will kindly bear best remembrances of it. Finally, I extend due thanks to the United States Agency for International Development and its responsible officials for all their obliging efforts to hold this seminar.

Welcome Address

by

JOSEPH C. WHEELER

Director, USAID/Jordan

Excellencies; Friends:

The United States Agency for International Development is happy to join with the Government of Jordan in extending a welcome to the Sixth Near East-South Asia Regional Irrigation Practices Seminar. We are pleased to welcome you to Jordan. Among other outstanding facts about Jordan is the fact that it is one of the fastest growing countries in the world. Jordan has maintained an average annual growth rate of ten percent in gross national product during the past ten years. Many factors have contributed to this growth, but surely one of the most important has been the development of irrigation projects. You will have an opportunity to study one of these — the East Ghor Canal project — which has unique features in land reform, water distribution and maintenance. Jordan has reason to be proud of this development.

This is the *Sixth* Irrigation Practices Seminar to be held in the Near East-South Asia Region. You have met every two years since 1956. Since 1956, vast amounts of money have been spent in the world to develop irrigation schemes. Unfortunately, the "payoff" has not always been up to expectations. It matters little how spectacular the large dams, or headworks may be, if the farmer does not utilize the irrigation water to good advantage, the project will not be successful. To assist the irrigation farmers in the proper utilization of soil and water requires many skills and considerable knowledge in engineering, extension methods, farm management, and crop practices. Your assignment in this seminar is to discover from each other how best to make the link between water availability and increased production. This assignment is of tremendous importance in a world in which food supply and increasing population are in a race challenging mankind to organize its knowledge or face the realities of a Malthusian catastrophe. It is you and your associates back home who will determine the outcome of this race. I wish for you a successful seminar and an enjoyable and profitable stay in Jordan.

As we say in Jordan, *Ahlan wasahlan!*

Welcome Address

by

DR. M. S. FAYYAD

Head, Jordanian Delegation

Excellencies,

Honorable guests,

Colleagues,

On behalf of the Jordanian National Committee for this seminar, I have the pleasure to welcome you all to this meeting.

I would like to apologize for any inconveniences and shortcomings that you might encounter during your stay in our country and throughout your participation in this seminar. This applies to the various facilities provided and to any undesirable weather conditions as well.

Our country is proud to have this seminar held here. Jordan, as all other participants, is concerned with irrigation problems, which have a great impact on our development. As you all know, Jordan is a small, developing country, with very limited potentialities which need to be most optimumly utilized. In particular, our national resources as to fertile land and water potential are too small and confined. Being deprived of large rivers and extensive plains, our irrigation practices are rather meager and quite recent. This imposes on us the need to be more concerned and to look forward to making use of experiences of other participating countries with better and wider potentialities in irrigation and agriculture.

I hope that our seminar will be successful in achieving all of its purposes. To my mind, one of the major objectives of such seminars is to promote international cooperation through an interchange of ideas and experiences for the welfare of our human society. This international cooperation is rather a must to secure decent human living for all peoples of our world. The other main objective is that expected from us all as delegates from developing countries. We have to admit that we are actually under-developed countries and ought to work hard to catch up with developed countries and to join others in the caravan of humanity in its march of progress in technology as well as other fields of human development.

In conclusion, it is my pleasure and duty to extend due thanks to all who contribute to the anticipated success of this seminar. On behalf of the Jordanian delegation I extend thanks to the United States Agency for International Development in Jordan. I also express my sincere thanks to all delegates participating in this seminar, and through them to their governments. Last, but never least, thanks are due to all individuals who have worked hard to arrange this seminar and insure its success. In particular I have to mention Dr. A. Alvin Bishop, the technical advisor for the seminar.

I hope each of you will enjoy your stay in our country and make the most of your participation in this seminar. Welcome to Jordan and *Ahlan wasahlan!*

Comments on Seminar

by

DR. A. ALVIN BISHOP

Technical Advisor

Excellencies, Director Wheeler, Delegates and Friends:

It was with a great deal of pride that I accepted the honor of serving as technical leader for the Sixth NESA Irrigation Practices Seminar. Irrigation became my life's work more than thirty years ago, and I must say, I have had many rewarding experiences and few regrets concerning my profession as Irrigation Engineer. Not the least of my rewarding experiences concerns this very seminar. I am thinking of last summer when I visited ten of the Near East-South Asia countries, many for the first time, to make preliminary arrangements for the seminar.

Although my first official contact with the seminar came last summer with my visit to the area, I must say that I have followed the seminar closely since its inception in 1956. At that time, 1956, I was working as an irrigation expert for FAO in Japan, assisting the Japanese with problems concerned with the irrigation of sloping lands. I learned of the seminar at that time through a friend in FAO. Later, in 1958, I had the pleasure of working in Japan with Mr. M. R. Lewis, who had just completed an assigment in Iran in connection with the second seminar.

As many of you know, the technical leader for the Third, Fourth and Fifth Seminars, Dean F. Peterson, is my lifelong friend. We grew up in the same irrigated alkali desert in the western United States and were initiated to the art of irrigation as small boys. Our fathers both had irrigated farms and we learned about irrigation on the business end of a shovel. At this time I would like to bring you greetings from Dr. Peterson. I talked with him a short time ago and he sends his best wishes for the seminar and his regrets that he is unable to attend.

At any rate, through my friendship with Dr. Peterson and Mr. Malcolm Jones, who was also identified with early seminars, I received the proceedings of the seminars and studied them because of the wealth of information contained. I am sure that you have also found much valuable information in the seminar proceedings.

So again I say, it was with pride that I accepted the responsibilities delegated to me in connection with the Sixth Seminar and to tell you that I am looking forward to the work we must do together in the next twelve days. And work I'm sure it must be if this seminar is to be profitable.

One of the major jobs of the seminar is to develop recommendations for continuing objectives. Thus the Fifth Seminar, held two years ago in India, provided the major objectives for the Sixth Seminar just now started. You will note that the agenda includes the following topics recommended by the Fifth Seminar:

(A) Drainage and salinity problems.

(B) National programs for improvement of irrigated agriculture.

(C) Education and on-the-job training.

(D) Farm layout for an irrigated agriculture.

(E) Small projects.

(F) Technical factors in irrigation practice.

(G) Research.

I would suggest that you give detailed consideration to these seven points. Here I would like to quote directly from the proceedings of the Fifth Seminar:

> It is recommended that the seminars shall be concerned with the problems of soil and water management on the farm, especially as they relate to agricultural production, drainage and land conservation, recognizing that such management depends on many resources which must be at the disposal of the farmer and whose integration into irrigated farm production practice should receive due consideration. Planning, engineering and construction activities related directly to on-the-farm production shall be included; and consideration shall be given to basic project water supply and drainage system planning, engineering and construction, insofar as these factors are related to the capability requirements for on-the-farm production.

This statement, drafted by the executive committee of the Fifth Seminar, recognizes, I believe, that irrigation farming is a way of life and that the farmer himself is the key to the success or failure of an irrigation project. As irrigation engineers we cannot be content until each unit of water is producing the maximum agricultural product. For example, our job is infinitely more difficult than that of the hydro-electric engineer who is interested in the maximum electrical energy per unit of water. He can control the efficiency of the power plant to a very large degree, and the machinery of the plant must function according to the plan and design of the project. However, the controlling factor in the irrigation project is not the machinery, the dams, canals or works of man but the irrigation farmer, and needless to say, his actions are much more difficult to control than the turbines and generators of a power plant. We know what the farmer should be doing, in most cases, but the problem is how to get him to do it. Here is where the practice lags far behind the technical knowledge. Here is where we must place a major emphasis in this seminar. The successful solution of the problem will be a major engineering achievement.

Much time has been devoted to this unsolved problem in previous seminars and by all who are concerned with irrigation development. This is indicated by the fact that two of the seven objectives recommended by the Fifth Seminar are directly connected with this problem. These are objectives "B" and "C," as follows:

Objective (B)

National programs for improvement of irrigated agriculture:

(1) How to deal with problems.

(2) How to link with the farmers' resources.

(3) Development of effective institutions.

Objective (C)

Education and on-the-job training:

(1) New training methods, programs and techniques.

(2) Problems encountered and how they are solved.

(3) Interchange in available schools.

(4) Programs for training farmers.

(5) Demonstration farms and irrigation farming camps in newly developed areas.

(6) Special emphasis on training middle-level technicians.

One item that I find lacking in this list of objectives concerns incentive. I mean incentive on the part of the farmer. All the training, demonstrations, education, etc., will go by the wayside if there is no incentive on the part of the farmer to put this knowledge or training to practice. True, the training, demonstration and education programs are designed to motivate the farmer to do the things wanted of him, but these may be easily offset by increased taxes on extra production or other devices which kill the farmer's incentive. Increased emphasis must be given to the complicated legal, sociological, technical interactions that may make it impossible for the farmer to do what is expected of him or which may kill his incentive to do it. To further complicate the matter, as we must all realize, irrigation is a complex art requiring the application of our best knowledge of soil and water. The application of this knowledge must be by the farmer. This implies that the farmer must have the knowledge, or that it becomes an integral part of the practice, so that the application of the knowledge becomes routine.

To integrate the best knowledge of soil and water into the practice of irrigation is a delicate and exciting challenge. If it is successfully achieved, the farmer routinely applies this knowledge in his day-to-day activities.

OPERATION OF THE SEMINAR

Your host country, Jordan, has done considerable work in arranging the many details required. The agenda for the meetings have been carefully planned. Housing accommodations for delegates, a meeting place, and transportation have been arranged. In short, the committee has worked long and hard on many items to make your stay in Jordan pleasant and to allow the work of the seminar to move forward. I'm sure that you are already aware of the work of this committee, which includes members from the Jordan Development Board, the Ministry of Agriculture, the East Ghor Canal Authority, the Central Water Authority, the Agricultural Credit Corporation and the USAID Mission.

It has been a matter of policy in the Near East-South Asia Irrigation Practices Seminars to form an executive committee. This committee consists of the head of each country's delegation, with the seminar advisor as ex-officio member. The executive committee will meet immediately following the session to decide on committee responsibilities and other important business.

The Fifth Seminar established six panels to conduct special studies and make recommendations concerning the special subject matter areas. These panels were concerned with (1) Education and Training, (2) Operation and Maintenance, (3) Field Irrigation and Drainage Research, (4) Waterlogging, Salinity and Alkali Problems, (5) Farm Irrigation and Drainage Systems, and (6) Standards for Irrigation and Drainage Investigations. I hope you have all had the opportunity to study the work of these panels in detail. I think that considerable progress was made resulting in sound recommendations. The seminar will need to re-evaluate these problem areas with the idea of making any amendments or including new areas for study.

There is always considerable interest in *research*. The quest for new knowledge is always exciting. It must continue if we are to advance. Likewise, technical aspects of irrigation are of major interest because the solution of the problem is more clear cut. Technical advances must be closely linked with research and must continue. If they are to be adopted, the improved irrigation practices shown to be desirable by research and technical advances must be clearly explained to the farmer. Here is where the education, demonstration and training programs play such an important role. All of the efforts and programs, and in fact the main goals of the seminar, are concerned with the problems of soil and water management on the farm. I believe we have a tendency to emphasize the importance of these items just mentioned, that is research, technical advances, education and training, yet overlook the importance of the organizations and institutions in regard to soil and water management on the farm. Dr. Peterson mentioned this aspect in his address to the Fifth Seminar, and I would like to endorse what Dr. Peterson said about organizations and institutions, and add my own observations. It is my belief that soil and water management on the farm is influenced to a large degree by:

(1) Institutional practices

(a) Management practices.

(b) Legal practices.

(c) Water delivery practices, including water measurement and method of delivery.

These items, all in the broad institutional framework, can only be influenced by the farmer to the degree he is involved, and quoting from Dr. Peterson's remarks:

> One point is clear, it is important that the farmers become full partners in the irrigation effort. They must be brought into the picture as early and effectively as possible.

I would urge, therefore, that the seminar give some attention to the practices listed above with regard to the role they play in relation to soil and water management on the farm.

And now in conclusion, I extend my greetings to you and express the hope that the seminar will be an instrument for the free exchange of ideas and information between the nations here represented, toward improving irrigation and solving irrigation problems.

CHAPTER II

RECOMMENDATIONS

Panel I

Education and Training

Korkut Ozal — Turkey — Chairman

The recommendations of the previous seminars have been reviewed by the committee and are found generally adequate and of high value. This committee concurs, in general, with these recommendations of previous seminars, and maintains the opinion expressed by their panels that one of the major reasons irrigation practices are not being fully adopted and applied in irrigation developments is the lack of adequate education and training of all types of required personnel.

Education and training are the most important keys to the success of irrigation development. Only through irrigation and training can the transfer and adaptation of modern irrigation technology be applied to help realize better crop yields.

The committee would like to point out that although considerable progress has been made in the training efforts, they are still far from being adequate to supply the qualified personnel requirements of ever growing irrigation development.

A major effort is deemed necessary to develop the procedure for educating and training the needed personnel in various countries.

The committee places emphasis on the recommendations of the previous seminars and makes the following supplementary recommendations.

I. Policy

(A) A policy must be adopted which will satisfy the education and training requirements of personnel at every level, not only the farm level.

(B) Personnel inventories from the project level up should be made to determine the qualified manpower requirements in a balanced way and for a reasonable time in advance.

(C) Maximum efforts should be exerted to educate and train personnel by local means, although external facilities may be temporarily employed in the early stages.

(D) Education and training systems should be planned in such a manner that a *self-generating, chain reaction* effect will be established and maintained. The educated and trained personnel should be used, in addition to their routine activities, for the education and training of others.

(E) Formal education and the training program should be designed in such a way that learning is followed by application of a reasonable amount of information and knowledge before new, refined information is introduced. It should also be essential to develop lower level personnel to assume jobs in higher specializations. Incentive rewards for in-service training among project personnel should also be provided.

(F) To make the education and training of farmers as desirable to them as it is to project authorities, the whole irrigation development program, including education and training, should be seen and dealt with in one perspective. This will help provide the incentives, such as markets for the products, credits, etc., which are indispensable to the success of efforts in education and training.

(G) Finally, more and better agricultural information and application should be incorporated into the normal curriculum of primary and secondary schools.

II. The Planning

(A) The planning of education and training for better irrigation practices should be considered as a job of primary importance, rather than a complementary or secondary activity. The manpower requirements of a project should be determined and measures for their success be provided in advance. Therefore, a department responsible for the planning, design, implementation and supervision of education and training activities with regard to irrigation practices is to be established and maintained within the agencies concerned.

(B) This department should conduct personnel surveys to determine the particular requirements of the agency, from the project level up, and prepare position requirements to obtain qualified manpower, and develop short and long range programs for their success, qualitatively and quantitatively.

(C) The programs should aim to cover all types of personnel and various types of education and training.

III. Implementation

(A) Basic education should be mainly the responsibility of ordinary educational institutions. However, agencies engaged in irrigation activities should provide active support to these educational institutions.

(B) Training and specialized education should be mainly the responsibility of related agencies. However, active coordination with educational institutions should be maintained, and the limited possibilities of higher educational institutions should be used for specialization until the agencies develop their own specialized training and educational systems.

(C) The training activities should be diversified and extended to all levels in order to have the needed flexibility. For this, the committee recommends the following:

(1) The training of professional and subprofessional personnel including extension workers may be progressively carried on simultaneously by: (a) on-the-job training; (b) short courses at the job site under the conduct and supervision of more experienced and highly trained personnel of the project; (c) periodic refresher and specialization courses at the job site; (d) intermediate term development courses at regional or central training centers; (e) highly specialized short term courses including management training.

(2) To have an adequate number of personnel for farm level training some manpower sources may be activated. An "Agricultural Corps" may be developed through recruitment of the graduates of high schools and higher education as agricultural workers on a compulsory or voluntary basis after they receive a certain level of training. In some countries army recruits are used for this purpose. This system should have a balanced and continuing program.

(3) The training of farmers should be mainly on a demonstration basis. Audio-visual means should be used. A comprehensive demonstration system should receive the utmost attention. Full use should be made of the means and ways already available to, or that could be provided by, the farmers. Complementary measures should also be elaborated.

(4) In addition to the above general suggestions, the committee recommends the following with particular regard to farmers:

(a) Through organized Farmer Planning Groups in villages, train farmers in soils and soil problems, solution to soil problems, and selection of practices for effective irrigation on their own farms.

(b) From Farmer Groups select outstanding farmers to assist technicians in training farmers of other groups.

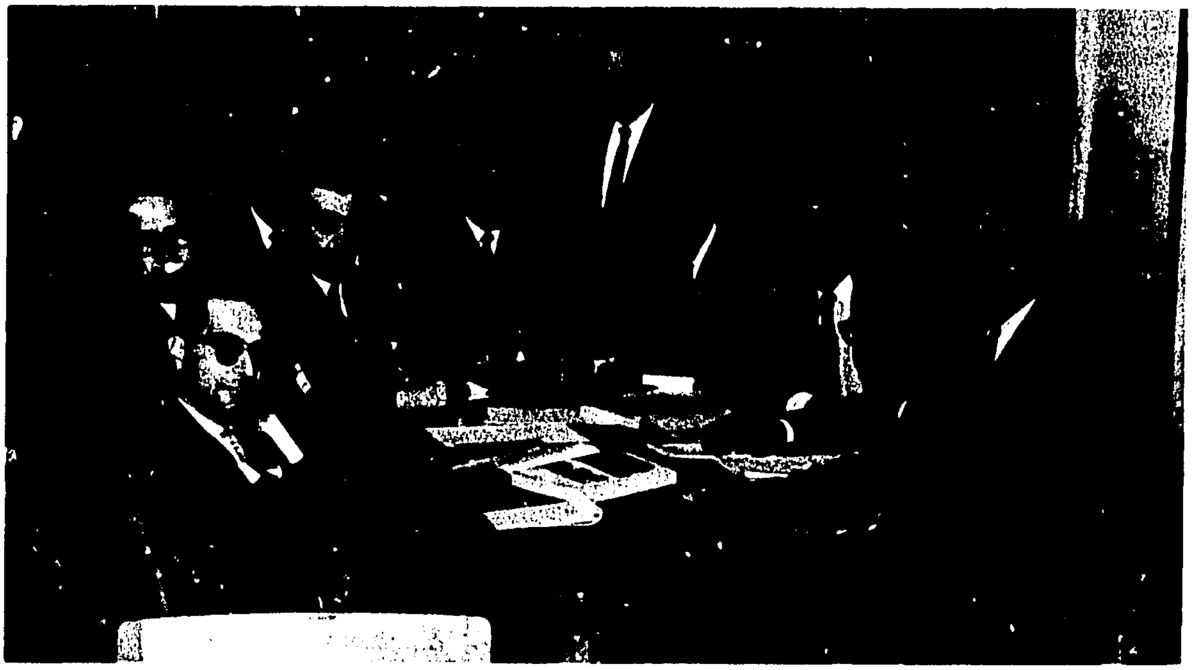
(c) Continue Farmer Field Trips to improve practice demonstrations of progressive farmers and on model demonstration farms.

(d) Assist farmers in development of land judging contests for irrigation agriculture.

IV. Coordination

The committee is of the opinion that NESA countries can actively and successfully cooperate in their training efforts. The experience and achievements of one country may save the other countries from repeating the same trials and errors. Consequently, the committee deems it useful to establish a routine for the regular exchange of experience and information among NESA countries. Also, joint programs in particular parts of education and training, such as highly specialized short term courses, may be launched.

To establish and maintain the above coordination the committee recommends the designation of a liaison officer in each country. The chairman of each country is requested to let the other country chairmen know the name and address of the designated officer at the earliest possible time.



Panel 1 Education and Training

Panel II

Farm Management for Irrigation Practices

Ayten Aydin — Turkey — Chairman

Panel II discussed the problems relating to farm management for irrigation practices. Problems were analyzed and discussed and constructive recommendations were made.

The committee realizes that one of the major factors causing low and inferior crop yields in most NESA countries is inadequate farm management for utilization of soil and water resources. Its recommendations agree with the deliberations of the Fifth Seminar. In addition, it wishes to make the following resolutions:

(1) The committee notes that in some countries certain traditional methods of irrigation result in low efficiency of irrigation and water logging. It is therefore recommended that governments should help the farmers in adoption of improved water application methods.

(2) To maximize benefits from irrigated farms, farmers should be induced to adopt improved cropping practices, such as using improved seeds, fertilizers, plant protection, etc., and to adopt better techniques of farming through demonstration, education and incentive programs.

(3) Governments should promote farm planning especially for irrigated agriculture where the capital investment is very high and yields should be raised to the maximum. Emphasis should be given to land preparation.

(4) In many countries, inadequate and/or poorly maintained water courses result in heavy water losses. Agencies responsible for water distribution should, where necessary, carry out, down to the farm level, water course construction and betterment programs in cooperation with, and at the cost to, the farmers.

(5) Farmers should be encouraged to develop groundwater resources within existing regulations, especially where existing supplies from other sources are inadequate or nonexistent.

(6) It is resolved that the land should be owned by the cultivator. The governments may implement proper measures for the selection of the optimum economical size of holdings, in addition to other assistance. In case of small fragmented holdings which lead to improper utilization of resources, land consolidation should be enforced.

(7) Motivation of farmers to improve their farming methods must be studied and incentives established. This may take the form of guaranteed minimum prices on farm products, subsidies, assistance in developing farm mechanization and processing industries, and special credit facilities. Land taxes should not be relaxed on land left uncultivated.

(8) Inasmuch as improper operation and maintenance of farm distribution systems lead to nonuniform diversion and utilization of resources, policies should be adopted governing the responsibility of the operation and maintenance of farm distribution.

(9) To achieve the most efficient use of water, especially in areas suffering from a shortage of irrigation water, the charge to farmers should be changed to volumetric basis, and where this is not feasible, to an area and cropping basis.

(10) All governments are urged to establish communications within irrigation projects. This includes farm-to-market roads, electricity for irrigation pumps and other uses, and telephone con-

nections between all irrigation facilities and villages.

(11) Agricultural cooperatives should be promoted, to make credit, irrigation and marketing facilities available to farmers on the farm level.

(12) Education and training of farmers by institutions or governmental agencies should be promoted.

(13) Necessary legislative measures and institutions to implement the above mentioned recommendations should be provided.

Panel 2 Farm Management for Irrigation Practices

Panel III

Irrigation Institutions—Farm Relationships

D. B. Anand—India—Chairman

Objective

The main objective of this panel was to examine (from the viewpoint of institutional responsibilities, policies, and legislation) the reasons potential agricultural production is frequently not obtained from irrigation water supplies developed at large expense and delivered to farmers near their farms.

Considerations

Discussions by the eight committee members from six countries brought out that, in general, the following problems exist in the NESA region:

(1) Properly delivering the right quantity of water at the right time to large numbers of small and often fragmented land holdings growing a variety of different crops.

(2) Getting farmers to properly shape and drain their lands for the maximum economic crop production.

(3) Getting farmers to use the irrigation water efficiently to obtain maximum benefits from the limited water supplies and expensive investments in project developments and farming operations.

(4) Getting farmers to efficiently grow crops with optimum yields.

(5) Getting farmers to actively participate in solving their own problems with a minimum of government assistance.

(6) Getting farmers to pay a fair share of the cost of government irrigation project expenses incurred in providing irrigation water and services to farmers.

(7) Developing the necessary effective institutions, policies, legislation, trained manpower, finance, and timely coordination between all the numerous government and private interests involved in developing and managing the irrigated agriculture necessary to equitably meet the requirements of the farmers and the nation.

In considering solutions to these problems, the panel considered the following: the desirability of developing more leadership, initiative, and group action by irrigation farmers; the reasonable division and delegation of authority and responsibility between government and farmers; identification of property and water rights; equitable distribution of project benefits; balancing of project investments for farm development and operations in relation to water supply development and distribution costs; relationships of the dependability of timely irrigation deliveries to the farmers' crop production activities; the requirements of the government and farmers for financial assistance in obtaining and utilizing the requirements for efficient maximum crop production; the needs for training and education of both government technicians and farmers; the importance of promoting soil building crops; the need to establish contact with farmers and associations; how to establish water and project charges that will be fair to farmers, under existing farming and educational conditions and not cause undue financial burden on the general community; the importance of assured markets for agricultural production; the role of land ownership in promoting intensive farming; the relationship of taxation in creating incentives for productive use of land; the role of volumetric water measurement in improving water efficiencies; and miscellaneous other factors affecting the most economical crop production on irrigated land.

Conclusions

(1) All the foregoing considerations are of

importance in developing efficient agricultural production from irrigated farms, and should be given careful consideration in promoting the best irrigated agriculture.

(2) Most of the member countries have the main government institutions required for developing efficient irrigation, but such organizations usually lack sufficient well trained personnel and sufficiently well delegated authority and legislation to enforce proper control over farm development and water utilization. Programs and budgets of the various government and private groups concerned are frequently not coordinated in the manner required to complete the full job of properly utilizing the irrigation water supplies in the most desirable manner. Hence much of the capital investment is not producing well because a relatively small yet vital part of the total requirements is left undone, due to ignorance, finances or lack of coordination between groups concerned.

(3) Local democratically constituted farmers' organizations capable of assuming a large degree of local leadership and responsibility generally either do not exist or do not operate effectively in developing common understanding between government agencies and the individual water user, or in assisting in irrigation activities. This is largely due to the low level of education and understanding of water users and the lack of trained local leadership in irrigation problems. Thus the governments have been burdened with the task of working individually with most water users, and the number involved is too large to effectively handle with reasonable cost by government agencies.

(4) Lack of well documented land ownership and water rights combined with uncertainty of water supplies, lack of knowledge of proven modern irrigation, drainage and production practices, lack of easily obtainable credit and productivity inputs, and lack of assured crop markets at fair prices have all had a depressing effect on the farmers' productivity.

Recommendations

(1) The operation and management of irrigation, distribution systems and drainage projects or portions of them should be gradually transferred to the beneficiaries through their own self-organized associations if and when the state considers them qualified. Such organizations should be of a nature, size and pattern as will best fit the needs of the particular project or project entity. Operation and maintenance costs and collection responsibilities should also be transferred gradually to the beneficiaries.

(2) The state should assume the responsibility for operation and repairs of such installations as large dams and reservoirs, major canals, hydro-electric plants, and multi-purpose structures, etc., where large public interests are involved.

(3) Member countries should encourage formation of irrigation associations, give serious consideration to establishing irrigation associations and, as necessary, provide short courses to their representatives in the general problems of irrigation and drainage, including instruction in how to obtain various goods and services related to irrigated farming, laws and legislation concerning the organization and operation of water users, the role and responsibility of water user organizations, and the policies and procedures of government agencies.

(4) Each country should prepare and publicize a booklet of all existing laws and government regulations now in effect concerning the rights, authority, and responsibilities of all government and private organizations relating to water rights, development and distribution of surface and groundwater supplies, farm development, irrigated crop production and marketing, operation and maintenance of irrigation projects, and formation and operation of local water user organizations.

(5) While santioning an irrigation project, the government should concurrently assure plans and budgetary provisions required by other agencies toward achieving speedy and efficient irrigation and farm development. For major government projects, the budgets of the various responsible agencies should be allocated by projects and each of the responsible government agencies be held accountable for completing its activities as

scheduled and budgeted. Steps should be taken to assure effective coordination among these various agencies.

(6) Subsurface drainage is an important part of all irrigation projects. Timely steps should be taken, therefore, to deal with the problem at the earliest time when the need arises, and constructed by government and/or the farmers, according to local conditions.

(7) Land shaping, unitization of large fields, and consolidation of land holdings are conducive to good irrigated farming, and should be encouraged.

(8) To promote intensified land utilization, the government should recover as much as practicable of its irrigation development and operation cost by levying a small charge on the command area capable of being served, regardless of whether or not the land is irrigated after a reasonable development period. In addition, there should be a crop charge on actual water used. The total of these two charges form the basis for the water rate. This total water rate should have a reasonable relationship to the gross or net benefit derived by the farmers from the irrigation facility.

(9) Where water is in scarce supply, an equitable policy for allocating or rationing the supply should be established.

(10) Credits and subsidies on easy terms should be provided to the farmers for financing their farm needs and ancillary operations. Also, where necessary, organizations should be created for making available to the farmers at reasonable terms the goods and services needed to improve farm operations.

Panel 3 Irrigation Institutions — Farm Relationship

Panel IV

Irrigation Practices Research

M. El-Madany — U.A.R. — Chairman

Introduction

Recognizing the importance of research to all branches of irrigation and drainage, and their direct reaction on productivity, the panel has reviewed the various recommendations of the preceding research panels, and discussions between representatives in the present NESA Seminar. It has felt the necessity of widening the scope of research to cover all those branches of irrigation and dainage that appeared of significant interests to the participant countries.

Part I

(A) The panel emphasizes that research recommendations should be published in a special report within three months after the seminar, and circulated in the participating countries for implementation.

(B) The committee recognizes the great difficulty in conducting research due to lack of requisite equipment. It is recommended, therefore, that reasonable funds should be allocated by each participating country for the timely procurement of equipment needed both in the laboratory and field.

(C) Arrangements should also be made to circulate research plans, on different subjects, among the member countries to acquaint them with the nature of work being undertaken. This is needed to enable them to exchange notes if they so desire. AID should alsb be requested to provide facilities for individual research workers to visit other countries where similar work is being conducted. Circulation of periodicals and bulletins on related subjects should be organized among the member countries to acquaint them with up-to-date research knowledge.

(D) The panel suggests that the Executive Committee should ensure that the NESA Seminar includes representatives from research workers for a better understanding of common problems and improved methods of solving them.

Part II

The panel recommends that research on the following subjects be given particular attention:

(A) IRRIGATION

(1) Application of different methods for the estimation of water use requirements for different cropping patterns.

(2) Economical aspects of water use in the field related to various systems and methods of application.

(3) Assessment and control of irrigation water losses in its various forms, including the use of chemicals for suppression of evaporation from open water surfaces.

(4) Sedimentation and erosion in farm ditches and farm ditch maintenance.

(5) Improvement of field irrigation practices in relation to specific soil and crop conditions.

(6) Development of farm devices for the measurement of irrigation water, and the standardization of these devices.

(7) Evaluation and standardization of various irrigation methods.

(8) Establishment of standards of quality of irrigation water for different crops under different soil conditions.

(9) Irrigation practices with reference to other agronomic practices such as fertilizer application and plant population.

(10) Effects of water quality and irrigation methods for various crops and different soils in relation to salinity.

(B) Drainage

(1) Evaluation of drainage co-efficients for disposal of surface and subsurface waters.

(2) Methods of measuring soil permeabilities in the field.

(3) Techniques and materials for horizontal and vertical drainage.

(4) Most economical depth of water table for different crops under different soil and climatic conditions.

(5) Effect of irrigation water on the quality of drainage water and its suitability for re-use.

(6) Relationships between drainage and quality of irrigation water for safe use.

(C) Soils

(1) Development of devices for soil moisture measurement.

(2) Soil physical conditions as affected by irrigation and other farming practices with special emphasis on soil compaction.

(3) Reclamation of saline and alkali soils.

(D) Crops

Cropping patterns and crop rotations under different climatic and soil conditions.

(E) Weed Control

(1) In canals.

(2) In farm ditches.

(3) In cropped fields.

Panel 4 Irrigation Practices Research

Panel V

Irrigation and Drainage Systems

M. H. Parwana — Afghanistan — Chairman

The committee fully endorses the recommendation made at the Fifth Seminar that the farm irrigation and drainage systems play a vital role in making efficient use of irrigation water and in obtaining sustained maximum benefits from irrigated agriculture, and that the countries should give serious consideration to this important phase of irrigation development.

The committee makes the following recommendations on various aspects of the problem:

I. Planning

(A) The drainage system should be regarded as an essential part of the irrigation system, and both irrigation and drainage systems should receive attention as integral parts of the irrigation project, right from the planning stage.

(B) Irrigation and drainage systems should be planned and designed with due regard to such considerations as: (1) topography; (2) size and shape of the field; (3) type of soil and sub-soil strategraphy; (4) depth of water table; (5) salinity and alkalinity status of the soil; (6) quality of irrigation water and of the local groundwater.

(C) Requisite data on the above factors should be collected and analyzed as part of the investigations for the main project.

(D) In planning and designing the drainage system, the need and prospects for eventual land consolidation operations should be kept in view.

II. Priorities

(A) Construction of the field irrigation channels should be completed simultaneously with construction of the main project and the conveyance and distribution systems, so that the irrigation water made available is put to use in an efficient manner without delay.

(B) Conveyance and distribution systems should be lined with suitable materials in the very first instance, if such lining is technically and economically feasible. The priority about lining or piping of field channels, however, may be decided in accordance with the financial resources available and the conditions obtained on each project.

(C) The following factors should be taken into account in determining the techno-economic feasibility of lining or piping: (1) the texture and structure of the soil; (2) topography; (3) the problems of weed control; (4) depth of water table; (5) cost of land; (6) cost of lining; (7) saving in maintenance cost; (8) cost and availability of irrigation water; (9) socio-economic status of the farmers and their interest in irrigated agriculture.

(D) The drainage system should be constructed as soon as its need is apparent. Execution of various phases of the system, such as the main drains, the laterals and the field drains, should be properly phased in accordance with likely needs. As a rule, construction of the main and lateral drains should be given priority over construction of the field channels.

III. Execution — Technical Factors

(A) The irrigation system should be aligned and graded with due regard to the topography, soils, weed growth, and the lay of the fields, so that irrigation water reaches most of the commanded area under gravity (unless a little lifting of the water at the field level is considered desirable for sake of its economic use) and there is no erosion or silting in the system.

(B) The capacity of the irrigation systems should be fixed, taking into account the following factors:

(1) The supplies available at the source during different seasons.

(2) The proposed usage of the available water in relation to the optimum cropping pattern under the agro-climatic conditions existing and likely to develop in the region.

(3) The area available for irrigation.

(4) The peak requirements of the optimum cropping pattern.

(5) The proposed delivery pattern of the irrigation supply.

(C) The irrigation system should be provided with adequate structures, measuring devices, etc., for control and regulation of supplies at the crucial points.

(D) Adequate number of drainage and road crossings and other communication facilities should be provided, to avoid wastage of water, to give accessibility to farm units, and to ensure maintenance of the system.

(E) The committee discussed various problems of drainage in irrigated areas and factors that should be taken into account in designing proper drainage systems.

The committee emphasizes that:

(1) In areas of groundwater pumping the number of wells and their capacity and the likely effect of pumping should be considered in determining the need for construction of field drainage channels.

(2) The likely impact of lining of irrigation channels or of other improvements in water use practices contemplated in the region should also be taken into account.

(3) Choice of the proper type of field drainage system, whether open drains or tile drains, should be decided after taking into account the local conditions of soil, topography, stratigraphy, drainage requirements, etc., and the relative advantages, disadvantages and economics of the two systems under these local conditions.

IV. Organization

(A) The committee emphasizes the need of a proper organization for efficier operation and maintenance of the irrigation a . l drainage systems.

(B) The committee agrees with recommendations made at the Fifth Seminar that while the responsibility for construction and maintenance of field irrigation and drainage channels is entrusted to the cultivators/village institutions, the latter should be supported with adequate finances and technical guidance in the alignment, layout, placement, spacings, etc., of these channels. The committee emphasizes that the organization at the field level for this purpose should be adequate and should include technicians who have been suitably trained or otherwise have proper background and experience in the subject.

Panel VI

Standards for Irrigation and Drainage Investigation

S. Ozgul — Turkey — Chairman

After reviewing the Fifth NESA Seminar Report on Standards, the following conclusions have been reached:

(A) The Panel unanimously endorsed the recommendations of the Fifth NESA Report in its entirety.

(B) It was agreed that some additional factors should be incorporated, as follows:

(1) System Operation and Maintenance (for item 18).

(2) Pollution Control (for item 19).

(3) Farm Credit (for item 20).

(4) Farm Machinery and Services (for item 21).

(5) Construction Sequence (for item 22).

(C) After discussing each factor of the Fifth NESA Seminar Report on Standards, the following recommendations on particular points were made:

(1) On item "Land and Soil Classifications" more study on economic consideration is recommended.

(2) On item "Drainage Requirement":

(a) Design should be based upon close correlation with soil and land classification.

(b) Close coordination should always be ensured between agencies responsible for carrying out drainage works.

(c) The determination of the benefit-cost ratio should be based upon sound economic evaluation.

(d) Extended investigations should be conducted on the possibility of re-use of drainage waters for extended irrigation water supply, subject to satisfactory water quality.

(3) On item "Water Planning":

(a) Where possibility of water requirement fluctuations have not been completely assessed, it is recommended that planning for water capacities and distribution should consider extra needs (changes in crop patterns, soil and drainage conditions, etc.) so that constructed facilities can be made adequate.

(b) The next seminar should consider achievement of some uniformity of standards in accordance with accepted internationally known terminology and standards.

(4) On item "Groundwater Supply":

(a) Any planning concerning groundwater supply — whether for water supply or for drainage, should be based upon groundwater explorations considering all the aquifer characteristics and legal aspects.

(5) Publications of the following agencies could be used for development of standards for each country:

(a) International Commission on Irrigation and Drainage (New Delhi, India).

(b) United States Bureau of Reclamation (Denver, Colorado, USA).

(c) U.S. Department of Agriculture, Soil Conservation Service (Washington, D.C., USA).

(d) U.S. Geological Survey (Washington, D.C., USA).

(e) U.S. Salinity Laboratory (Riverside, California, USA).

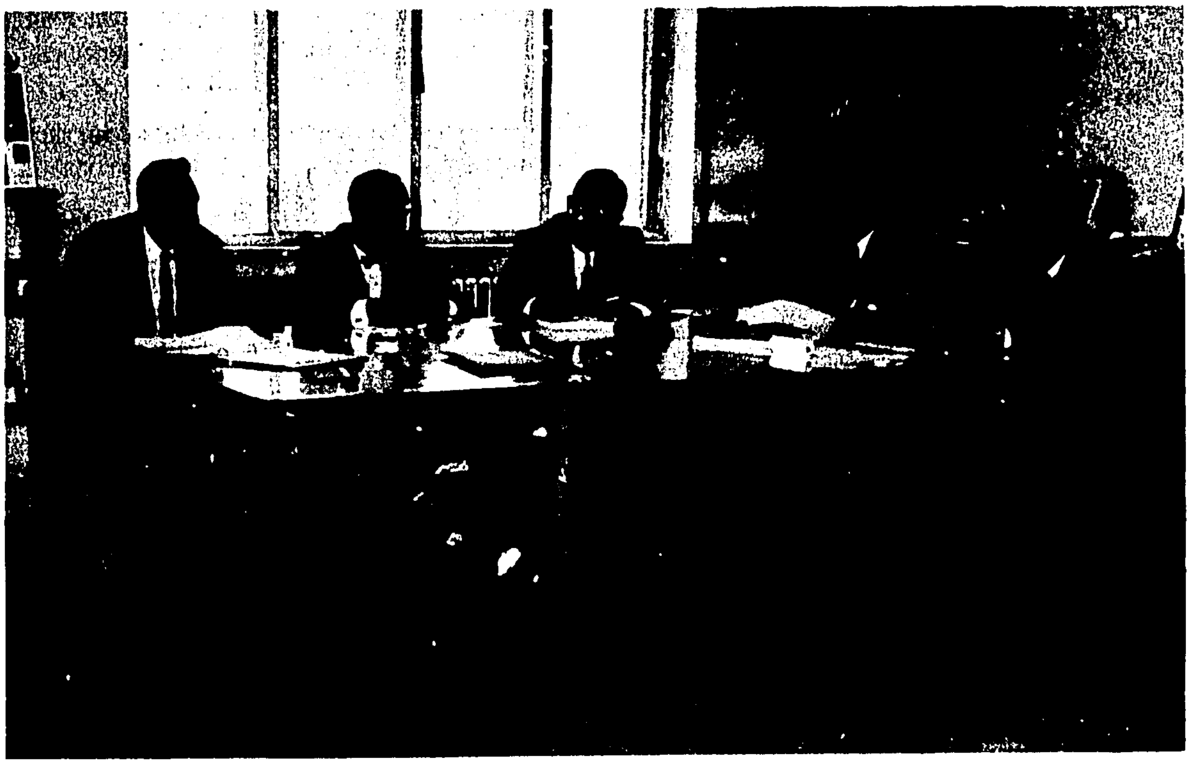
(f) International Institute for Land Reclamation and Improvement (Wageningen, Holland).

Suggestions for Improvement Of Irrigation Practices Seminar

A. Executive Committee should consider the formation of technical groups for the technical discussions.

B. The metric system, should be used in reference to dimension, area, or volume, and the unit of the specific country be included in parentheses.

The U.S. dollar should be used as the unit of cost, followed by the local country's currency in parentheses.



Panel 6 Standards for Irrigation and Drainage Investigations

Panel VII

How to Live with Salinity

K. Haddad — Jordan — Chairman

In most of the participating NESA countries, salinity is quite a serious problem affecting agricultural production. It was felt that this seminar should consider the various aspects of salinity with special reference to the proper use of those lands under existing circumstances. For this purpose, Panel VII was formed to deal with the subject, "How to Live with Salinity."

The members of the panel discussed various aspects of salinity problems under various conditions in the different participating countries and felt that the efforts should be mainly concentrated on those problems that are most common among these countries. The panel discussed certain conditions under which the problem of salinity may exist and considered some of the ways and means to make the best possible use of these lands.

The panel considers that for use of the saline and alkali lands, thorough investigations should first be conducted to study the soils and waters in order to learn the nature of the problem. On the basis of these findings suitable practices should be adopted.

The various categories under which the problem of salinity may exist, and the broad measures that could be adopted to use these problem lands, are briefly summarized below:

(A) Saline and alkali soils with good quality and quantity of irrigation water.

(1) *Good drainage facilities.* The problem of using these lands is not acute, since leaching is possible and should be done by providing needed drainage. If necessary, leaching should be done with suitable amendments.

(2) *Inadequate drainage facilities.*

(a) To prevent rise in the water table and water logging, use of excessive amounts of irrigation water should be avoided.

(b) The crop water requirements should be met by giving frequent light irrigations.

(c) Salt-tolerant crops and those having high water requirements that can survive under moist conditions, preferably with shallow root systems, should be used.

(B) Saline and alkali soils with poor quality irrigation waters.

(1) *Good drainage facilities.*

(a) Necessary drainage should be provided.

(b) Sufficient amount of water may be used for leaching, provided the total soluble salt content of the water is less than the saturation extract of the soil.

(c) If the soluble salt content of the irrigation water is higher than 2500 parts per million, then these waters should be used with due caution. Investigations should be made for sodium adsorption ratio (SAR) and residual sodium carbonate, to determine the required amounts of amendments.

(2) *Inadequate drainage facilities.*

In such cases, the soils and water are

already bad. Efforts should be made to conserve and utilize a maximum amount of rain water and encourage growing of crops, if possible. Preferably such areas should be developed as grazing lands, along with growing salt-tolerant tree vegetation such as palms, eucalyptus and others.

(C) Saline and alkali soils where sufficient irrigation water is not available. Under such conditions, the use of the land would depend mainly upon the rainfall. Therefore, maximum conservation of rain water and its efficient utilization are essential.

(1) *Rainfall below* 350 *mm.*

Such lands normally have low productivity under the restricted climate conditions. Efforts to conserve rain moisture should be made with the least amount of investment. Grasses and other vegetation should be encouraged for grazing purposes.

(2) *Rainfall between* 350 *to* 600 *mm.*

Maximum amount of rainwater should be conserved so as to leach the soils and encourage some crop growth and development of grass lands. Investigations should be conducted on drainage feasibility for crop production.

(3) *Rainfall above* 600 *mm.*

(a) Maximum amount of rain water should be conserved to grow the crops.

(b) Adequate drainage facilities should be provided according to local existing conditions and cropping pattern.

(D) Non-saline and non-alkali soils (normal soils) with saline and poor quality waters.

(1) *Good drainage facilities.*

(a) Adequate drainage systems should be provided.

(b) Saline waters should be used with necessary amendments to check development of salinity.

(c) There should be occasional heavy applications of irrigation water to prevent salt accumulation within the root zone and to provide for leaching of salts.

(d) Maximum utilization of rainwater should be made for growth of the crops.

(e) Whenever possible, groundwater should be recharged with fresh waters to dilute the salinity of the water, particularly in coastal areas in Middle East countries when, due to over-pumping of groundwater, sea water intrudes. Under such conditions, in addition to having recharge works, strict control should be enforced on pumping groundwaters.

(2) *Inadequate drainage facilities.*

In such case, the suggestions already given for the (B-2) category are applicable.

Agronomic and Cultural Practices

The panel considers that proper agronomic and cultural practices can prove very helpful in using the saline and alkaline lands. Most of these practices are common for various categories described earlier. Some of these practices are given below:

(1) Salt-tolerant crops and such other vegetation as rice, beet root, sesbania, etc., should be grown.

(2) More than normal seed rate should be used to compensate for germination mortality.

(3) In high water table areas shallow rooted crops, preferably those that are tolerant to excessive moisture, should be used.

(4) Row crops should be planted in the middle of the ridges or in other suitable spots where salt concentration is comparatively low.

(5) In case of small grain crops, more uniform spreading of water should be attempted so that salts do not concentrate in patches.

(6) Winter flooding should be practiced wherever possible, as leaching is more effective during this period.

(7) Green manure or other organic manures should be used, wherever possible.

(8) Suitable fertilizers should be used preferably those containing calciums as an ingredient and having acidic residual effect.

(9) Wherever possible continuous cropping, mulching and other helpful practices should be used.

General

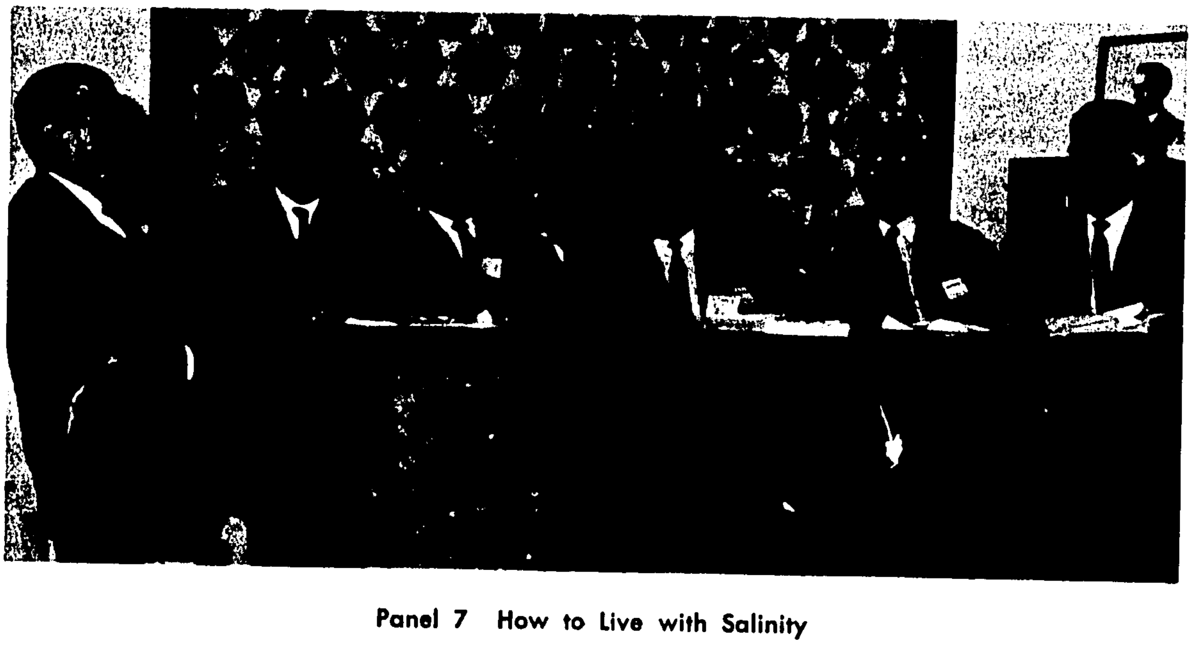
(1) The use of amendments wherever necessary should be encouraged. In many cases, the use of amendments is reported to be very costly. The panel recommends that the amendments should be subsidized by the governments.

(2) The panel understands that there is in a number of countries useful information available on various aspects of using saline and alkali lands. A compilation and exchange of this information would be helpful. It is suggested that the good offices of USAID in participating countries can help in such a compilation and exchange of this information.

(3) It is felt that necessary research projects should be encouraged on use of saline and alkali lands, such as improvements of drainage, use of amendments, improved agronomic and cultural practices, involving salt-resistant varieties and other aspects. Research is also needed on relationships of salinity of groundwater with depth of drains for different textured soils. The panel considers that this subject, "How to live with salinity" is of great importance and interest to most of the participating countries. Therefore, the panel recommends that this subject be repeated in the Seventh NESA Regional Irrigation Seminar.

Miscellaneous

As the ultimate goal of irrigated agriculture is to attain the maximum production, this panel feels that more stress should be given to the agronomic aspects, such as cultural practices, fertilization, irrigation frequencies, irrigation amounts needed for different crops, and other practices. Therefore, the panel recommends that the Seventh NESA Regional Irrigation Practices Seminar include the topic, "Improved Agronomic Practices in Irrigated Agriculture."



Panel 7 How to Live with Salinity

Membership of the Panels

Panel I — Education and Training

Korkut Ozal, Turkey (Chairman)
M. Harrison Taylor, Turkey
A. Azarnia, Iran
Atif Y. Bokhari, Saudi Arabia
B. H. Griffin, Cyprus
Joma Mohamedi, Afghanistan
Thomas Ramsay, U.A.R.
H. R. Roumani, Syria
T. Thiruchittampalam, Ceylon

Panel II — Farm Management for Irrigation Practices

Ayten Aydin, Turkey (Chairman)
Naim Shouka, Jordan
Reed H. Lewis, Iran
Ali Rejali, Iran
Abdel Monem Azouz, Syria
A. P. Joseph, India
K. R. de Silva, Ceylon
Earl S. Sumner, Pakistan
Kyros L. Savvides, Cyprus
Kemal Ertunc, Turkey

Panel III — Irrigation Institutions — Farm Relationship

D. B. Anand, India (Chairman)
A. M. Wardak, Afghanistan
Fahd Natur, Jordan
Huseyin Yegin, Turkey
Joseph Miller, Afghanistan
C. A. C. Konteatis, Cyprus
A. W. Plummer, USAID/Iran
M. Yazdi, Iran
J. A. Amassian, Lebanon

Panel IV — Irrigation Practices Research

M. El-Madany, U.A.R. (Chairman)
Y. Azzeh, Jordan
B. Bahrani, Iran
N. G. Dastane, India
Y. Stylianou, Cyprus
M. Hussain Chaudhry, Pakistan
H. A. Thompson, U.K. (visitor)

Panel V — Irrigation & Drainage Systems

M. H. Parwana, Afghanistan (Chairman)
Jagat Kishore Jain, India
Tuna Tunaman, Turkey
Timucin Tumer, Turkey
Saade Nabih, Syria
P. P. Gorkhaly, Nepal
Mahmoud Abu-Zied, U.A.R.
Mohammad D. Hani, Jordan
Savvas J. Chimonides, Cyprus
F. Raji, Iran

Panel VI — Standards for Irrigation and Drainage Investigation

S. Ozgul, Turkey (Chairman)
M. G. Barclay, Afghanistan
Warren J. Leatham, India

B. Sayan, Turkey
K. C. Hassabis, Cyprus

Panel VII — How to Live with Salinity

K. Haddad, Jordan (Chairman)
Y. P. Bali, India
K. Constantinides, Greece
S. H. Krashevski, Pakistan
C. Soteriades, Cyprus
N. Hayali, Iraq
A. H. I. Moustafa, U.A.R.
A. I. El Shabassy, U.A.R.

CHAPTER III

CLOSING SESSION

DR. M. FAYYAD — Jordan

Chairman

Report of the Executive Committee

by Dr. Sami Suna'

I. Continuation of Seminars

It is recommended that the NESA Seminars be continued. It is believed that continuation of the seminars will further benefit irrigated agriculture in the NESA region.

II. Scope and Objectives of Future Seminars

It is recommended that future seminars keep the focus on irrigation practices and that continued attention be given to the experience and findings of the countries participating in the seminars and possibilities of applying these findings elsewhere.

The Executive Committee, while generally endorsing the recommendations of the panels and the proposed actions to achieve them, would like to recommend the following points as objectives for the next seminar:

(A) EDUCATION AND TRAINING

(1) The value of establishing inventories of existing personnel at various levels and future requirements for both short and long term needs.

(2) The desirability of establishing an agricultural corps through recruitment of graduates of agricultural engineering faculties and of agricultural high schools or similar institutions.

(3) The establishment of pilot demonstration farms and irrigation farming camps in newly developed areas.

(4) The importance and necessity of training middle level technicians.

(5) The need of inservice training and refresher courses.

(6) Planned programs for training in soil and water problems.

(B) Farm Management for Irrigation Practices

(1) Farm planning for irrigation.

(2) Survey and development of groundwater resources and integration with surface water resources.

(3) Criteria for selection of optimum size of holdings, and in particular, land consolidation.

(4) Importance of establishing agricultural credit, and marketing facilities.

(5) Area development, including communication facilities.

(6) Legislative measures to implement farm management programs.

(C) Irrigation Institutions—Farm Relationship

(1) Transfer of management and operation of parts of irrigation and drainage systems to the organizations of beneficiaries when and where deemed practicable.

(2) Formation of irrigation associations, their role, responsibilities, and government policies and procedures regarding these associations.

(3) Laws and regulations regarding water rights and water use.

(4) Water charges in relation to benefits derived.

(D) Irrigation Practices Research

Papers should generally deal with research projects and findings related to Panel IV recommendations.

(E) Farm Irrigation and Drainage Systems

Papers should generally deal with the recommendations of Panel V, with emphasis on case histories.

(F) Standards for Irrigation and Drainage Investigations

The participating countries should summarize and present standards and practices in use at the farm level with regard to land leveling, size and shape of plots, water delivery level, control structures, water allowances, etc.

(G) How to Live with Salinity

Papers should include case histories of both successful and unsuccessful projects.

III. Modifications and Improvement of the Program and Procedures

It is recommended that the following modifications and improvements be introduced in the program and procedures of the next seminar:

(A) The duration of the seminar be approximately two weeks.

(B) The scope of the seminar be limited to the aforesaid recommendations made by the Executive Committee.

(C) The seminar leader contact NESA countries about one year prior to the seminar to determine what technical papers would be most appropriate.

(D) The country progress reports present progress since the previous seminar in the field of irrigation and related problems. These should be prepared according to the outline given below:

(1) Brief description of the country and the present status of irrigation development.

(2) Accomplishments since the last seminar.

(3) Progress on water supply development mainly as related to farm irrigation.

(4) Development of institutions and procedures for improvement of farm irrigation.

(E) The total number of technical papers to be discussed may be limited to about thirty.

(F) Technical papers to be presented at the next seminar be prepared and printed at least two months before the date of the seminar and distributed according to instruction from the seminar leader.

(G) A general technical session be included in the program, preferably after field tours have been made.

IV. Responsibility for Organizing and Conducting Future Seminars

It is recommended that:

(A) The United States Agency for International Development should continue to take leadership responsibility for organizing and conducting future seminars.

(B) An invitation to participate in the next seminar be extended to interested UN specialized agencies.

Invitations for 1968 Seminar

On behalf of the Government of Cyprus, Mr. C. A. C. Konteatis extended an invitation to hold the Seventh Irrigation Practices Seminar in Cyprus.

On behalf of the United Arab Republic, Mr. Mahamad El Madany extended an invitation to hold the Seventh Irrigation Practices Seminar in Cairo.

Resolution

The following resolution was prepared and read by

HASHIM ROUMANI

Syrian Arab Republic

and adopted by the seminar

Mr. Chairman, Dr. Bishop,

Fellow Delegates,

It gives me great pleasure to extend, on behalf of all the honorable delegates to this Sixth Near East-South Asia Seminar, our deep thanks and gratitude to our host country, the Hashemite Kingdom of Jordan, to his Majesty King Hussein, to the Jordan Government and the people of this country, for the warm welcome we have had, the noble sensation we have felt, and the great generosity we have received since we arrived here.

I think you agree with me that this country has a right to be proud and to be distinguished from other countries of the world for its holy places, which constitute the heroic, heavenly religions calling for peace and brotherhood for all human kind.

After this closing session of the seminar, we will leave this wonderful country, carrying with us the nice spiritual feelings and the best memories we have of our visit and the friendships formed among the respected delegates of the different member countries.

Will you allow me finally, in behalf of all delegates, to extend again our deep thanks to all Jordanian authorities who, with the assistance of the USAID Mission to Jordan, did their utmost in preparing the seminar program, which has been very successful. We express our thanks mainly to the personnel of the Jordan Development Board, East Ghor Canal Authority, and all those who helped in organizing this seminar. We also thank the secretariat of the meeting for the excellent work they have performed.

Seminar Report

by

DR. A. ALVIN BISHOP

In a very short time now, we will bring to a close the Sixth Near East-South Asia Irrigation Practices Seminar, and most of the delegates will be completing, what I might call, the active phase of the seminar. You have been actively preparing for and participating in the seminar. Now comes the practice phase, of returning to your home country and putting into practice the ideas, methods and knowledge that you have gleaned from the seminar which may improve irrigation practices in your country. I hope that you have each found something useful. Now I would like to quickly summarize some of the accomplishments of the seminar.

Many of the worthwhile aspects of the seminar were achieved before the meetings officially opened on March 19. I am referring to the planning done during my visits to many of your countries last summer, which for me, incidently, was the official beginning of the seminar. I am referring also to the preparation of country reports and technical papers developed in anticipation of the seminar. I am referring too to the recommendations from previous seminars that have had a role in improving irrigation in this part of the world. All of these things happened before March 19, 1966.

First, regarding the planning during the summer of 1965: At this time, each country gave serious consideration to what worthwhile contributions it could make to the seminar. This caused an exchange of ideas within the country, which I believe is necessary and beneficial. At the same time, since reports and papers had to be prepared, it became necessary for people working with agricultural problems from different branches of government within the country to get together to discuss mutual problems. Thus a favorable atmosphere was created to get a report written.

Following my planning visits each country selected delegates who, with the help of their colleagues, prepared the reports and technical papers for presentation here. The subject matter of the technical papers, of course, was selected so as to be in accord with the recommendation of previous seminars. Nevertheless, many of these valuable papers would not have been written if it had not been for the seminar. So I believe that much good was done before our official meetings began here in Jordan.

Now concerning the seminar itself: First, the country progress report noted the development of irrigation in each country, the pressing problems were identified, and in some cases the importance of previous seminars in suggesting solution to the problems was mentioned.

The technical papers and discussions during the technical sessions provided a meeting ground for the solution of many problems and the exchange of many worthwhile ideas. *Drainage and Salinity* was the central theme for the first five papers in the technical sessions. *National Programs* provided the theme for six. *Farm Layout for Irrigated Agriculture* then was the central topic for three technical papers and *Small Projects* followed with six. Four papers were concerned with *Technical Factors* and *Research* contributed seven, with *Education and Training* providing three. As one reads the titles of these thirty-four papers, he is impressed with the tremendous breadth of the problems in irrigation. It is little wonder that irrigation is said to be so inefficient in many areas. How is it possible for the farmer or the cultivator to know all of the factors influencing his irrigation practices? I believe I mentioned once that the challenge facing the irrigation engineer, the irrigation scientist and government officials concerned with irrigation problems is to design, manage and operate the irrigation system in such a way that the farmer naturally makes the decisions that will yield for him the highest economic returns and will be in the best interest of national aims and objectives.

This seminar, above all, has been a working seminar. I have been impressed with the dedication of the delegates. All have shown a keen interest at all times in all of the papers, discussions and deliberations. The seven panels suggested by the executive committee went right to work, gave detailed consideration to the subject matter area, and formulated a comprehensive report with recommendations. In these panels, the free exchange of ideas and opportunity for individual discussion were evident. I believe much good will result from the hard work and that all countries will be the beneficiaries.

I believe that special mention should be made of the work of the executive committee. Its work was concerned with the program of the seminar and the selection of subject matter areas for panel discussions. Many hours were spent by this committee and its work was a major contribution.

I must also mention the field trips. These were designed as a study of irrigation practices of Jordan's newest irrigation project, the East Ghor. I'm sure that the delegates from other countries found many things of interest from the standpoint of irrigation practices. The main objective of the trips was therefore achieved, and in addition, an enjoyable experience was shared by all.

I think you would all be interested to know that more countries were represented at this Sixth Seminar than at any previous seminar. Last night I quickly reviewed the proceedings of all previous seminars and found that eight countries were represented at the first seminar, nine in the second, ten in the third, ten in the fourth with an FAO representative in addition, nine in the fifth and fifteen in this, the sixth.

Now, in closing, I would like to commend the committee here in Jordan and the USAID Mission here for a job well done.

Delegates' Appraisal

by

D. B. ANAND

India

Mr. Chairman, Dr. Bishop, and
Fellow Delegates,

It is my pleasure and proud privilege to extend heartiest thanks on behalf of the delegates and myself to His Majesty's Government of Jordan for hosting us here. We are highly indebted to our Jordanian colleagues and friends who have spared no efforts in making excellent arrangements for the seminar and the field trips.

The seminar was initiated by USAID in the year 1956, and has gained strength in the five sessions preceding the present one. We owe a debt of gratitude to USAID for its continued sponsorship of the seminar, and to the organization and its staff who have worked ceaselessly to make the present seminar the success it has been.

Irrigation in the NESA region is an age-old science, and has had a historic growth in each country. The vast and increasing populations of the region are tradition-bound in agriculture as in other matters. A great responsibility, therefore, lies on the technical men of these countries to achieve a break-through toward the acceptance and adoption of modern science in the matter of irrigation practice and agricultural production, so that not only the barest minimum but a reasonable level of sustenance is provided for the people. This needs not only pure scientific knowledge but also an understanding of the past background, and local compulsive and motivating factors. Success can be achieved only by dedication, and by almost heart breaking efforts.

I commend this challenge to the patience of the technicians of the NESA region.

Science knows no boundaries, and the task is pressing. The need of looking across the geographical boundaries is therefore self-evident. Seminars like this one provide such opportunities. The conditions differ from country to country, yet there is usually a thread of common approach toward a common goal. The personal contacts and discussions in the seminar induce understanding of the various conditions, the typical problems, and the probable solutions; no amount of cold logic could be as useful. And yet, by the very nature of things, no seminar can make mandatory decisions; it can merely indicate directions within broad guidelines. Such a goal the seminar has eminently achieved in its discussions and selection of subjects for future study.

We have had days of ceaseless work. The field trips were no less strenuous. The visit to the East Ghor Canal was stimulating, and technically rewarding. The hospitality of the Project Authority will be a thing to remember. The members of the executive committee had to burn the evening lamp for long hours; Dr. Bishop, Dr. Suna' and some of their aides for longer hours still. Delegates to future seminars will look forward to somewhat relaxed, though increasingly useful, sessions.

Now, like all good things, the seminar comes to a close. All delegates, I am sure, will join me in expressing deep appreciation of the efforts by our host country and the USAID authorities.

While departing with pleasant memories of a very successful seminar, we look forward to renewing contacts and friendships in the next seminar.

Thank you.

Observations of USAID

by

EMORY M. HOWARD

Chief, Irrigated Farming Division, USAID/J

This is the closing session of the Sixth NESA Regional Irrigation Practices Seminar. There have been eleven days of energetic study and work by the delegates in matters related to the improvement of irrigated agriculture in this region. There has been a valuable exchange of experience and technical information that, I am sure, has been well received, but from which the real benefits will come at a later date, as the new experiences are translated into meaningful water deliveries to thirsty acres.

The enthusiasm shown among the delegates to this seminar has lead me to believe that the coordinated efforts of the participating countries in the Near East-South Asia Region will have lasting results in the improvement and expansion of effective farm irrigation.

There have been fifteen countries represented, with observers from FAO of the United Nations, the United Kingdom, and the United States. If the number of delegates and participating countries are criteria for the success of these seminars, certainly this seminar has been successful. But I believe that the continued growth of the NESA Irrigation Practices Seminar is indicative of the ever increasing professional competence of the delegates attending. And the growth has continued since the beginning of the seminars in 1956.

I have been able to attend only a part of this session but I have kept in touch with the seminar progress, and I am impressed by a number of things, of which I will mention only three.

First, the fine quality of technical papers. It has been interesting to note that when a paper has been presented the author has had to be well acquainted with his subject and able to defend his position because he was delivering it to a competent group of technically trained people. This observation might well be noted by delegates who will attend future seminars.

Second, the recommendations made by the seven panels. These recommendations show a good deal of thought and study of important problems in farm irrigation.

And third, the executive committee, which has demonstrated its ability to focus the recommendations of these panels into a coordinated program for future study and for future seminars.

At the opening session of the seminar, Mr. Wheeler, Director of the USAID Mission in Jordan, extended a welcome on behalf of USAID. At this closing session, may I, on behalf of the USAID Mission in Jordan, express our appreciation for the fifteen participating countries. I would like also to express to the Jordan Government our sincere gratitude and USAID's appreciation for its part as host to the conference. We are also indebted to Dr. Bishop for his guidance in the affairs of the seminar. He has left a very busy schedule at his university to give us the assistance needed in making this a successful meeting.

I am hopeful that the value received from the seminar by the exchange of ideas and the building of new friendships among the delegates can be lasting and continue into the future. There are many problems in the overall development of water resources and farm irrigation that extend beyond the boundaries of a single country. For others to have a knowledge of the problems confronting neighboring countries can have lasting effects.

In closing, I sincerely trust that you have obtained something of value to take back to your country. I want to challenge each of you attending this seminar to return home dedicated to pursue a little harder the cause of developing improved irrigation practices. Increasing and hungry populations requiring an ever increasing food supply can certainly be assisted by your dedicated efforts.

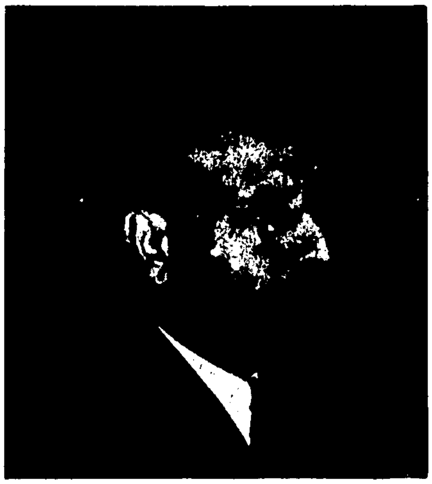
Thank you.

Closing Address

by

DR. NIJMEDDIN DAJANI

Secretary General, Jordan Development Board



At the conclusion of your deliberations, I should like to express our gratitude to all who have come here to Jordan for the Irrigation Practices Seminar. We have been very glad to see you here, and we owe a special debt to those of you who produced papers for this seminar. I have been advised by the technicians of the great knowledge which is shown in these papers. I should like to thank those of you who were responsible for the preparation of the seminar. I know something of the hard work and administrative detail which it involved. I would like to congratulate you for your efforts and achievements, and I am sure that the report of the seminar and its recommendations will constitute a valuable scientific and practical document for all participant countries.

The seminar has already aroused wide interest in Jordan, and I feel justified in saying that further seminars for the examination of some other irrigation matters or matters related to irrigation practices will be needed.

Up to now you have had the pleasure of listening to papers read by gentlemen whose credentials in scientific training and technical experience are unquestioned. You must not grumble if an amateur tries to make a few comments on the subject. I hope you will bear with me as I make some of these remarks even as you are ready to go home.

I feel that one of the serious problems facing irrigation development has been the inadequate attention given in planning the legislative, institutional, and organizational aspects of irrigation development, while giving all the attention to the engineering aspects of the development. It is because of this that I feel that future seminars ought to consider these aspects. The Arabs have had a long and sustained experience in irrigation. Whenever one reads history of the Arabs one always concludes that the periods when their irrigation and agriculture flourished most in the past, were the periods when there was a strong ruler, and in more recent times when there was suitable legislation properly enacted and firmly enforced. It is not possible to think of conserving soil, preventing malaria, developing and securing the future of agriculture without the full control of water, a control which can be met only by governments and for which the individual interest must in many cases give way to the interest of the state.

From our experience with the East Ghor Canal scheme we have found that for the implementation of irrigation schemes of this magnitude and complexity a new organizational technique is needed: adequate control for proper irrigation and coordination of the work at the different levels of planning and operations. To meet this need and cut across the multiplicity of work through several government departments it has been found advisable in Jordan to establish a separate, independent statutory agency. In addition to the above, such a body has the advantage of being able to reduce red tape. It will also have more freedom in recruiting qualified staff and paying higher salaries than those prevailing in the established government departments.

The shortage of trained and experienced personnel at all levels is a matter of concern to us in this country. This has been due to our continuous loss during the past five years to some of the neighboring countries where the salary scales are much higher than those prevailing in Jordan.

I was glad to see that your seminar paid adequate attention to the problem of salinity, a factor which may have a considerable bearing on the future of many of the irrigated lands in this part of the world. While highly saline water which has a direct and immediate adverse effect on crops is rarely used, a large proportion of the irrigation water has a relatively high saline content, the effect of which, though not immediately apparent, is cumulative and may have a permanently injurious effect on the soil. This problem has already arisen in certain areas in Jordan where intensive cropping coupled with continuous irrigation has been practiced for the last ten to fifteen years. Our knowledge is limited as to the influences on yields of (a) the various qualities of water and (b) the methods of irrigation. It is therefore evident that the problem needs further study.

Ladies and gentlemen, before I close, I should like to take this opportunity of thanking the United States Agency for International Development for making this seminar possible and for the valuable contributions of Dr. Bishop, its technical adviser and seminar leader.

I hope that you have spent a pleasant time here during your stay in this country and that you have had the opportunity to get acquainted with our development program and our plan for the future. I take this opportunity to thank you and your countries for accepting our invitation to participate in this seminar, and I hope that you will come back again. I wish you success in your future efforts and your safe return home.

CHAPTER IV

Country Progress Reports

AFGHANISTAN

In the country report submitted by Afghanistan at the last seminar on "Irrigation Practices," in New Delhi, India, in March, 1964, information was presented concerning irrigation developments and related water resources activity which had occurred in Afghanistan during the preceding two-year period. This report presented here today gives up-to-date information on those projects discussed two years ago, as well as discussion of work on new projects. Also, we hope to give you some idea as to what our plans and hopes are for future expansion and improvement of irrigation. Since almost all agriculture in Afghanistan is based on irrigation, it is natural that discussions of this conference are of major interest to the delegates from my country.

Rainfall in the southern section of Afghanistan was above normal in the spring of 1964 and about normal for 1965. Runoff of the rivers in the southern half of the country was about average for 1964, while heavy snows plus rains in the central highlands where the Helmand and Arghandab rivers rise, created well above normal runoff during the spring and early summer of 1965. Records indicate that streamflow for 1965 for rivers in the south was about 160 percent of the average for the period of 1952-65. Both the Helmand and Arghandab rivers were at flood stage for a considerable period of time. Because of storage provided by the Kajakai Reservoir on the Helmand River and the Arghandab Reservoir on the Arghandab River, water supply has been adequate in the Helmand Valley Project for the past two years. Also water supply for irrigation in other sections of the southern part of the country has been average or above average.

On the basis of records and observations, it is found that runoff and water supply for irrigation were about average for the northern part of Afghanistan for the past two years. There were no droughts, and no severe flooding conditions.

At present, the prospect for the coming year is not so encouraging. Snow surveys made in February and March indicate that runoff from snow melt may be low in 1966, as there is presently little or no snow on most of the snow survey courses.

In the past two years irrigation development throughout Afghanistan has continued through construction and investigations. The largest project type of development in the country is the Helmand River Project, which is being executed under the general administrative direction of the Helmand Valley Authority. This multi-purpose project, which provides for irrigation, flood control and hydroelectric power, was initiated about twenty years ago, through construction of two major reservoirs, the Kajakai Reservoir on the Helmand River, and the Arghandab Reservoir on the Arghandab River. Four irrigation canals with a total length of about 253 kilometers, together with a few laterals, drains and project roads, were also constructed during the initial stage of development. Also, two small power plants have been built at drops in main canals, and plans are now being made for installing a large power plant at the Kajakai Reservoir. Although all the main supply canals and some of the distribution works and drains were installed during the initial phase of project construction, many of the laterals, drains, and most of the land development have not been completed. To bring additional land into higher production through improved irrigation systems, the Afghan Construction Unit, a division of the Helmand Valley Authority, has continued land development work and other construction activity. During 1964 and 1965, thirty-five kilometers of deep drains were dug in the Darweshan unit in the Helmand Valley, and some forty-seven kilometers of farm drains were constructed in the Marja unit on the west side of the Helmand River on a desert bench area. Also, some fifty-seven kilometers of laterals were constructed in the Darweshan unit on the Helmand River and the Tarnak unit in the Arghandab Valley near Kandahar. As part of the land development program in the Tarnak area, 300 hectares* were leveled to get the land in shape for irrigation and subsequent settlement. Road construction has continued and some thirty kilometers were completed on the Kajakai road. Also in the past two years, the Girishk hydro-electric power plant on the Boghra Canal was rehabilitated and further studies are now being made of this plant to determine the cause of erratic fluctuations in turbine speed. Another activity in the Helmand Valley that has been initiated in the past two years is that of project development planning. This work has been undertaken to make a better selection of lands to be developed in the future. Planning work is being based on land classification, engineering plans and economic studies to insure engineering and economic feasibility of future work.

Also, as ancillary programs for the Helmand Valley, the Helmand Valley Authority is promoting modernization of agriculture and agricultural based industries. A research station has been established on the Helmand River at Bost, to test and improve seeds for the farming community as well as run experiments in farming practices and use of fertilizers. Also, a modern cotton gin has been built and is now operating at Bost, and a modern plant for extracting vegetable oils from oil seeds is under construction.

The Nangharhar Project on the Kabul River near Jalalabad, Afghanistan, is another major irrigation project under construction since the fall of 1961. In the current plans for this project, it is contemplated that some 30,450 hectares of land will be developed for irrigation by diversion of water from the Kabul River by means of a diversion dam, a main canal seventy kilometers long having an initial capacity of fifty cubic meters per second, and laterals, sub-laterals, and drains as required. Of the total area to be irrigated, it is planned that 6,500 hectares will be irrigated by pumping from the main canal and the remainder of the lands will be served by gravity flow. The plan also provides for construction of a hydroelectric power plant at the diversion site with three generators having a total installed capacity of 11,500 K.W. Part of the electricity generated at this power plant will be used by Jalalabad and nearby towns and villages and the remainder will be used for the irrigation pumping plants.

In the report submitted two years ago, progress on the Nangharhar Project was discussed in detail. Since then work has continued and the main canal, including two tunnels and several siphons, has been completed, and most of the laterals and drains for lands to be served by gravity have also been completed. Work on one of the irrigation pumping plants is almost complete, and the main supply lateral which will deliver water from the pumping plant discharge pressure line is also al-

* One acre equals 0.40 hectare.

most complete. The power plant is now complete and power is being provided to Jalalabad for domestic and municipal use. Land preparation is underway by leveling and installation of farm ditches, and this work his been completed on about 16,000 hectares. Irrigation is being provided to these lands. Intensive operations are underway to improve their fertility through a program of crop rotation and other practices designed to make the lands capable of high production. Crops now being grown are citrus fruits, alfalfa, peas, and truck crops. Land development is being continued to bring additional lands under irrigated cultivation as soon as possible.

Construction of the Sardeh Dam and Reservoir near Ghazni, reported on at the last conference, has been continued and is now almost complete, and water is being stored in the reservoir. The reservoir at present has a useful designed capacity of 125 million cubic meters, and it is contemplated that water supply developed at this reservoir will be used for irrigation. Studies are now being initiated for developing the irrigation features of the project. When these plans are completed it is anticipated that as much as 21,000 hectares may be irrigated from this reservoir.

Other construction work for irrigation in Afghanistan during the past two years has been devoted largely to rehabilitation of existing systems so that water supply for irrigation will be more dependable and adequate. Most work performed has consisted of repairing or improving diversion works or intake structures and in some instances improving old canal systems. The location of points where such work has been accomplished is shown on the accompanying map.

In the north part of the country the Sharawan Canal diverts water from the Amu (Oxus) River to a large area of land along the south side. Due to degradation of the bed of the river, the normal flow of the river fell below the canal intake and diversions could not be made. To overcome this difficulty, the main canal was extended upstream during the spring of 1965 and a new intake was constructed at a point that would permit diversions into the canal when the river flows at a normal or low stage. This work was an emergency operation and was done to insure irrigation water supply during the 1965 irrigation season.

Work on the Adjmir Canal intake, initiated more than two years ago, was completed in the fore part of 1966. This canal is located on the Khunduz River near Pul-i-Khumri in Baglan Province. This intake canal is about two and a half kilometers long, extending between the diversion works at the tail race of a power plant and the upper end of the existing old canal system. This new intake canal has a capacity of fifteen cubic meters per second and serves an area of 12,000 hectares. Consideration is now being given to improvement of the existing main canal and lateral system that presently serve the old irrigated lands.

Work of lining about ten kilometers of the Badak Canal a few kilometers southwest of Kabul was initiated in 1964 and is now in progress. It is contemplated that this work will be completed in 1966. Lining consists of stone masonry with cement mortar joints. The canal serves an area of about 5,000 hectares.

The Reza-Kohestan Project at Gulbahor in Kapisa Province is another project that has recently been rehabilitated. Work consists of improving a canal some forty-two kilometers long, having an initial capacity of five cubic meters per second. The area served by this canal is about 3,200 hectares. About one-half is old lands and the remainder is new lands to be served by canal and lateral extensions.

In addition to the construction work just discussed, planning has been accomplished or is underway for three projects in the Khunduz River Basin in the northern part of the country. These are the Kalagai, Lankharbi and Alchin projects. Planning and design have been completed on the Kalagai and Alchin projects and construction can be initiated whenever approval and financing are provided. Planning is underway on the Lankharbi project, with surveys completed, and design work underway.

In the plan for the Kalagai project, it is contemplated that a new diversion dam and a main canal eighteen kilometers long will be constructed.

The initial capacity of the canal will be four cubic meters per second. The terminal end of the canal will join an old canal system that serves about 1,500 hectares of presently irrigated lands. In addition to the old lands to be served, about 1,000 hectares of new land will be served by a gravity canal that will be located above the original irrigated lands. Also, 200 hectares will be served by pumping by means of a ten-meter lift in elevation. Capacity of the pumping plant is designed to deliver 0.3 cubic meter per second.

The plan for the Lankharbi project has not been completed, as the economic feasibility of the pump irrigation phase of the project has not yet been determined. The project as presently conceived will be largely rehabilitation of a canal system which serves about 3,000 hectares of presently irrigated lands. By extension of the canal system an additional 1,000 hectares will be served by gravity. Also, if determined feasible, possibly as much as 1,000 hectares of new land may be irrigated by pumping.

The initial diversion capacity of the main canal will be about 3.3 cubic meters per second, and the capacity of the extension of the system to serve new land is 2.5 cubic meters per second. The final plan for this project will be determined after further studies.

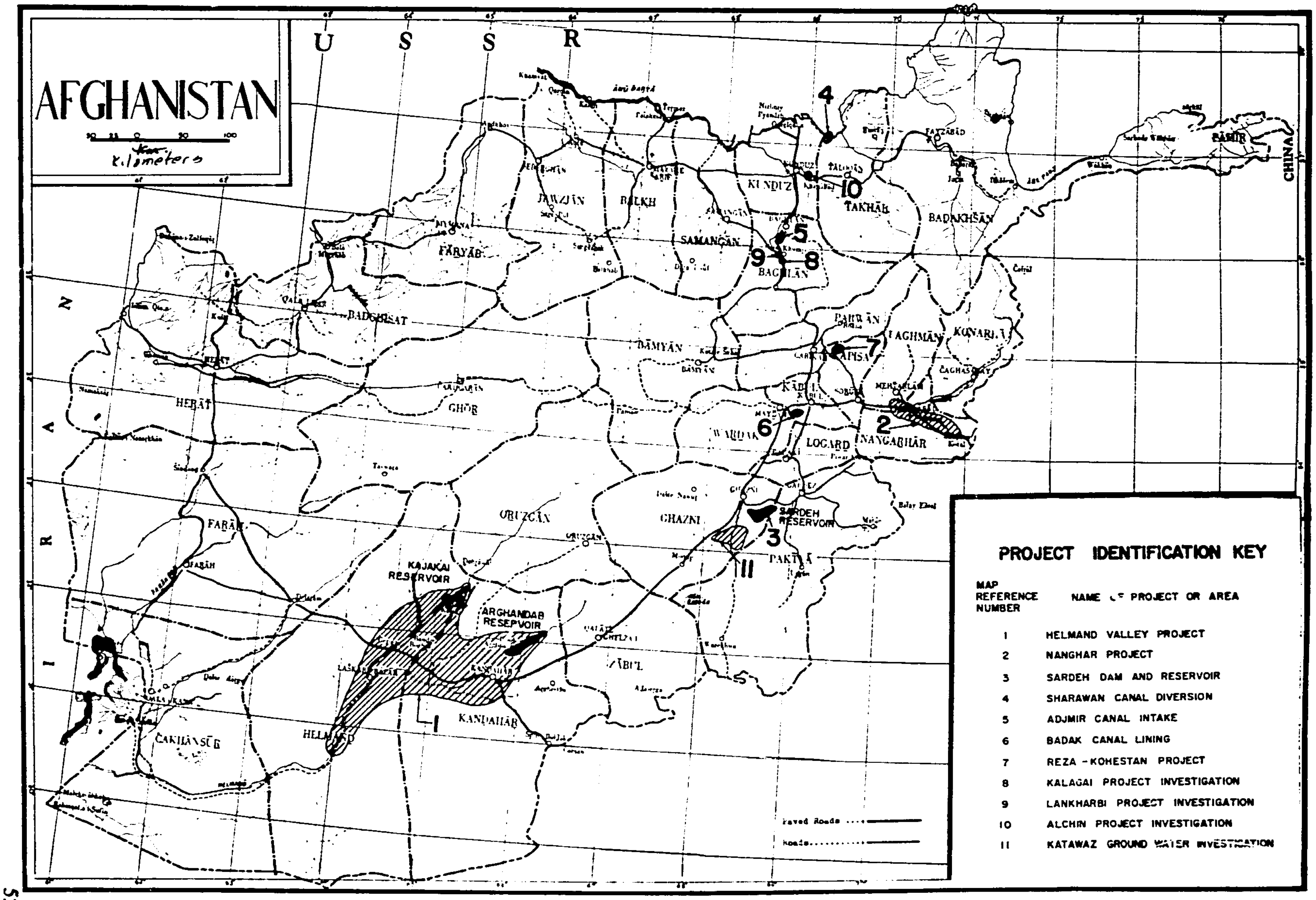
The Alchin project is a combination rehabilitation project for existing irrigated land and new land development. The works contemplated will consist of a diversion works and a main canal one kilometer long to its junction with the existing Asqualon Canal. This new diversion canal will have a capacity of eleven cubic meters per second. Old irrigated lands under the Asqualon Canal total 5,200 hectares. At the junction with the Asqualon Canal, a pumping plant is planned which will lift water fifteen meters at a rate of 1.9 cubic meters per second. The pumping plant will discharge into a canal eight kilometers long and serve 1,350 hectares of new land to be irrigated.

In addition to the construction work and detailed planning work described above, soil and topographic surveys have been carried out by the Soil and Water Authority of the Ministry of Agriculture and Irrigation. Work done during the past two years by this agency consists of reconnaissance surveys in the Khunduz River Basin for developing irrigation on about 15,000 hectares. In the Kokcha River Basin, semi-detailed surveys were made for an area of about 20,000 hectares. Also, reconnaissance surveys have been conducted in the northern provinces covering extensive areas of land, including both new lands and old irrigated lands under existing systems. Surveys in the northern provinces also include studies of eleven dam sites. Surveys of multi-purpose projects for flood control, hydro-electric power and irrigation have been made in the Panj and Amu (Oxus) River basins where ten dam and reservoir sites have been studied.

In the realm of groundwater, work has been initiated for making comprehensive groundwater investigations in the Kabul area and the Katawaz area south of Ghazni. The total area to be studied comprises about 26,000 square kilometers, which appear to have possibilities for shallow groundwater pumping. Planning for the program has been completed and equipment for the work is now being mobilized.

In addition to this work, investigations are being considered during the coming year for the Lagman, Balkh and Kunar projects. Also, studies of the Hari Rud and Kabul River basins are being continued to determine the possibilities of multipurpose projects for irrigation, hydro-electric power, and flood control.

In our planning work, we have not overlooked the need for basic data. At the present time fifty-six stream gauging stations are being operated with automatic water stage recorders, and eight stations are being operated by means of staff gauges. Plans are being made for more than doubling the number of stream gauging stations throughout the country. Also, some thirty-three weather stations are being operated to provide information on precipitation, temperature, and in some instances, wind velocities and evaporation.


AFGHANISTAN
Kilometers
U S S R
IRAN
CHINA
KAJAKAI RESERVOIR
ARGHANDAB RESERVOIR
SARDEH RESERVOIR
PROJECT IDENTIFICATION KEY
MAP REFERENCE NUMBER
NAME OF PROJECT OR AREA
1 HELMAND VALLEY PROJECT
2 NANGHAR PROJECT
3 SARDEH DAM AND RESERVOIR
4 SHARAWAN CANAL DIVERSION
5 ADJMIR CANAL INTAKE
6 BADAK CANAL LINING
7 REZA - KOHESTAN PROJECT
8 KALAGAI PROJECT INVESTIGATION
9 LANKHARBI PROJECT INVESTIGATION
10 ALCHIN PROJECT INVESTIGATION
11 KATAWAZ GROUND WATER INVESTIGATION
Paved Roads
Roads
HERĀT
FARĀH
KANDAHĀR
HELMAND
GHAZNI
KĀBUL
BAGHLĀN
KUNDUZ
TAKHĀR
BADAKHSHĀN
NANGARHĀR
LOGARD
WARDAK
BĀMYĀN
GHŌR
ORUZGĀN
ZĀBUL
PAKTIA
SAMANGĀN
BALKH
JAWZJĀN
FĀRYĀB
BADGHISAT
KAPISA
PARWĀN
LAGHMĀN
KONARHA
CAKHĀNSŪR

CEYLON

Geographical Features

The Island of Ceylon is situated southeast of the southern extremity of India and lies between 5°-55′ and 9°-50′ North latitude and between 79°-42′ and 81°-52′ East longitude. It is separated from the subcontinent by a narrow strip of shallow water, the Palk Strait. The greatest length of the island is 270 miles from north to south and its greatest width is 140 miles from east to west. It has a total surface area of 25,332 square miles.

The relief of Ceylon may be said to comprise a mountainous area about the south-central part, averaging in elevation from about 3,000 feet to 7,000 feet, and surrounded by an upland belt of about 1,000 to 3,000 feet, while the coastal plain occupies the rest of the island. This plain is narrower on the west, east and south, but broadens out to a vast tract in the north.

Geologically, about nine-tenths of the island is occupied by crystalline rocks of Archaean age, with only narrow belts of more recent sediments along the coast. The only extensive development of sedimentary rocks is along the northwestern coast of the island, which is built up of limestones of the Miocene age.

Climate and Rainfall

Although its situation is close to the equator, the mean temperature in the low country is moderate, about 80° to 82°F due to the oceanic effect. In the hill country the temperature falls off at a steady rate of about 1°F for each 300 foot rise in elevation.

A noteworthy feature in many parts of Ceylon is the small variation in the mean monthly temperature and pressure. Highest temperatures are experienced in the districts to the north or northwest of the hills and in the eastern or northeastern low country, generally during the period of March to June. But they seldom exceed 99°F. The lowest temperatures experienced in the hills are generally of the order of 45°F, but do occasionally fall below freezing point.

Rainfall is unevenly distributed and is the only form of precipitation. There are two main rainfall seasons, the southwest monsoon period from May to September and the northeast monsoon period from December to February, each preceded by an inter-monsoon period of about two months' duration. The southwest monsoon rain is mostly confined to the southwestern parts of the island and the northeast monsoon to the northeastern parts. The rainfall during the inter-monsoon period of October and November is widespread and exceeds twenty inches at many stations. On the island as a whole, this is the rainiest period of the year. Conditions are similar during the other inter-monsoon period of March and April, but the rainfall received is less, mainly because of less depressional activity.

The average annual rainfall varies from below forty inches in the driest areas in the northwest and southeast of the island to over 200 inches in certain areas on the southwestern slopes of the hills. There are two recognized rainfall zones, namely the "wet zone" and the "dry zone," separated by the seventy-five-inch isohyet. This distinct separation is mainly due to the physiographical effect of the central mountainous region. The wet zone covers approximately the southwest quadrant of the island and the dry zone the remainder.

The wet zone receives most of its rainfall during the southwest monsoon. The average annual rainfall generally varies from seventy-five to 200 inches. The rainfall in the dry zone is due mainly to the northeast monsoon. The average annual rainfall is from forty to seventy-five inches.

Rivers and Waterways

The hydrographic pattern is a function essentially of relief, and in Ceylon with its central hilly mass, a general radial pattern is clearly revealed. The rivers flowing to the west, east and south are shorter than those flowing to the north, northwest and northeast.

There are 103 rivers and streams that form the main waterways, draining areas varying from 4,034 to four square miles. The largest and the longest river is the Mahaweli Ganga, 203 miles long. It has a catchment area of 4,034 square miles. The other large rivers are the Kelani Ganga (885 square miles), the Kalu Ganga (1,050 square miles), the Walawe Ganga (954 square miles) and the Aravi Aru (1,268 square miles). The total average annual discharge of all rivers and streams is estimated at 27.6 million acre feet, representing a runoff of about twenty-one inches depth or 1,100 acre feet per square mile. The discharge of the twenty rivers that flow entirely in the wet zone is sixteen and one half million acre feet, while the other eighty-three rivers flowing through the dry zone discharge 11.1 million.

National Resources and Population

The estimated population of Ceylon in 1964 was 10,971,000, with a density of 440 persons per square mile. The annual increase in population is about two and one half percent. The greatest concentration of population is mainly along the western and southern coastal regions and the central region, which comprises the entire wet zone area. In the rest of the island, the density of population is low.

Agriculture is the most important industry in Ceylon. About four million acres of land are under cultivation, in the following crops:

Rice	1,250,000 acres
Tea	587,000 acres
Rubber	671,000 acres
Coconut	1,100,000 acres
Highland cultivation	392,000 acres
Total	4,000,000 acres

Besides agriculture there are no other industries of much significance. Manufacturing industries are confined to producing common salt, cement, asbestos, plywood, leather, glassware, ceramics, garments, soap, paper, cigarettes, biscuits, confectionery, and matches. But most of these do not produce the island's requirements and have to be supplemented by imports.

There are no known deposits of coal or petroleum, and easily exploitable industrial raw material resources are few. The only minerals of commercial significance at present are graphite, limestone, precious and semi-precious stones and ilmenite and monozite sands.

Hydropower is not available in sufficient quantity, and large quantities of fuel have to be imported.

Agricultural Problems

Ceylon's national economy depends almost entirely on agriculture. While over ninety percent of her foreign exchange is earned by the export of her primary agricultural products, such as tea, rubber and coconuts, about thirty percent of these earnings are spent on the importation of rice, wheat and subsidiary foodstuffs.

The staple food of the population being rice, it has to be imported annually at a cost of about 225 million rupees* to meet the deficit in local production. Another 167 million rupees has to be spent on the importation of subsidiary foodstuffs, such as chillies, onions, potatoes, pulses, etc. The production of these additional requirements will not only save the country very valuable foreign exchange but will also to a large extent reduce the heavy unemployment and under-employment.

The total extent of developed paddy land in Ceylon in 1964 was 1,249,160 acres, comprised of 736,363 acres of irrigated lands and 512,797 acres of "rain-fed" lands. However, the actual acreage cultivated in 1964 was 1,013,611 during the maha season (October to March) and 571,587 acres during the yala season (April to September), or a total of 1,585,198 crop acres, some lands being double-cropped. The total yield was fifty million bushels of paddy, equivalent to 705,000 tons of rice, which was sixty-one percent of the total consumption of 1,139,000 tons. The deficit was therefore about thirty million bushels of paddy. The consumption requirements of the annual increase in population will be two million bushels.

If the total consumption requirements are to be grown in the existing developed area, the average yield per acre has to be increased to about sixty-two bushels, compared to the present yield of 38.6 bushels. To meet the needs of the annual increase in population the yield per acre should be further increased by about one and a half bushels per year. On the other hand, with the present yield about 650,000 acres of lands should be developed to meet the deficit in production, and another 45,000 acres per year to meet the needs of the increase in population. The increase in crop acreage during the six-year period 1958-1964 was only 203,000 acres and the yield during the same period rose from 34.1 to 38.6 bushels in maha and from 34.9 to 38.9 bushels in yala. The production has to be increased therefore, both by increasing the yield per acre and by extending the area under cultivation.

* £1 equals rupees 13.33.

As regarding the subsidiary foodstuffs, of the 167 million rupees worth imported in 1964, chillies account for nearly thirty percent. In that year the import of chillies was 425,383 cwt. at a cost of 46.5 million rupees. This quantity can be produced locally by developing about 40,000 acres under irrigation. There has been no organized cultivation of chillies under irrigation so far. The extent under cultivation in 1964 was about 40,000 acres, of which about 1,900 acres were under lift irrigation from "dugwells" and the balance was rain-fed, mainly in *chenas* and home gardens. Chillie production cannot be expanded at the required speed and quantities by relying exclusively on rain-fed cultivation. The solution lies in providing irrigation in those areas best suited for this crop. If this is done, chillie cultivation will establish itself as a system of settled farming in which not only chillies but also a variety of other subsidiary crops can be grown by a system of rotation.

Land Resources

The total area of Ceylon is 16.21 million acres, of which about four million acres are under cultivation. The remaining area of 12.21 million acres may roughly be grouped as follows:

(a) Roads, Streams, Tanks, Towns, Villages, etc.	1,300,000 acres
(b) Forests (including national reserves and sanctuaries) ..	3,500,000 acres
(c) Rocky, steep lands, etc.	4,750,000 acres
(d) Balance available for future agricultural development	2,660,000 acres
Total........................	12,210,000 acres

Thus there are about 2.7 million acres almost entirely in forest, which is available for agricultural development. As the wet zone has been fully developed, most of the available land is in the dry zone.

Agricultural Development of the Dry Zone

Agricultural development of the dry zone under irrigation has hitherto denoted the development of lands under rice cultivation. The dry zone covers an area of about 12.5 million acres or about three-quarters of the island. The mean annual rainfall in the dry zone is about forty to seventy-five inches. From an agricultural point of view these figures are much less significant than the seasonal distribution, variability and effectiveness of the rainfall. The mean monthly rainfall for the southwest monsoon months of June, July and August is low and in certain places very low. These months constitute the dry season. Although about seventy-five percent of the mean annual rainfall is experienced during the wet season, September to January, eighty percent of this seasonal fall is realized in about 100 days. Even during this period there are long spells of dry weather which make organized agriculture a hazardous undertaking. The soil is generally shallow, hard and relatively impervious, with the result that when precipitation occurs, a large percentage of it flows down as surface runoff. The rate of evaporation is also high. In these unfavorable conditions, impounding of the wet weather flow in storage reservoirs becomes a necessity, and irrigation an essential requirement for dry zone agriculture, as water has to be supplied for cultivation not only during the dry season but during the wet season as well.

The extent under rice cultivation in the dry zone in 1964 was about 850,000 acres, of which 600,000 acres were under irrigation and the other 250,000 acres were "rain-fed." Detailed studies of the irrigation potential of the available land and water resources have yet to be made. However, preliminary studies indicate that an additional 900,000 acres of new lands can be developed from the yield of the eighty-six river basins in the dry zone.

The groundwater resources of the dry zone have not been assessed. Except in the Jaffna Peninsula in the north and a narrow northwestern coastal strip, the dry zone is floored by crystalline rocks which hold no water, except in relatively rare fissures and permeable bands. Underground water is limited to a thin permeable surface layer, usually varying from two or three to forty feet thick of decayed rock, sub-soil and soil, and even when these materials are saturated during the northeast monsoon the quantity held is scanty. Hence extensive development from groundwater resources is not possible. However, proposals are in hand to assess the groundwater resources and develop a small extent of land in the northwestern coastal strip of the island under subsidiary food crops.

Agricultural Development of the Wet Zone

The total land mass of the wet zone is about 3.75 million acres, more than seventy-five percent of which is developed. The balance is mostly forests, marshes and inland lakes. The lands available for development are therefore the marshes in the coastal belt, about 60,000 acres, some of which were cultivated and abandoned due to want of proper drainage, salt water intrusion or both. These areas are generally flat and almost at or a few feet above sea level, while certain areas are below sea level, ranging down to about - 2.0 M.S.L., and lie in the most thickly populated parts of Ceylon. The unemployment here is very acute and the demand for land is pressing.

A scheme for the reclamation and development of these lands has been drawn up to provide drainage by gravity and pumping where necessary, prevent sand bar formation, intrusion of salt water and treatment of soils to make them cultivable.

The extent of developed paddy land in the wet zone in 1964 was about 400,000 acres, of which 140,000 acres were under irrigation schemes and the balance "rain-fed." As the rainfall in this zone is adequate and fairly evenly distributed, the streams are perennial and storage reservoirs are not quite necessary for irrigation. The irrigation schemes in the wet zone are mainly small anicut* schemes for diversion of water from these perennial streams, or are drainage schemes.

Peasant Colonization for Irrigation Development

The trade slump of the early thirties in the principal commodities of the island reduced employment in the wet zone and brought about a vital necessity for expansion to the dry zone as a

* Anicut is a gated diversion wier.

means of livelihood to the people. On the one hand there were large extents of jungle lands in the dry zone, on the other there were thousands of families living in congested areas in the wet zone with no means of sustenance. Thus the population pressure in the wet zone caused the government to initiate a scheme of colonization and land utilization in the dry zone. The settlement on idle land served with irrigation facilities held out to the peasant bright hopes of improving his standard of living and at the same time increasing the wealth of the nation. The general policy of the government had been to establish a peasant on a unit of holding consisting of irrigated land and a highland area to enable him to settle on the land and derive from it an income sufficient to maintain himself and his family.

In the earlier settlement schemes the irrigated land unit was five acres and the highland three acres. As the price of agricultural produce improved, the demand for lands by the peasant settlers increased, the unit of allocation was first reduced to three acres of irrigable land and two acres of highland. The units of allocation to a colonist at present is two acres of irrigable land and one acre of highland. The smaller unit will induce the cultivator to do intensive cultivation and pay more attention to his land.

The colonization under irrigation schemes in the dry zone commenced with the Minneriya Scheme, which could be said to be the first area of organized settlement provided by the government. To date about 50,000 colonist families have been settled in about seventy colonization schemes covering approximately 250,000 acres, of which 150,000 acres are under irrigation and the balance highland.

Irrigation Works

The irrigation works are classified as major irrigation works and minor irrigation or village works.

The major works are those maintained and operated by the Irrigation Department from general funds and the lands under them have to pay irrigation rates in accordance with the agreement between the government and the proprietors under the Irrigation Ordinance. There are about 200 major schemes irrigating 366,000 acres. Minor flood protection schemes and salt water exclusion schemes are also classified under major works.

Minor works are small tank or anicut schemes which do not pay any irrigation rate. The construction of these works is the responsibility of the Irrigation Department, while the operation and maintenance are the responsibility of the cultivators under the supervision of the Department of Agrarian Services. There are over 7,000 minor works which irrigate 375,000 acres.

Irrigation Organizations

The organizations responsible for irrigation development in the country are the Irrigation Department and the River Valley Development Board under the Ministry of Lands, Irrigation and Power, and the Department of Agrarian Services under the Ministry of Agriculture and Food.

The Irrigation Department handles all activities relating to water resources development and drainage of agricultural lands. The departmental organization consists of ten territorial divisions, each administered by a divisional engineer. Each division is further divided into three or four subdivisions each in the charge of a sub-divisional engineer. The sub-divisional engineer is the executive officer in charge of all investigations and construction of all irrigation works and the operation and maintenance of all major works.

Each of the twenty-two revenue districts in the island has a district agricultural committee, under the chairmanship of the revenue officer, which brings up new items of minor works for investigation and construction by the Irrigation Department. These are included in a priority list. After investigation by the sub-divisional engineer, these are taken up by him for construction.

The planning and research division of the department, in the charge of a deputy director, is responsible for the overall planning of the island's water resources, for the investigations and designs of the major projects, and for carrying out laboratory and field tests, foundation exploration works and collecting hydrologic data throughout the island.

The maintenance and operation of the minor irrigation works is under the supervisory control of the Department of Agrarian Services. The main function of that department is to provide the services required for assisting the cultivators in the production of rice and subsidiary foodstuffs. The services provided are: granting of credit facilities, supply of fertilizer at subsidized rates, payment of a guaranteed price for the food crops, a marketing scheme for the purchase of produce from the cultivator, operation of the Paddy Lands Act by which security of tenure of land is assured to the cultivator and the crop insurance scheme.

The Gal Oya Development Board was established in 1949 as an autonomous body for the complete and coordinated development of the area under its authority, inclusive of all irrigation, power development and supply, flood control and other agricultural and industrial development. The activities of this board have now been expanded with the object of entrusting the development activities in other river basins, and the board has been reconstituted as the River Valley Development Board. This new board has been placed in charge of the development work of the Uda Walawe Basin.

Five-Year Plan of Irrigation Development

The five-year plan for the period 1966-1970 has been drawn up for the development of 195,000 acres under irrigation and 47,000 acres of highland. The land under irrigation is made up of 106,000 acres under major projects, 50,000 acres under minor projects, 19,000 acres under drainage and reclamation schemes and 20,000 acres under lift irrigation schemes for subsidiary food crops. The lift irrigation program introduced for the first time into the irrigation plan comprises 15,000 acres under lift irrigation from surface sources and 5,000 acres from groundwater. Some of the major projects in the program of construction are listed below:

Rajangana Reservoir Project

This project, located in the northwestern province of the island envisages the construction of a reservoir 81,000 acre feet in capacity to irrigate under rice cultivation 15,000 acres of land now in jungle, the settlement of 7,200 families, and the development of 11,000 acres of jungle land under highland crops.

The dam, two and a half miles in length, consists of a central concrete dam 1,175 feet in length and a maximum height of about seventy feet, with rolled filled earth dams on both flanks. The spillway, incorporated in the concrete dam, consists of an uncontrolled overflow section 220 feet long and a gate section controlled by thirty-two radial gates each twenty feet by ten feet high. Two sluices, one on each bank of the river, discharge into two main canals. The right bank canal, five miles long, together with about ninety miles of minor channels, irrigate 4,500 acres, while the left bank main canal, thirty-five miles long, together with about 200 miles of minor channels, irrigate 10,500 acres. The estimated cost of the project is thirty-one million rupees.

Construction of the earth dam and ninety percent of the concrete dam and sluices has been completed. About ten miles of the main canal and twenty-five miles of the minor canals are also complete. The project is scheduled for completion in 1970.

Kaudulla Reservoir Project

This is a flood control-cum-irrigation project situated in the northeastern part of the island. It consists of a reservoir 104,000 acre feet in capacity, formed by the restoration of an ancient breached dam across the Kaudulla Oya and the provision of two sluices and a spillway consisting of twelve radial gates each twenty feet by twelve and a half feet high. It is designed to develop under irrigation for rice cultivation 10,000 acres of land now in jungle, the settlement of 4,500 families in 5,500 acres of highland, which will also be developed under highland crops. In addition, this project will protect 3,000 acres of rice lands under Gal Amuna Anicut Scheme from damage by floods.

The low level main canal seven and a half miles long, and minor channels about eighty miles long, will irrigate 4,500 acres, while the upper main canal ten miles long, and about 100 miles of minor channels, will irrigate 5,500 acres.

Under the first stage, the embankment has been raised to seven feet below its final top level and the low level sluice, its main canal and seventy percent of the minor channels have been completed. About 3,000 acres have already been developed under irrigation. The high level sluice and spill are under construction. The estimated cost of the project is seventeen and a half million rupees.

Minipe Yodi Ela Extension Project

The Minipe Yodi Ela Project situated in the central province, is a diversion project on the left bank of the Mahaweli Ganga, the largest river in Ceylon. It is comprised of a diversion weir across the Mahaweli Ganga, an inlet sluice, a main irrigation canal eighteen and a fourth miles long and minor channels for the development of 3,200 acres of new lands under two rice crops per year. This project was completed about fifteen years ago.

The Extension Project now under construction provides for —

(1) the improvements to the existing works to supply water to an additional 10,000 acres,

(2) the extension of the main canal by thirty miles and the provision of necessary minor channels to develop 10,000 acres of jungle land for rice cultivation by the settlement of 5,000 families on 6,500 acres of highland.

The improvements to the existing works have been completed. The main canal has been extended by twelve miles and irrigation facilities have been provided to about 3,000 acres. The project is scheduled for completion in 1970.

Muttuaiyankaddu Reservoir Project

This is the first of the irrigation projects for the cultivation of subsidiary food crops. Muttuaiyankaddu Project is situated in the northern province. The reservoir, 32,000 acre feet in capacity, is formed by the restoration of an ancient breached dam across the Per Aru by the closing of the three breaches, improvements to the bund and the construction of a masonry clear overfall spill and two sluices, one on each bank of the river.

It is designed to irrigate 1,000 acres of developed private land now cultivated under "rain-fed" conditions and 11,000 acres of crown land blocked out into 3,660 lots of three acres each, on each of which will be settled a landless peasant family. The construction of the headworks is nearing completion and that of the channel system just commenced. The scheme is scheduled for completion in 1969.

Multi-Purpose Projects

Gal Oya Reservoir Project

The development under the Gal Oya Reservoir Project — the first of the multi-purpose projects for irrigation, flood control, and hydro-power development — is nearing completion. Besides the construction of the main reservoir, capacity 770,000 acre feet, five major reservoirs and several small tanks of total capacity 218,000 acre feet, have been constructed. The completed irrigation system includes the construction of 274 miles of main and distributary canals and 846 miles of minor channels. The necessary roads, telecommunication facilities and social amenities have also been provided.

To date irrigation facilities have been provided to 53,550 acres of new lands for rice cultivation and improved facilities to 34,500 acres of existing rice fields. Irrigation facilities have also been provided for 7,000 acres of sugar cane plantation and 1,300 acres of tobacco fields. Besides the 96,350 acres of land developed under irrigation, 22,000 acres of highland have also been developed and about 9,000 colonist families have been settled.

The installed capacity of the hydro-power plant is ten M.W. The necessary transmission and distribution lines have been laid to supply power to the industries set up in the project, as well as to the consumer needs in the area and the neighboring areas. The income in 1964 from the various industries set up in the area was seventeen and a half million rupees.

The work on irrigation that remains to be done is the restoration of two breached ancient reservoirs and the provision of irrigation to 12,000 acres for paddy cultivation and 4,000 acres for sugar cane cultivation.

Uda Walawe Reservoir Project

This is the second multi-purpose project undertaken in this country. It is situated in the southern province. The reservoir is formed by the construction of a rolled filled earth dam two and a half miles long and maximum height of 130 feet across Walawe Ganga, one of the large rivers in the country. The spillway is located on the left bank end of the dam with provision for five radial gates and an emergency natural rock spill. The installed capacity of the power plant is 5.4 M.W. with an annual generation of twenty-one million k.w.h. of energy. The hydro-power developed will be fed into the main island grid.

The area to be developed under irrigation is 60,000 acres of which 36,500 acres will be under rice, 6,200 acres under sugar cane, 2,000 acres under citrus and 15,300 acres under cotton. The associated development of highland will be 30,000 acres. The number of families that will be settled on the rice land alone will be 18,250.

Industrial development in the area will for the present be confined to those industries which are ancillary to the land development and colonization work of the area. A tile and brick factory with capacity of about two and a half million tiles per year and a timber impregnation plant for treatment of soft woods will be established.

The estimated cost of the headworks, including power plant, transmission lines and irrigation facilities, is 132 million rupees. The construction work commenced in 1964 and about three-fourths mile of the dam and six miles of channel have been completed. The project is scheduled for completion in 1971.

Irrigation Practices

Irrigated Crops

Irrigation hitherto has been directed toward rice cultivation. With the exception of a small area in the northern province, which grows subsidiary foodcrops under lift irrigation from "dug wells," and a small area in the hilly districts which grows vegetables, all the lands in irrigation are under rice cultivation.

Cultivation Seasons

As rice cultivation requires an assured supply of water, the cultivation seasons correspond to the rainfall seasons. There are two cultivations — the "maha" season corresponding to the northeast monsoon rains from October to March and the "yala" season corresponding to the southwest monsoon rains from April to August. In the dry zone, where most of the rice is grown under irrigation and where the rainfall is during the northeast monsoon, the main cultivation is the maha. The yala cultivation is dependent upon the carryover storage that remains after the maha cultivation. Normally a maha crop is a four-month variety while the yala crop is of three months.

Preparation of Fields

Cultivation meeting of the proprietors is held for each of the irrigation schemes well ahead of the cultivation season, and dates for the various operations for the season are decided. Water is let into the field two or three days before the first ploughing. A larger extent of lands under irrigation schemes are now tractor-ploughed. Due to the insufficiency of tractors, the ploughing operations take a long period, resulting in wastage of water. After the initial ploughing, the fields are kept flooded for about a week or two to allow sufficent time for the weed and other organic matter to decay. The field is then ploughed a second time and puddling commenced, either by buffaloes or by tractors. Then the field is leveled and excess water drained for sowing or transplanting. This operation requires a large quantity of water — about twenty to twenty-five percent of the full crop requirements.

Chief reason for the use of a large quantity of water for this operation is the elimination of weeds. Climatic conditions in Ceylon favor weed growth. Unless the fields are ploughed several times and water impounded for a long period weeds are not properly decomposed. Considerable weed growth develops in the fields even after sowing, and an excess of irrigation water is required to inhibit their growth.

Sowing

Practically every cultivator is aware that transplanting gives better yields. Due to shortage of labor during cultivation season, particularly in the dry zone areas, and due to the high initial cost, transplanting is not common. In 1964 the total extent transplanted was less than ten percent. The balance was sown by "broadcasting." Seed certified by the Department of Agriculture for purity, germination and quality is made available to the cultivators through the cooperative societies, and these are largely used.

Duty of Water

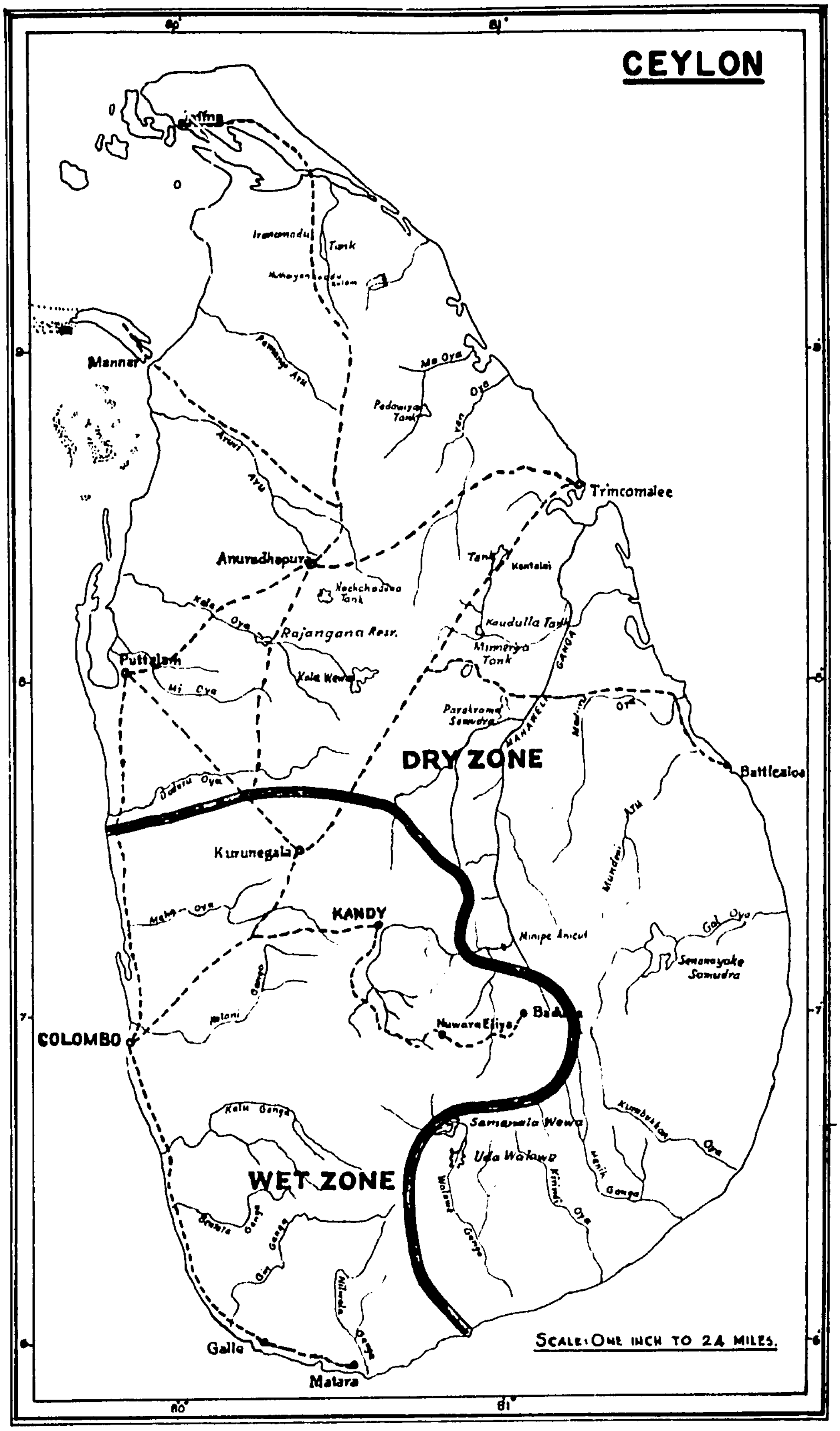
The duty of water for rice cultivation refers to the quantity of irrigation water required to successfully cultivate one acre of rice land. The duty depends on the useful rainfall during the cultivation period. The use of irrigation water can be considered as supplemental to the rainfall. In the recent past a duty of five acre feet per acre for the maha crop and seven and a half acre feet per acre for the yala crop was considered normal. The duty was based on the issues at the main canal offtake. However, the actual duty worked out to be higher than these figures.

In recent years, a duty of four acre feet per acre for mala and six acre feet per acre for yala have been allowed in the design of major irrigation projects. This was on the assumption that better irrigation practices would be introduced in the new projects. One reason for the excessive use of irrigation water is the inhibition of weed growth in the fields. Another is the long period of field preparation due to shortage of tractors. A third is the continuous issue of water from the reservoir, from commencement to the end of the cultivation season.

Uncontrolled weed growth in the rice fields depresses the yields considerably. Weed control by manual labor is proving increasingly difficult in most areas and particularly in the dry zone areas where there is a serious shortage of labor for manual operations during the cultivation seasons. The use of weedicides is not very popular, and until such time as this is made popular, the excessive use of irrigation water on this account cannot be avoided.

With a view to reducing wastage by continuous water issue from the reservoir during the cultivation period, observations were made by cutting off issues intermittently on three major projects. The total extent cultivated under these projects was 35,000 acres. During the first month of cultivation, i.e., up to the time of sowing, the sluices were kept open continuously. This was to allow for the large quantities of water required for the field preparation. When the sowing was completed, the sluices were shut off for a continuous period of three days every week. When the crop was about sixty days old for the maha and forty-five days for yala, the sluices were kept open continuously for a period of two weeks, as the plant requires more water during this period. The four-day weekly issue was then continued until the crop matured.

This system of issue was put into operation during the 1964-65 maha and the 1965 yala, and considerable saving of water was effected. It is hoped to extend this to a few other projects and make observations for a longer period.


CEYLON
Jaffna
Mannar
Trincomalee
Anuradhapura
Rajangana Resr.
Puttalam
Kala Wewa
Kaudulla Tank
Minneriya Tank
Parakrama Samudra
DRY ZONE
Batticaloa
Kurunegala
KANDY
Minipe Anicut
Senanayake Samudra
COLOMBO
Nuwara Eliya
Samanala Wewa
Uda Walawe
WET ZONE
Galle
Matara
SCALE: ONE INCH TO 24 MILES.

CYPRUS

Topography

Cyprus covers an area of approximately 3,500 square miles. Some 3,900,000 donums are arable, constituting about sixty percent of the whole island. Of these, 3,300,000 donums are cultivated, of which 650,000 donums are irrigated. Seven hundred square miles representing twenty percent of the total area are forests, located mainly on the hills. The topography of the island is chiefly distinguished by two main features: The first feature is the big plain between Morphou and Famagusta bays, known as the Mesaoria, which covers an area of over 1,000 square miles, dividing the mountainous regions in two, the northern and the southern ranges, which form the second feature. The northern range, known as the Kyrenia range, is the smaller of the two, covering an area of about 150 square miles and reaching heights of up to 3,000 feet above sea level. The southern range, known as the Troodos range, is by far the larger, covering about 1,350 square miles and reaching a height of 6,600 feet above sea level. The remaining 1,000 square miles are the coastal strips around the island, which are below the 1,000 foot contour and form good agricultural lands. (See Dr. No. G 3996.)

Geology (see Drawing G4015)

The main geological features of the island are as follows:

The Troodos Igneous complex, covering 900 square miles, includes the Pillow Lavas covering 260 square miles. In addition we have the Mamonia complex, covering about 100 square miles. These rock formations constitute the main geological features of the Troodos range.

The Hilarion Limestone (Jurassic), covering about sixty square miles, is the most striking feature of the Kyrenia range.

The Lapithos Group (from upper Cretaceous to lower Miocene) covering about 210 square miles, and the Kythrea beds and Pakhna formations (Miocene), covering about 1,180 square miles, are encountered in the foothills of the two ranges.

The Mesaoria Group (Pleiocene), plus the Fanglomerates (Pleistocene), and the recent deposits, covering about 1,150 square miles, form the main geology of the plains.

Meteorology

Cyprus is a semi-arid country. Annual rainfall varies from ten inches to forty-four inches on Troodos, the isohyetal lines following a close relationship to the topographic contours. The average annual rainfall throughout the island is about nineteen inches, half of it falling in December and January. Rainfall normally occurs from October to April. From May to September the weather is normally dry.

Rainfall intensities are normally moderate except for short periods when four inches per hour have been recorded in certain cases. The recorded maximum in twenty-four hours is about ten inches.

The temperatures vary from several degrees below zero in winter on the Troodos range to 112°F in the plains in summer. The Troodos range is normally covered with snow between January and April. There are about 140 Rainfall Stations on the island, some of them automatic. Among them there are a number of meteorological stations which have instruments for measuring temperatures and humidity. Rainfall data exist in many cases for over fifty years. For the distribution of rainfall please see Dr. No. G 2427.

Hydrology

The total quantity of rainfall on the island represents one million million (10^{12}) gallons of water in an average year (nineteen inches). (Please see Dr. No. Ir. 3844.)

(A) Surface Runoff

Cyprus is divided into 39 hydrological areas. (Please see Dr. No. Ir. 3844.) The maximum surface flow in an average year is estimated to be about 73,000 million gallons and the loss to the sea, about 40,000 million gallons. (Please see Table 4.)

The biggest runoff is that of the Kouris-Garyllis watershed, at 9,000 million gallons every year.

No river in Cyprus flows the year-round, except at the upper reaches above 3,000 feet elevation. In the lower reaches the best rivers flow until June only.

Many automatic flow recorders are installed on these rivers to measure the flow.

The amount of water from surface flow presently utilized for irrigation is of the order of 35,000 million gallons a year, mainly for spate and for winter irrigation of cereals. (Spate irrigation is the annual spreading of flood waters across unleveled lands.)

(B) Groundwater

Wells and boreholes. The main aquifers are the Western Mesaoria, South Eastern Cyprus, Akrotiri, Kiti-Pervolia, Polis Chrysochous and Kyrenia. In addition there are a few minor coastal strips and some river valley aquifers. The water from these aquifers is pumped through about 10,000 boreholes and several thousands of shallow wells, the total extraction being estimated to be of the order of 40,000 million gallons annually for irrigation and about 4,000 million gallons for domestic and industrial purposes.

All the main aquifers are overpumped and there is a constant decline of the water table. This problem has arisen because of numerous illegal boreholes and the uncontrolled extraction, while in certain areas, such as Famagusta, Syrianochori, Akrotiri and Pervolia, sea water intrusion has been observed. In Famagusta, where the problem is the most serious, sea intrusion has resulted to the destruction of a large area of coastal citrus groves.

However, in certain small aquifers such as chalks and gravel beds along river valleys, some underground loss of water to the sea is observed and therefore only a limited development is possible.

There is a network of observation boreholes over the island from which measurements of the water table and quality are taken monthly and which enable the production of groundwater table contours and isosalinity curves.

A five-year United Nations Special Fund Project is now in operation for the evaluation of the groundwater resources of the island.

Springs. There are no really big springs on the island because the Troodos mountain range, which is the largest mountainous region, is of igneous rocks, which are of impermeable characteristics, except along fractures and joints which form the feeder zone of springs of moderate capacity. The biggest springs existing are those found on the Kyrenia range on the north of the island and which have their sources from the carstic limestone. Also, in the periphery of the Troodos range, the permeable sedimentary rocks give rise to the flow of springs.

Many of the smaller springs are rapidly disappearing and the larger ones have been decreasing considerably in yield during the last ten years, due to the many boreholes being drilled around them, and to the enormous extraction from these boreholes.

Many of these springs, except the bigger ones, are used solely for domestic water supplies. From the bigger ones an appreciable amount is also used for the same purpose. The total yield from springs is estimated to be about 6,300 million gallons annually, 5,000 million gallons of which are utilized for irrigation and the remaining for domestic and industrial use. Records of the flow and quality of 300 springs, representing the most important ones, have been kept for many years.

I. Domestic Water Supplies

(A) Rural Water Supplies

Rural water supplies cover the needs of 627 villages with a population of 392,000 people, representing sixty-six percent of the population of the island.

The sources of supply are springs and boreholes of good quality water which needs no filtration or sterilization.

The conveyance is by means of asbestos or steel pipes as necessary. Storage is always provided for at least half a day's supply in concrete reservoirs or elevated tanks. The distribution is by asbestos or steel pipes and it usually involves house-to-house distribution with metered supply. The quantity of water provided in these projects is calculated on the basis of twenty gallons per capita per day.

The financing of these projects is fifty percent by government grant and fifty percent village contribution provided by a long-term, low-interest government loan.

The administration and operation of these projects is governed by the Water (Domestic Purposes) Village Supplies Cap. 349 which provides for the establishment of Village Water Commissions under the chairmanship of the District Officer of the particular district.

The position regarding the progress in rural supplies at the end of 1965 is indicated in the following table.

Table 2

DISTRICT	VILLAGES WITH PIPED WATER SUPPLY SATISFACTORY NUMBER	UNSATISFACTORY NUMBER	TOTAL NO.	VILLAGES WITH NO PIPED WATER SUPPLY NO.	%	TOTAL VILLAGES NO.
Nicosia	147	29	173	2	1.10	178
Larnaca	44	13	57	2	3.39	59
Limassol	101	11	112	1	0.88	113
Famagusta	72	26	98	..	..	98
Paphos	131	1	132	..	..	132
Kyrenia	32	14	46	1	2.13	47
Totals	527	94	618	6	0.96	627
Percentage	84.05	14.99	99.04		0.96	100.00

It is anticipated that soon there will be practically no village without a piped supply. Improvements and extensions will of course have to be made in the future.

(B) Town Water Supplies

There are four main towns in Cyprus: Nicosia, Limassol, Famagusta and Larnaca.

There is piped water supply in each town and the situation is as follows:

(1) *Nicosia*, including all its suburbs, has a population of about 100,000. The maximum consumption in summer reaches four and a half million gallons per day, which means that per capita per day consumption is forty-five gallons.

The sources of supply are:

20 boreholes at Kokkini Trimithia, Akaki
3 boreholes at Dhikomos
1 infiltration gallery at Dhikomos (Sychari)
3 boreholes at Dhali
4 boreholes at Laxia
1 chain-of-wells (*Arab Ahmet*) at Strovolo
1 chain-of-wells at Machedhonitissa
2 boreholes at Athalassa
2 boreholes at Morphou Emergency Scheme
14 boreholes at Syrianochori, Morphou
—
51 total number of boreholes

All water is conveyed through steel or asbestos cement pressure pipes ranging from eight inches to eighteen inches in diameter, the largest pipeline being that from Syrianochori, extending for twenty-four miles. The conveyor pipelines supply storage tanks situated at commanding points around Nicosia, with a total capacity four and a half million gallons — twenty-four hours' storage. From these tanks the water is then distributed to sixteen independent areas through ring mains of asbestos cement pressure pipes ten inches to twelve inches diameter. The distribution system varies from four inches to eight inches diameter and each house is provided with a separate connection and water meter.

The Water Supply of Nicosia, as for all towns, is governed by the Water Supply (Municipal and other Areas) Cap. 350 Law which provides for the establishment of Water Boards and generally for the administration of domestic water supplies. This law is administered by the Water Board which is made up of not more than three persons appointed by the Government and not more than three members nominated by the municipality.

In the case of Nicosia, in addition to the Water Board, for certain areas which have not yet been handed over to the Water Board, the operation is done by the Water Development Department, and within the walls by the Nicosia Water Administration.

The waterworks, which were started in 1950 and completed in 1962, have cost about two and a quarter million pounds ($6,300,000), except the old system within the walls.

Nicosia at the moment has sufficient water, but the problem is that several of the boreholes have been depleting, mainly those at Kokkini Trimithia, and others are in danger to become saline from sea intrusion, like those at Syrianochori, which may have to be abandoned.

Investigations are being carried out for one or more of the following schemes to provide additional supplies: more groundwater; impounding scheme on the rivers west of Morphou; desalting plant at Morphou-Syrianochori.

(2) *Limassol* is the second largest town, with a population of about 45,000.

The daily consumption in summer is two million gallons, equivalent to forty-five gallons per capita per day.

The sources of supply are:

Three springs at Halassa at the foothills south of Troodos.
Five boreholes on the Garyllis river bed.
One chain-of-wells at Chiflikoudhia.
Four boreholes at Yermasoyia river bed.

The most distant sources are the springs at Halassa eleven miles away. The water is conveyed to a storage tank of 800,000 gallons capacity at a commanding place in Limassol, then distributed to ten independent areas, where a house-to-house metered supply is connected.

The largest scheme now in the course of completion conveys one and a half million gallons of water per day from Yermasoyia valley and includes the building of a storage tank of 450,000 gallons capacity and additional distribution.

(3) *Famagusta* is the third largest town, with 37,000 people.

A quantity of one and two tenths million gallons per day is used.

The consumption is equivalent to thirty-two gallons per capita per day. The sources of supply are fourteen boreholes at Phrenaros. There are three storage tanks of 700,000 gallons capacity and the water is distributed house-to-house by metered supply.

The boreholes at Phrenaros are badly declining and their replacement or relieving is essential.
The water supply problem of Famagusta is the most acute, for all the groundwater of the district is declining and there are no prospects of finding any new significant groundwater resources of good quality water. Further, there are no big rivers in the district.

A study is being made to: improve the Phrenaros boreholes; convey additional groundwater from the neighboring district of Larnaca; convey water from impounding reservoirs on the nearest rivers in Larnaca district; install a desalting plant at a later stage.

(4) *Larnaca* is the fourth largest town, with 20,000 people.

The present sources are one chain-of-wells known as the "Bekir Pasha" and four boreholes in the Tremithios river valley. The total quantity of water now available is about 800,000 gallons daily, which is enough to supply forty gallons per capita per day. Storage of 450,000 gallons is now provided and additional storage is scheduled to be provided in 1966. The Distribution System is rather old and requires considerable improvements.

II. Brief History of Irrigation and Drainage Development

Cyprus has a long history of irrigation: it has been practiced for over 2,000 years. Water was conveyed in irrigation canals from springs, gravity chain-of-wells, river intakes and also pumping from shallow wells by means of Persian wheels or windmills.

The first storage works on a large scale to impound river water were constructed from 1896 to 1912 in the form of long, low earth embankments with the necessary spillways and outlet works. These works were the Eastern Mesaoria Kouklia, Akhyritou and Syngrasis reservoirs, impounding water of the Pedieos Idalios rivers and of the Kyrenia range. The capacity of one of these, the Kouklia reservoir, which is still in use, is 1,000 million gallons. Until 1950 these were the only impounding works in Cyprus, for until that time the responsible local opinion as well as opinion of experts from abroad was that no more impounding works should be constructed in Cyprus because, according to them, it would be uneconomic and the aquifers would suffer by the construction of dams.

Between 1950 and 1960 this policy gradually changed after extensive hydrological, topographical, geological and economical studies. During this period fifteen dams of rather small size were built, three of which are of gravity mass concrete section, nine in gravity masonry section and three in earth.

In 1961 a big dam program was initiated. In 1961 one concrete and two earth dams were constructed, in 1962 five earth dams and one big earth reservoir were constructed, and in 1963 three big rockfill dams, five earth dams and one earth reservoir. (Please see Dr. No. AG/IR/g/1A.)

Table 3 shows the land irrigated in 1963, the type of crops and the water consumed. Also Dr. No. V/G/g/1 indicates the main crops and vegetation cover.

Waterlogged and saline lands in Cyprus are not a major problem, as such lands do not cover more than seventy square miles. And as the available water resources that could ever be developed in Cyprus would never irrigate more than a small fraction of the available land, the drainage of these saline lands is not a priority problem.

However, some drainage works have been carried out, but the main purpose was the eradication of malaria. Some have been combined with irrigation. Certain drainage schemes that were designed were never carried out because of the drop in the water table by excessive pumping for irrigation in these areas. In one particular area at Morphou bay where there were marshy conditions in 1950, signs of sea intrusion have now been observed due to the overpumping in the area. (Please see Dr. No. Ir. 3843.)

III. Special Problems as a Result of the Introduction of Irrigation Works

In Cyprus problems such as waterlogging, salinity and malaria are encountered only to a limited scale because of: Heavy overpumping and lowering of the water table; limited irrigation; natural drainage conditions. However, many other problems have arisen, such as: Artificial recharge of underground water; water conservation; land consolidation; other aspects, such as legal, financing, administration and economics, are being dealt with later.

(A) Artificial Recharge

Artificial recharge has been necessary for about ten years due to the limited underground water and to excessive pumping of it.

Artificial recharge works have been carried out in many parts of Cyprus since 1953. The first scheme was in Famagusta, where sea intrusion was first observed. Spreading reservoirs and an underground gallery through the sandstone aquifer were constructed following a parallel line to the coast for a distance of about six miles. Many other infiltration reservoirs, and a big open recharge canal six miles long have since been constructed in Famagusta district. In 1962 a big dam to serve for recharge was constructed in Morphou, where the water table had made an alarming drop, and another big one at Kiti. Experiments in recharging water through boreholes are now carried out and a program is being prepared for more recharge works.

(B) Water Conservation Measures

The control of extraction is the primary requirement. Now the extraction is not controlled in the majority of cases. It is necessary to fix water meters on each borehole and control the water to be extracted from each borehole according to the potential of the aquifer and the needs of the crops. New legislation is now being studied for this purpose.

Due to the limited water supplies and to the many needs, especially for irrigation, the problem of using the water in the most efficient manner is most important. Still a lot of water is wasted in Cyprus, especially from surface source supplies. But for the underground water where the danger of exhaustion and sea intrusion is great, many steps have been and are being taken for efficient utilization. It is estimated that at this moment the efficiency of irrigation water from underground supplies on the average throughout Cyprus is of the order of fifty-five percent. The aim, however, is to attain about eighty percent. This efficiency, which it is hoped can be reached in about ten years, necessitates the following measures where applicable:

(1) Land leveling.
(2) Land consolidation.
(3) Lined canals.
(4) Piped distribution.
(5) Efficient systems of irrigation.
(6) Control of extraction.

(C) Land Consolidation

This is a very difficult problem in Cyprus. Most land has been divided over the centuries too many times and the parcels are very small. There is no law for land consolidation as yet, but one is in the course of preparation. The problems are not easy, for oftentimes in a small piece of land, the land belongs to one person, the trees belong to another and the water to somebody else.

IV. Brief Description of Some Typical Irrigation, River Training, Drainage and Flood Protection Works

(A) Irrigation Works

(1) Conveyance systems are canals lined or unlined, irrigation pipes made of steel, cast iron, asbestos or concrete, which are used for conveying the water from the source to the irrigable lands. Hundreds of miles of conveyance systems consisting mainly of reinforced concrete rectangular sections have been constructed in Cyprus. In fact, during the past the expenditure on these works constituted one of the main items in the budget. Now trapezoidal concrete canals are used also, and a study is being made for the introduction of the elevated polycentric or semicircular sections.

(2) Works on springs include excavations for increasing the yield and building works protecting the source. These works were until only ten years ago one of the most important sources of irrigation and culinary water supply in Cyprus. But recently, due to the many boreholes drilled, quite a number of these springs have dried up.

(3) Chain-of-wells are infiltration underground tunnels traversing an aquifer and conveying the collected water by gravity to the surface. These works were until about ten years ago a most important source of supply. But due to the recent drilling most of them are now disappearing.

(4) Pumping Works include pumping installations on wells or boreholes for the extraction of underground water from an aquifer. These schemes were introduced in Cyprus about fifteen years ago when the extensive exploitation of the aquifers by drilling started. Much private work has been done in this field, which culminated in the recent illegal drillings.

(5) Diversion works are earth, masonry or concrete works or intakes constructed in the river beds for diverting the flow or part of the flow of a river to the lands for irrigation.

A large number of diversion schemes have been and are being constructed both on the mountains, mainly for summer irrigation, and on the plains, mainly for spate irrigation of winter crops.

(6) Storage works include the construction of earth, masonry or concrete reservoirs or impounding works formed of dams made of earth, rock, masonry or concrete. Small tanks have been built in Cyprus, especially on the mountains, since the establishment of the Water Development Department, and are used for storing water from springs or streams.

The construction of dams in Cyprus started on a small scale about fifteen years ago.

Until 1960, fifteen rather small dams, mainly of the mass concrete and masonry gravity type, were constructed particularly on the mountains, having a total capacity of about 200 million gallons, at a cost of about $560,000.

Since 1960, eighteen major dams, and many smaller ones, mainly of earth and rockfill construction have been completed or they are being constructed with a total capacity of about 4,000 million gallons, and at a total cost of $6,160,000, excluding the canalization. The major dams are mainly of earth and rockfill construction. (Please see Dr. No. AG/IR/g/1A.)

(B) Recharge Works

Artificial recharge works in Cyprus constitute one of the major works undertaken by the Water Development Department. The problem has become very serious in the last few years because of the uncontrolled pumping and the depletion of the aquifers. The most seriously affected areas are the Morphou, the Famagusta-Larnaca and the Akrotiri aquifers, where the water table constantly drops by more than two feet every year.

The main recharge works in Cyprus during the past few years are:

(1) The Famagusta System, comprised of the Ay. Nicolaos lake 300 m.g. capacity, the fresh water lakes 600 m.g. capacity, the Ayios Lucas Reservoir 100 m.g. capacity feeding an infiltration gallery five miles long, and the Ay. Memnon recharge reservoir. Also we have the Paralimni lake 300 m.g. capacity feeding a six-mile-long recharge canal and about fifty small recharge dams with an average capacity of two m.g. In addition we have in other areas of the Southeastern Mesaoria another twenty small dams with an average capacity of two m.g. More of such small dams are now built in Famagusta-Larnaca Districts.

(2) The Morphou recharge dam built on a pervious foundation, 450 m.g. capacity.

(3) The Kiti Dam near Larnaca, 450 m.g. capacity.

Some other schemes are a combination of recharge and surface irrigation.

(C) Drainage Works

Where natural drainage conditions are not satisfactory, artificial drainage is required to drain surplus water either from irrigation or rainfall or from percolation through any nearby canal system.

In the past decade, some drainage works were built in Cyprus, but the main purpose was the eradication of malaria.

The following are some of the main drainage schemes designed by the Water Development Department. Not all of these have been completed, either because the water table dropped during recent years due to excessive pumping, or because the schemes proved too expensive.

(1) Drainage of about 10,000 donums of the Syrianochori marshes. Partly carried out.

(2) Drainage of the Achyritou saline reservoir lands. Partly carried out.

(3) Drainage of the Patriki Lake. Carried out.

(4) Drainage of the Ayios Lazarus and Pamboula swamps. Partly carried out.

(5) Drainage of the Polis, Ayia Kebir, Kouklia, Xeros and Mandria swamps. Not carried out.

(6) Drainage of about 10,000 donums of the Akrotiri marshes and the salt lake. Partly carried out.

Some of the above schemes are combined irrigation and drainage schemes.

(D) River Training Works

These are works carried out in river beds mainly for one or more of the following reasons:

(1) Flood control.
(2) Land reclamation.
(3) Town or country planning.

In Cyprus river training is mostly undertaken for land reclamation and flood control purposes. River training works by protective walls, gabions and staking have been constructed in many places, such as: Xeros river bed in Paphos, Limnatis tributary of the Kourris, Limnatis river bed, and Yermasoyia river bed.

The most important river beds in Cyprus, where land reclamation could be substantial, by reducing the width of these beds from over 1000 feet in many cases to two or three hundred feet, are: the Serrachis, the Pedieos, the Idalias, the Yermasoyia, the Kourris, the Dhiarizos, the Xeros, the Ezuza, the Chrysochou, the Pyrgos and the Limnatis.

These land reclamation and river training works could also be combined with recharge schemes. In some cases town planning is also of importance, such as the case of the Pedieos passing through Nicosia, for which river training works are required.

(E) Flood Control Works

The purpose of flood control schemes is to reduce or eliminate completely the intensity of a river flow likely to cause destruction by flooding inhabited areas or agricultural land.

In Cyprus many such works are being designed and built by the Water Development Department. One flood control reservoir, the Athalassa earth dam, built in 1962, is also used for irrigation, and one flood control dam built in 1963 has been designed for protecting Famagusta town from floods and in addition helps in recharge.

Many flood protection embankments are built along river beds, and in many cases *groynes* of concrete or *gabions* are built — cylinders filled with stone and mud to serve as a dike.

In other cases diversion canals are built to divert the floods away from inhabited areas, such as the Voroklini scheme.

V. Multi-Purpose Schemes — Basin-Wide Development

Some of the constructed dams serve for two or three of the following purposes:

(1) Surface irrigation.
(2) Underground water recharge.
(3) Flood control.

For example, the Athalassa dam constructed in 1962 serves for surface irrigation, underground water recharge and flood protection. The Morphou dam constructed in 1962 serves for recharge and surface irrigation, while the Famagusta dam constructed in 1963 serves for flood protection and recharge. It is anticipated that some of the future dams may also serve for domestic water supply and probably for the generation of electricity to a limited extent.

The dams that have been constructed up to now are chiefly in small rivers and have not required a very detailed basin development study. However, the necessary studies have been made to determine that the dams fall within an integrated basin development project.

VI. Future Water Development

(A) Underground Supplies

A United Nations special fund project is now in operation for evaluation of the groundwater supplies and also for finding any new supplies possible from greater depths. However, it is considered doubtful whether any new significant underground source will be found.

This project employs, in addition to the local staff, many foreign experts. Part of it has been conducted by a German mission partly financed by the German government, and part of it has been carried out by a French mission partly financed by the French government.

Considerable technical data has been collected in the last few years, such as observations of the water table fluctuations, quality of water, rainfall, surface runoff, and evapo-transpiration. This work must continue.

(B) Surface Supplies

The present surplus flow to the sea from the rivers is the only reliable source of water for future development. To store this water for irrigation, many relatively small dams are necessary, due to the topographic conditions. These development projects are among the most expensive in the world, but due to the special circumstances prevailing on the island and the high revenue earned, they are feasible.

Technical data such as runoff figures, rainfall and evapo-transpiration are available, but more records are necessary. By the end of this year it is hoped to complete all the necessary network of automatic flow recorders and rainfall stations.

With regard to technical staff, there are now enough locals who are assisted and trained by experts from the United Nations, the United States Aid Mission and foreign consultants.

Funds are available from the Cyprus Development Budget, but some loans have been issued by the German and the United States governments.

The 1964-1965 dam construction, numbering nine relatively large dams which have now been substantially completed, is an indication of the government's interest in water development.

Table 4 shows the anticipated water development which may result in the construction of dams to store the surface flow now lost to the sea.

VII. Water Laws, Administration, Economics, Financing

(A) Water Laws

The water legislation problems in Cyprus constitute one of the most serious difficulties in the water development of the Island. All the springs and many surface and underground water supplies are privately owned, either in the form of registered rights or in the form of ab antiquo rights. The main water laws are:

(1) *Irrigation Division* Cap. 342

Deals with the formation of an Irrigation Division by at least ten proprietors (owners of land) for the purpose of constructing, operating, improving, maintaining, or repairing irrigation works and/or for the protection of their water resources or their water rights.

(2) *Irrigation Association* Cap. 115

Provides for the formation of an Irrigation Association by at least seven proprietors (owners of water) for the construction, operation, maintenance, repair of any irrigation works or/and protection of their water resources or water rights.

(3) *Wells* Cap. 351

It gives power for the prohibiting of the sinking or construction, widening, deepening or clearing of a well or borehole without a permit and for the imposing of any conditions on the permit.

(4) *Water Development and Distribution* Cap. 348

Provides for the declaration of certain regions into development areas for the conservation and better use of water resources in these areas or for the effective execution of an Island-wide policy relating to water.

(5) *Government Water Works* Cap. 341

This law vests in government all underground waters, all water running to waste from any river, spring or water course and all other waste water.

(6) *Public Rivers Protection* Cap. 82

Gives power to the government to declare any public river or portion of a public river to be protected against damages to banks, removal or carrying away of stones, shingle, gravel, sand, soil or other material from any river and the dumping of any rubble, rubbish or other refuse in the river.

(7) *Water Supply (Municipal and other Areas)* Cap. 350

Provides for the establishment of Water Boards in towns to administer Water Supply Works, and is comprised of government members and municipal members.

(8) *Water (Domestic Purposes) Village Supplies* Cap. 349

Provides for the establishment of Village Water Commissions for administering the domestic water supplies of the village.

(9) *New Legislation*

A new law has recently passed which gives more power to the government for enforcing measures toward the control of extraction from boreholes and the efficient use of the water.

A revision and certain improvements of these laws have been recommended by a United Nations team of water legislation experts who visited Cyprus and studied the water legislation problems. Their recommendations are being considered by the government.

(B) Administration

Irrigation works are operated and maintained either by an Irrigation Division, if the proprietors are land owners, or by an Irrigation Association, if the proprietors are water owners. These divisions are under the chairmanship of the District Officer of the District Administration, and a committee made up of local proprietors is formed. This committee is responsible for the operation, maintenance and financial affairs of the works.

This type of committee has worked satisfactorily in the case of small irrigation works which do not face any appreciable technical, administrative or financial difficulties. But as the works now under construction are relatively on a large scale, to ensure their success it will be necessary that these works be controlled by a committee comprised not only of administrative officers and representatives of the proprietors, but also by water engineers, agriculturists, and economists, and the works should belong to the government, which should undertake to sell the water to the proprietors. This method has already been put into effect with five major dams which have been declared as Government Water Works under the respective law.

(C) Economics

That an irrigation scheme should be economically feasible is a prerequisite for its approval. The economic feasibility of an irrigation project mainly depends on a comparison of the expenditure for construction, maintenance and operation, and the direct benefits which are:

(1) Irrigation benefit measured in terms of increase of crop production and income.

(2) Reclamation benefits.

(3) Flood control benefits measured in terms of damages prevented.

Although many of the irrigation projects in Cyprus involving the construction of a dam are rather expensive, yet the income from the crops is so great that the schemes are feasible and sometimes benefit-cost ratios of more than three are attained. For example, an acre of orange groves gives an average net profit of over $560 every year, an acre of apple trees gives an average net profit of over $1,120 every year and an acre of carrots gives an average net profit of over $420 every year.

(4) Financing

Irrigation works carried out for irrigation divisions or associations are financed by the government, which makes money available, partly in the form of a grant and partly in the form of a loan. It has been an established practice that the government contribution to water works conducted for an irrigation division is as follows:

(a) Winter crop irrigation schemes, eighty percent.

(b) Spring crop irrigation schemes, seventy-five percent.

(c) Perennial irrigation schemes, sixty-six and seven tenths percent.

(d) Drainage schemes full cost to government except where irrigation works are also involved, which are then financed as previously explained.

(e) Flood protection works full cost to government except where irrigation works are also involved, which are then financed as previously explained.

The government contribution to domestic water supplies for villages is fifty percent but there is no government contribution in the case of town water supplies.

The government contribution for irrigation associations does not depend on the type of irrigation but on the distribution of shares of water *among* the proprietors. The government contribution to these is usually less than to irrigation divisions.

The village share is made available by the government in the form of a long term, low interest loan. This system of financing does not apply to the major irrigation schemes, especially those incorporating a dam, which are built at full cost to the government. The government controls the works and imposes water rates per unit volume of water used in these cases. The advantages of this method of financing are:

(a) More efficient water utilization, because the proprietors will pay according to what they use.

(b) The works will belong to the government and the government will operate and maintain them by appointing an appropriate authority comprised of administrative, technical and financial representatives of the government and representatives of the proprietors.

(c) The government will be able to establish priorities of construction and selection of works, instead of awaiting schemes requested by the proprietors.

(d) Administrative difficulties and delays in issuing loans and starting the works are overcome.

This system of financing has already been introduced in the case of five major dams.

VIII. Research Program

No real laboratory research regarding water development has been conducted in Cyprus, but the following are being studied: rainfall; runoff in rivers; underground water table observations; silting up of dam reservoirs; water requirements of crops.

It is important to note that since 1962 two main research organizations have been established with the United Nations' help:

(1) The Agricultural Research Institute, which conducts a research program in all branches of agriculture, including water use and animal husbandry.

(2) The United Nations Special Fund Project, to make a determination of the potentialities of all underground water and to find new underground supplies.

IX. Statistics

Total area of Cyprus ....6,750,000 donums*

Total arable area ....3,900,000 donums

Total area cultivated ....3,300,000 donums

Total area cropped per year ..1,800,000 donums

Total area irrigated .... 650,000 donums

Seldomly drainage is necessary on irrigation schemes.

Length of main canals ....About 1,500 miles

Length of distribution canals ....About 1,500 miles

Cost per unit area irrigated

- Pumping scheme ....$70 per acre
- River diversion scheme ....$42 per acre
- Impounding scheme ....$84 per acre

Cost per unit area cropped

- Citrus ....$101 per acre
- Carrots ....$110 per acre
- Potatoes ....$ 50 per acre
- Olives ....$ 42 per acre
- Grapes ....$ 50 per acre

X. Drainage Statistics, International Agreements and Flood Control Works

(A) Drainage works, as mentioned before, are not significant in Cyprus. The enclosed drawing No. Ir. 3843 gives all that is available.

(B) No international agreements are necessary since Cyprus is an integral island.

(C) Flood control works are also of minor importance. Some details have been mentioned previously.

* One donum equals one-third of an acre.

Table 1

HYDRO-GEOLOGICAL CLASSIFICATION OF THE ROCKS OF CYPRUS

AGE	FORMATION	GROUP	LITHOLOGY	THICKNESS FEET	AREA OF OUTCROP SQ. MILES	YIELDING WATER TO
Recent	Alluvium		Silts, sands and gravels	up to 200	) 210	Wells and Boreholes
Pleistocene	Fanglomerate Series		Boulder beds, gravels, sands, silts, clays & havara	10-170	)	Wells and Boreholes
Upper Pliocene to Upper Miocene	Athalassa Formation	MESAORIA GROUP	) Fragmental limestone with) subordinate brown marl	150	782	Wells and Boreholes
	Nicosia Formation		)	300	165	Wells and Boreholes
	Myrtou Marl		Khaki and grey marls with calcareous siltstones with			
	Pissouri Marl		some intraformational conglomerates	2,000 480	10 5	Few Boreholes
Middle Miocene	Koronia Limestone	DHALI GROUP	Reef limestone	200	12	Springs, Wells & Boreholes
	Pakhna Formation		Gypsum, chalks, limestones and marls	1,800	575	Wells and Boreholes — water is highly mineralized
	Kythrea Formation		Marls, sandstones, limestones greywackes & conglomerates	13,600	506	No useful water
Lower Miocene to Upper Cretaceous	Terra Limestone	LAPITHOS GROUP	Reef limestone	200	8	Springs, Wells & Boreholes
	Upper, Middle & Lower Lapithos		Chalks, chert, marls, shales & limestones	2,000	219	
Upper Triassic	Mamonic Complex		Micaceous sandstones, limestones, tuffs red marls	600	95	No useful water
	Perapedhi Formation	TRYPA GROUP	Black shales, umber bentonitic clays and radiolarites	80		No useful water
	Akamas Sandstones		Sandstones, locally quartzitic		8	
	Petra tou Romiou Limestone		Recrystallized and brecciated reef limestones		2	Small springs
	Schist Series		Quartz-mica schists, hornblende gneiss			No useful water
Upper Cretaceous to Upper Carboniferous	Hilarion Limestone		Recrystallized and brecciated limestones	1,000	61	Springs and Boreholes
Undated	Troodos Igneous Complex				926	Springs

Tabl

IRRIGATION, CROPS, EXTENT AND WATER CONSUMPTIO

TYPE OF CROP	G R O U N D W											
	WESTERN MESAORIA		S.E. MESAORIA		KYRENIA				AKROTIRI-PHASOURI		POLIS	
					B.Hs & Wells		Springs					
	Total Area Irrigated (Dons.)	Total Q. of Water Extracted (M.G./Y.)	Total Area Irrigated (Dons.)	Total Q. of Water Extracted (M.G./Y.)	Total Area Irrigated (Dons.)	Total Q. of Water Extracted (M.G./Y.)	Total Area Irrigated (Dons.)	Total Q. of Water Discharged (M.G./Y.)	Total Area Irrigated (Dons.)	Total Q. of Water Extracted (M.G./Y.)	Total Area Irrigated (Dons.)	Total Q. of Water Extracted (M.G./Y.)
1. Citrus & other trees	24950	7610	11785	2990	4825	925	2375	380	7140	2195	140	40
2. Deciduous	..	..	..	..	300	50	300	50	..	..	..	..
3. Vines & Table grapes	200	25	200	25	120	12	80	10	2400	300	50	6
4. Harricot beans	4120	680	460	80	195	25	180	20	1015	235	100	15
5. Melons & Water Melons	3970	610	2630	565	..	..	..	..	410	90	1160	290
6. Potatoes (Spr.)	3595	350	16865	1490	260	25	250	25	545	75	55	5
7. Potatoes (Aut.)	3510	535	8590	1165	70	10	20	3	95	17	55	10
8. Tomatoes	1300	250	2220	440	50	10	20	5	530	120	320	80
9. Colocasse	..	..	940	300	..	..	..	..	..	..	..	..
10. Cucumbers	500	100	750	150	150	30	20	5	270	55	240	50
11. Artichokes	..	..	200	60	..	..	..	..	500	150	..	..
12. Clover	730	440	..	..	..	..	..	..	..	..	..	..
13. Carrots	3500	315	100	10	..	..	..	..	400	40	50	10
14. Tobacco	..	..	..	..	..	..	..	..	..	..	..	..
15. Cotton	..	..	..	..	..	..	..	..	..	..	..	..
16. Cow peas	2000	350	300	50	100	15	..	..	300	50	200	40
17. Other Seasonal Crops	2620	650	610	150	380	80	50	10	430	100	100	20
18. Peas	..	..	..	..	..	..	..	..	..	..	..	..
19. Broad beans	..	..	..	..	..	..	..	..	..	..	..	..
20. Cereals (wheat, barley, oats)	..	..	..	..	..	..	..	..	..	..	..	..
TOTALS	50995	11915	45650	7475	6450	1182	3295	508	14035	3427	2470	566
Domestic, Animal Husbandry & Ind.		866		459		109		46		713		349

Note: Other Seasonal Crops include: Onions 3000 d., Cabbages 2100 d., Cauliflowers 2000 d., Okra (ladies' fingers) and Groundnuts 1300 d.

Deciduous Crops include: Apples 8300 d., Pears 2800 d., Quinces 250 d., Apricots 5400 d., Cherries 3500 d., Peaches

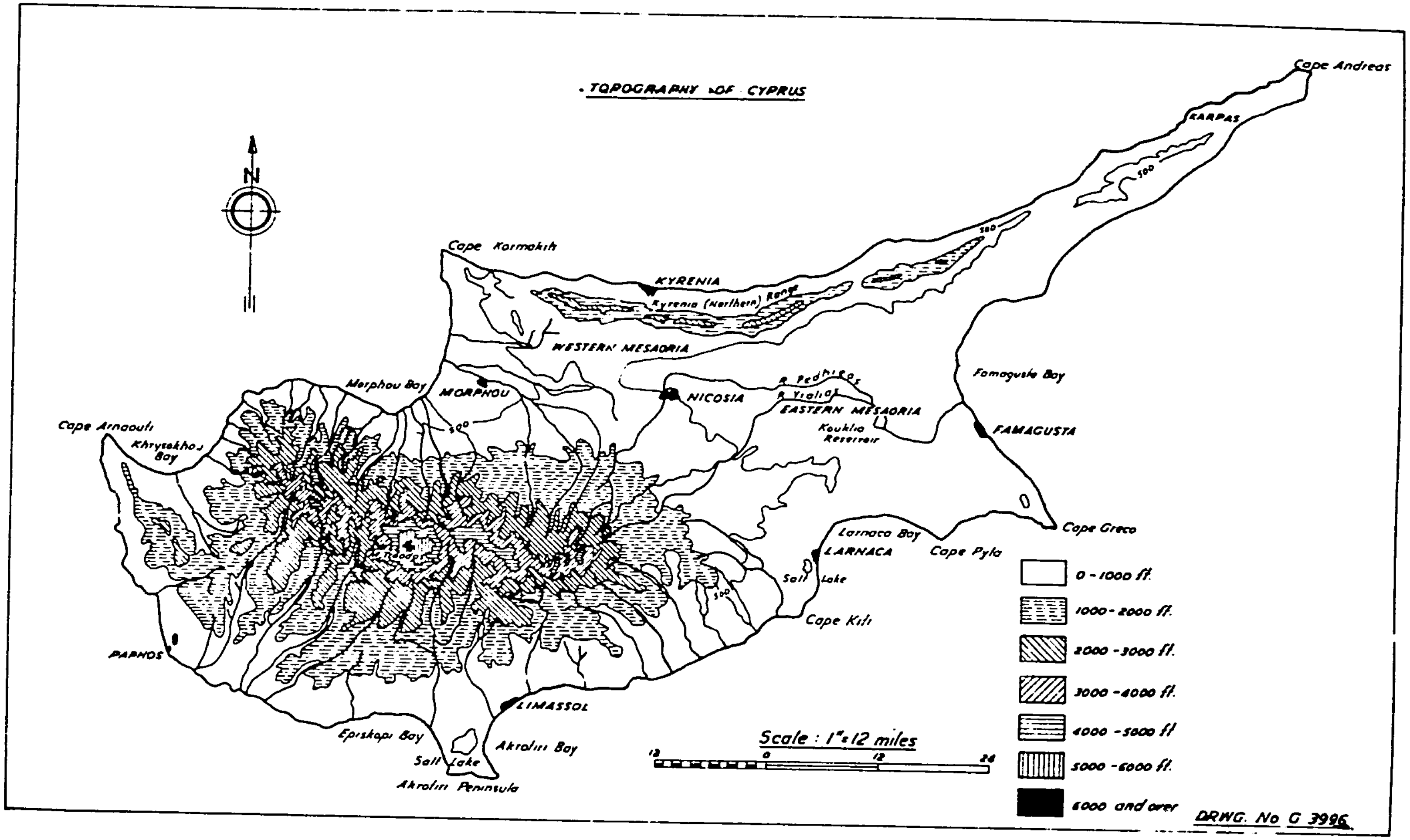
Citrus & other trees include: Oranges, Lemons, Grapefruits, Tangerines, 60000 d., Pomegranates 4800 d., Bananas

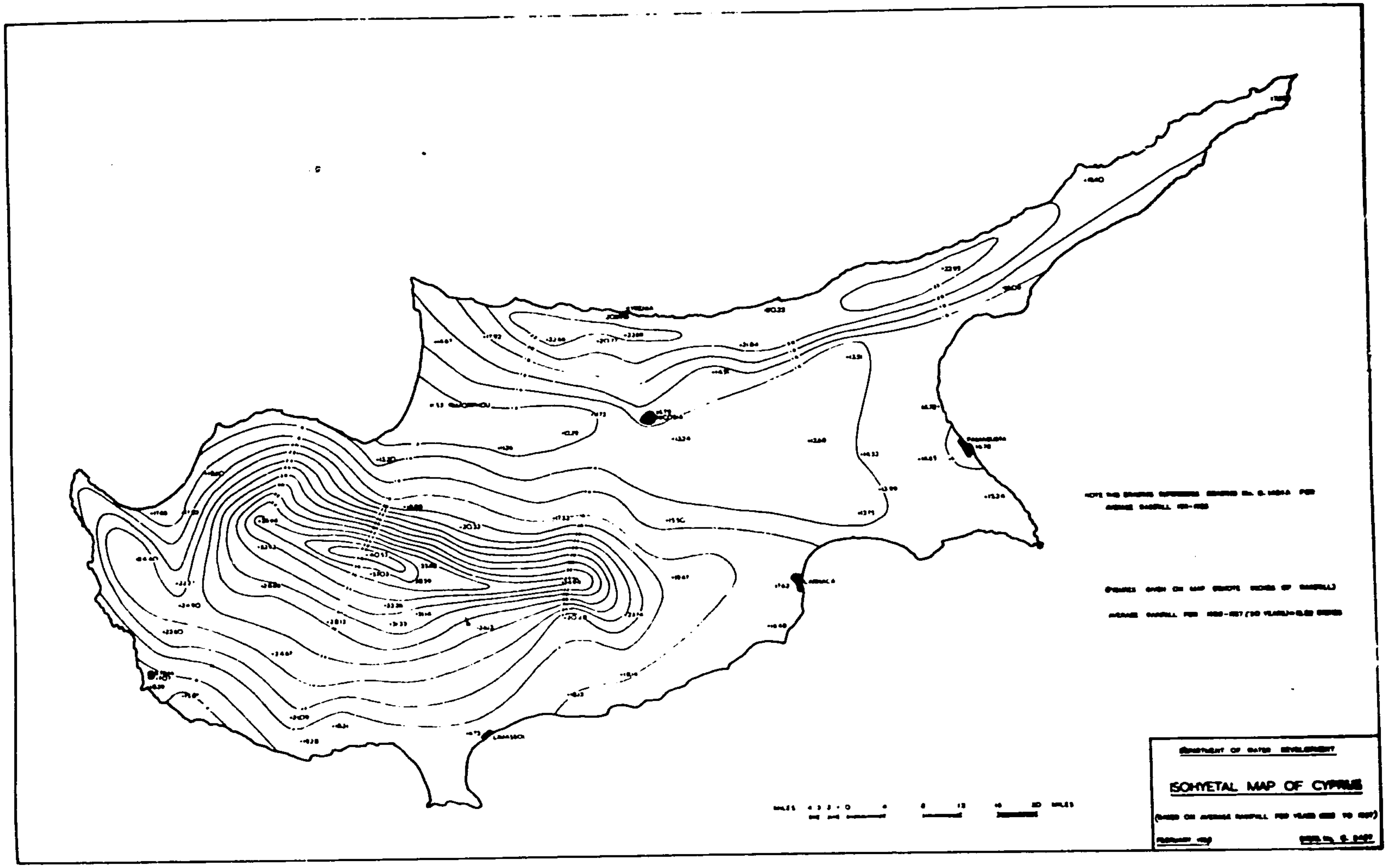
Table 4

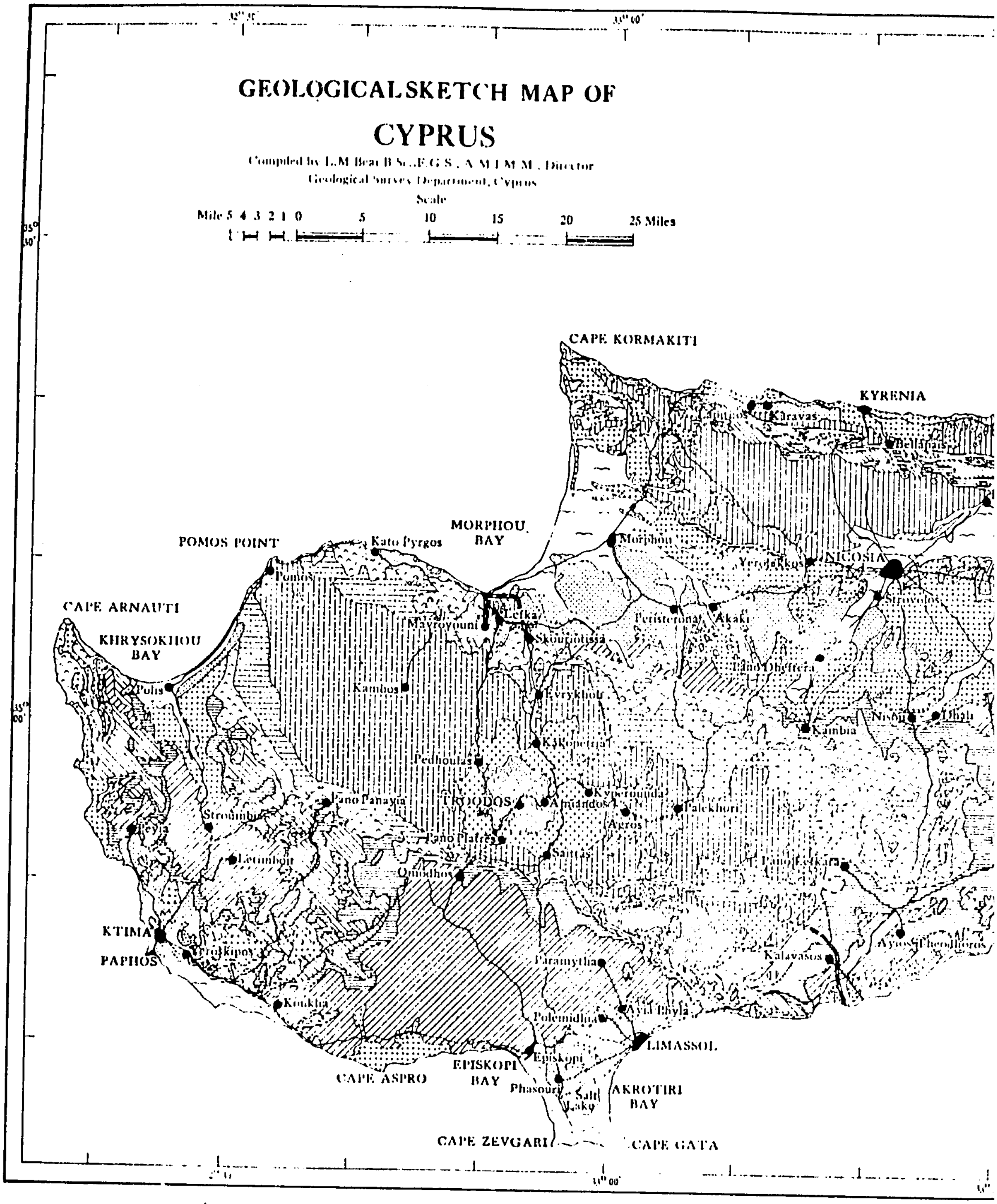
POSSIBLE WATER STORAGE DEVELOPMENT

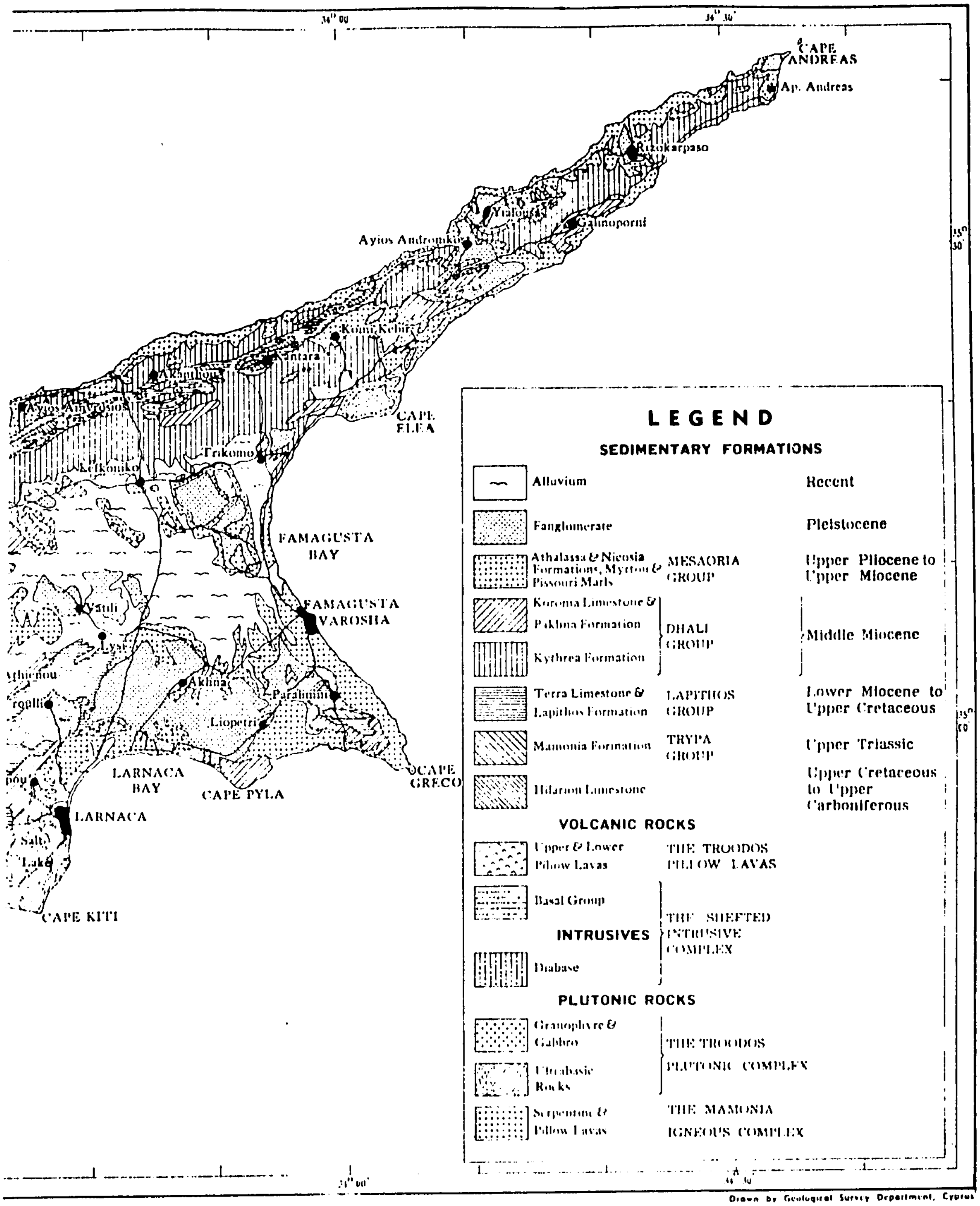
Catchment		Estimated runoff in average year, Storage and land to be irrigated										
					Existing storage				Proposed Storage	Possible irrigation from proposed storage (Donums)		
Hydr. No.	Name	Surface Runoff to the sea Mill. Gals.	Max. Annual flow Mill. Gals.	Flow from Nov. to Mar. Mill. Gals. (a)	No. of Dams	Storage Mill. Gals. (b)	Allowance for Recharge Irrigation Upstream without storage Mill. Gals. (c)	Evaporation Percolation etc. from Nov. to March Mill. Gals. (d)	Flow for storage Mill. Gals. (e) = a-b-c-d compare with the runoff to sea	Citrus & Bananas	Vegetables (two crops)	Deciduous
1	Yialias	Negligible	1500)	)	1	1000		--	--	--	--	--
	Pedieos	"	1050)	)								
2	Serrachis Ovgos	1000	6750	5500	3	650	4200	150	500	800	800	1000
3	Elea	200	1600	1300	..	..	850	50	400	..	1600	..
4	Atsas	150	850	600	2	12	408	30	150	200	400	..
5	Karyotis	750	2650	2200	..	..	350	50	1800	2000	3200	2000
6	Marathassa	400	2000	1650	2	280	270	70	1030	1000	2000	1000
7	Xeros	150	1500	1200	1	28	240	32	900	1600	2000	..
8	Kambos	150	650	500	1	5	185	10	300	600	600	..
9	Limnitis	600	1750	1400	..	..	570	30	800	1000	2200	..
10	Pyrgos	400	1300	1050	..	..	300	30	720	1000	1800	..
11	Katouris	100	180	200	1	60	35	25	80	100	200	..
12	Ay. Theodoros	80	120	..	..	..	20	20	80	100	200	..
13	Livadhia	200	450	370	1	270	70	30	..	..	..	..
14	Xeros (Ay. Marina)	100	200	160	1	70	60	30	..	..	..	..
15	Yialia	100	280	220	..	..	40	30	150	300	300	..
16	Magounda	400	1000	800	1	270	480	50	..	..	..	..
17	Khrysochou	1950	3050	2500	..	..	700	100	1700	3000	3800	..
	Mavrokolymbos Ktima-Akamas	500	750	600	1	500	60	40	..	..	..	..
18	Peninsula Minor Catchment	1000	1250	1000	..	..	770	30	200	200	600	..
19	Ezuza	2500	2750	2200	..	..	400	100	1700	2500	800	500
20	Xeropotamos	3500	4650	3800	..	..	250	150	3200	4000	6000	2800

21	Dhiarizos	4000	5450	4400	..	..	430	170	3800	5000	5000	3200
22	Khapotami	1200	1300	1050	..	..	130	120	800	1000	1000	1200
23	Episkopi Bay Minor Catchment	1050	1050	800	..	..	170	800	150	200	400	..
24	Kourris-Garyllis	7500	9000	7100	4	900	500	200	5500	10000	5000	7000
25	Yermasoyia	1700	3300	2500	1	5	350	145	2000	3000	3000	2000
26	Moni Area Minor Catchment	450	550	400	..	..	120	30	250	500	500	..
27	Vasilikos	750	2200	1700	..	..	260	40	1400	2000	3000	600
28	Maroni	350	750	600	..	..	70	30	500	500	1500	..
29	Pentaskynos	650	1550	1550	..	..	300	50	1000	2000	2000	..
30	Puzis and Xeropotamos	350	400	320	..	..	30	20	250	200	800	..
31	Tremithos	450	1550	1300	1	400	630	170	100	..	400	..
32	Larnaca Minor Catchments	500	500	400	1	10	140	50	200	..	800	..
33	Achna-Famagusta-Cape Grego Minor Catchments	2000	2000	2000	50 (including 40 small)	1500	Recharge Dams		500	..	..	..
34	Karpas Peninsula, Minor Catchments	3000	3100	2700	..	..	2080	120	500	..	2000	..
35	North Kyrenia Range Coastal Strip	1500	1500	1200	..	..	790	110	300	..	1200	..
36	Paleomylos	250	250	200	..	..	100	20	80	..	300	..
37	Kormakiti Minor Catchment	250	250	200	..	..	150	10	40	..	150	..
38	Aloupos	250	380	300	..	..	180	20	100	..	400	..
39	South Kyrenia Range Minor Catchments	..	..	..	..	..	..	..	..	..	1950	..
i	Kanli	..	270	270	1	245	..	25	..	..	..	..
ii	Almyros	..	250	250	1	230	..	20	..	..	..	..
iii	Tengelis	..	35	35	..	..	..	5	30	..	..	..
iv	Ay. Vassilios	..	30	30	..	..	..	5	25	..	..	..
v	Symeas	..	90	90	1	74	..	16	..	..	..	..
vi	Aksoyu	..	55	55	..	..	..	10	45	..	..	..
vii	Kodja Dere	..	55	55	..	..	..	10	45	..	..	..
viii	Yeni Dere	..	70	70	..	..	..	10	60	..	..	..
ix	Yerokolymbos	..	120	120	..	..	..	20	100	..	..	..
x	Kryos	..	50	50	..	..	..	10	40	..	..	..
xi	Kyparishia	..	50	50	..	..	..	5	45	..	..	..
xii	Other Minor Streams	..	155	155	3	55	..	..	100	..	..	..
	TOTALS	40444	72590	57200	78	6564	16688	3298	31670	42800	58900	21300


TOPOGRAPHY OF CYPRUS
N
Cape Andreas
KARPAS
Cape Kormakiti
KYRENIA
Kyrenia (Northern) Range
WESTERN MESAORIA
Morphou Bay
MORPHOU
NICOSIA
R. Pedhieos
R. Yialias
EASTERN MESAORIA
Kouklia Reservoir
Famagusta Bay
FAMAGUSTA
Cape Arnaouti
Khrysokhou Bay
Cape Greco
Larnaca Bay
LARNACA
Cape Pyla
Salt Lake
Cape Kiti
PAPHOS
LIMASSOL
Episkopi Bay
Salt Lake
Akrotiri Bay
Akrotiri Peninsula
Scale : 1" = 12 miles
12
0
12
24
0 - 1000 ft.
1000 - 2000 ft.
2000 - 3000 ft.
3000 - 4000 ft.
4000 - 5000 ft.
5000 - 6000 ft.
6000 and over
DRWG. No G 3996

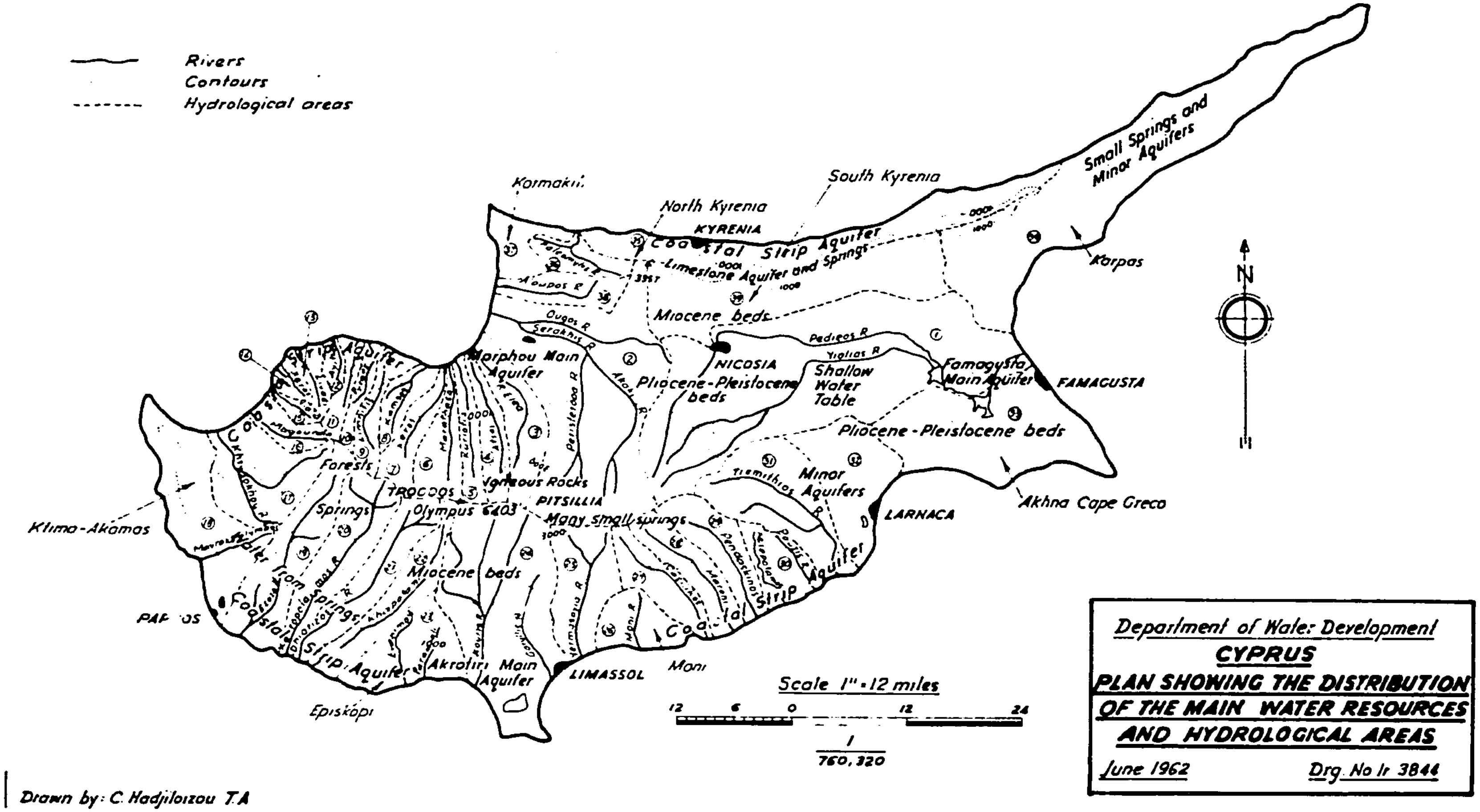

ISOHYETAL MAP OF CYPRUS


GEOLOGICALSKETCH MAP OF
CYPRUS
Geological Survey Department, Cyprus
Scale
Mile 5 4 3 2 1 0 5 10 15 20 25 Miles
CAPE KORMAKITI
KYRENIA
Karavas
Bellapais
MORPHOU BAY
Morphou
NICOSIA
POMOS POINT
Kato Pyrgos
Pomos
CAPE ARNAUTI
KHRYSOKHOU BAY
Polis
Lefka
Mavrovouni
Skouriotissa
Peristerona
Akaki
Kambos
Evrykhou
Pano Dheftera
Nisou
Dhali
Kambia
Kakopetria
Pedhoulas
TROODOS
Pano Panayia
Kyperounda
Amiandos
Agros
Palekhori
Stroumbi
Peyia
Pano Platres
Letumbou
Saittas
Omodhos
Pano Lefkara
KTIMA
PAPHOS
Prodhromi
Yeroskipos
Kalavasos
Ayios Theodhoros
Paramytha
Kouklia
Polemidhia
Ayia Phyla
LIMASSOL
EPISKOPI BAY
Episkopi
CAPE ASPRO
Phasouri
Salt Lake
AKROTIRI BAY
CAPE ZEVGARI
CAPE GATA



CAPE ANDREAS
Ap. Andreas
Rizokarpaso
Yialousa
Galinoporni
Ayios Andronikos
Komi Kebir
Kantara
CAPE ELEA
Trikomo
Kefkoniko
FAMAGUSTA BAY
FAMAGUSTA VAROSHA
Lysi
Akhna
Paralimni
Liopetri
LARNACA BAY
CAPE PYLA
CAPE GRECO
LARNACA
Salt Lake
CAPE KITI
LEGEND
SEDIMENTARY FORMATIONS
Alluvium
Recent
Fanglomerate
Pleistocene
Athalassa & Nicosia Formations, Myrtou & Pissouri Marls
MESAORIA GROUP
Upper Pliocene to Upper Miocene
Koronia Limestone &
Pakhna Formation
Kythrea Formation
DHALI GROUP
Middle Miocene
Terra Limestone & Lapithos Formation
LAPITHOS GROUP
Lower Miocene to Upper Cretaceous
Mamonia Formation
TRYPA GROUP
Upper Triassic
Hilarion Limestone
Upper Cretaceous to Upper Carboniferous
VOLCANIC ROCKS
Upper & Lower Pillow Lavas
THE TROODOS PILLOW LAVAS
Basal Group
INTRUSIVES
Diabase
THE SHEETED INTRUSIVE COMPLEX
PLUTONIC ROCKS
Granophyre & Gabbro
Ultrabasic Rocks
THE TROODOS PLUTONIC COMPLEX
Serpentine & Pillow Lavas
THE MAMONIA IGNEOUS COMPLEX
Drawn by Geological Survey Department, Cyprus

DRWG № G. 4015


Rivers
Contours
Hydrological areas
Small Springs and Minor Aquifers
South Kyrenia
North Kyrenia
Kormakiti
KYRENIA
Coastal Strip Aquifer
Limestone Aquifer and Springs
Karpas
Miocene beds
NICOSIA
Pedieos R
Yialias R
Morphou Main Aquifer
Pliocene-Pleistocene beds
Shallow Water Table
Famagusta Main Aquifer
FAMAGUSTA
Pliocene-Pleistocene beds
Forests
Minor Aquifers
Various Rocks
TROODOS
PITSILLIA
Olympus 6403
Many small springs
Akhna Cape Greco
LARNACA
Klimo-Akamas
Springs
Miocene beds
Coastal Strip Aquifer
PAPHOS
Akrotiri Main Aquifer
LIMASSOL
Moni
Episkopi
N
Scale 1" = 12 miles
12 6 0 12 24
1/760,320
Department of Water Development
CYPRUS
PLAN SHOWING THE DISTRIBUTION OF THE MAIN WATER RESOURCES AND HYDROLOGICAL AREAS
June 1962
Drg. No Ir 3844
Drawn by: C. Hadjiloizou T.A

DAMS IN CYPRUS

November 1965

Drg No AG/II/9/1

A. Dams constructed before 1962

No.	NAME	TYPE	HT.	MG	YEAR
1	Lymbia	Masonry	17	4	1945
2	Lythrodhonda	"	35	75	1945
3	Kalokhorio (Kl.)	"	30	18	1947
4	Akrounda	"	22	5	1947
5	Galini	"	36	5	1947
6	Petra	"	30	7	1948
7	Petra	"	30	5	1951
8	Lythrodhonda	"	34	7	1952
9	Kafizes	"	75	25	1953
10	Ayios Loucas	Earth	11	100	1955
11	Gypsos	"	11	22	1955
12	Kandou	Masonry	43	8	1956
13	Perapedhi	Con Grav	60	12	1956
14	Pyrgos (Tyll)	"	60	30	1957
15	Trimiklini	"	105	75	1958
16	Sotira	Earth	25	10	1962
17	Prodhromos	"	20	25	1962
18	Panayia (F)	"	23	10	1962
19	Morphou	"	37	450	1962
20	Lefka	Con Grav	80	80	1962
21	Geunyeli	Earth	50	230	1962
22	Ayios Yeorghios	"	20	20	1962
23	Athalassa	"	42	174	1962
24	Aloa	"	15	4	1962

Total Storage Capacity 1334

B- 1963 Projects

No	NAME	TYPE	HT	MG
25	Argaka-Magounda	Rockfill	135	253
26	Ayia Marina	"	108	66
27	Ayia Napa (7)	Earth	27	12
28	F'sta Anti-Flood	"	25	36
29	F'sta Recharge	"	16	11
30	Kanli Keuy	"	63	245
31	Mia Milea	"	71	74
32	Ovgos	"	52	186
33	Pomos	Rockfill	126	189
34	Tremithios	Earth	74	555
35	Paralimni (45)	"	15	25

Total Storage Capacity 1452

C 1964 Projects

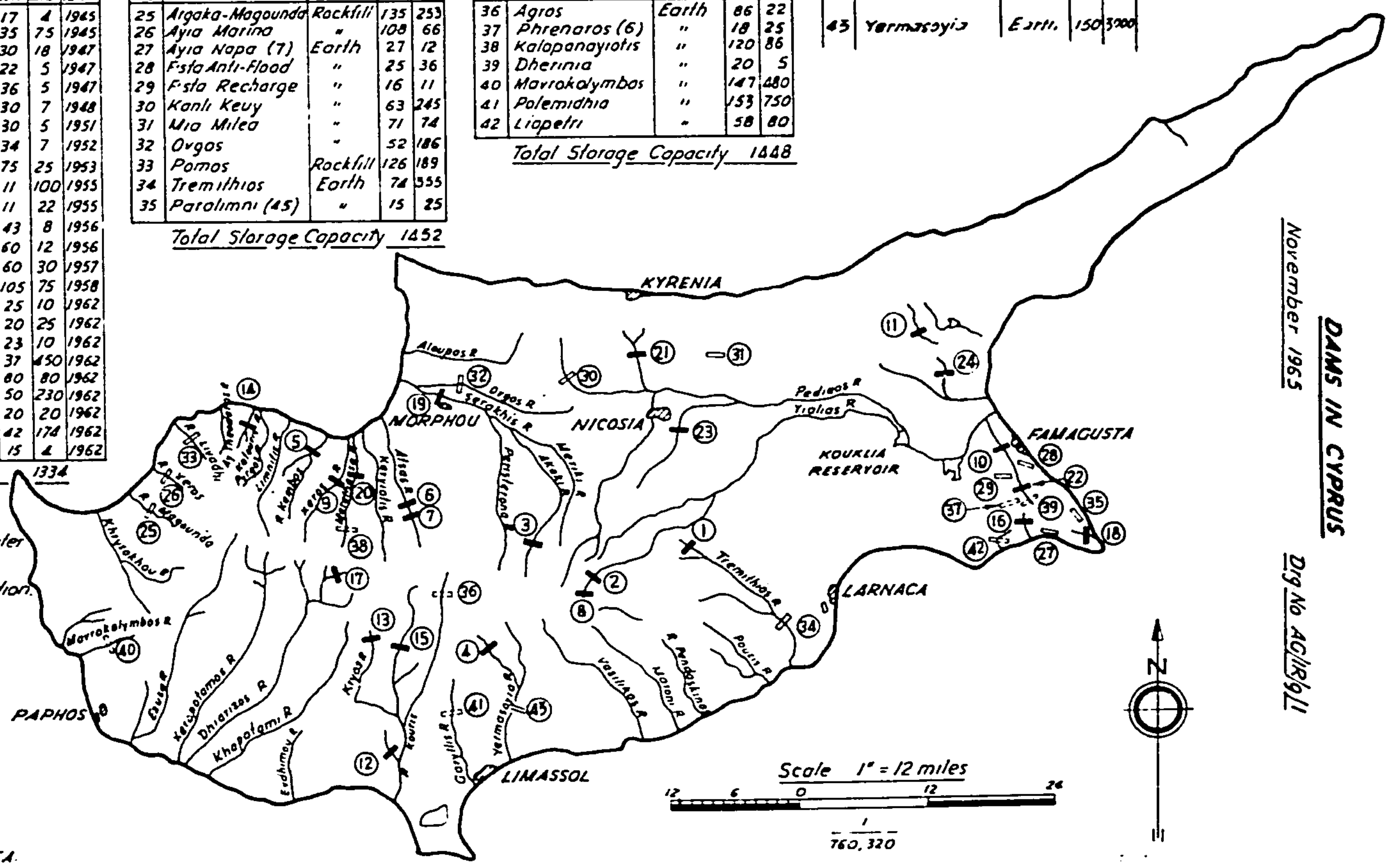
No.	NAME	TYPE	HT	MG
36	Agros	Earth	86	22
37	Phrenaros (6)	"	18	25
38	Kalopanayiotis	"	120	86
39	Dherinia	"	20	5
40	Mavrokalymbos	"	147	480
41	Polemidhia	"	153	750
42	Liopetri	"	58	80

Total Storage Capacity 1448

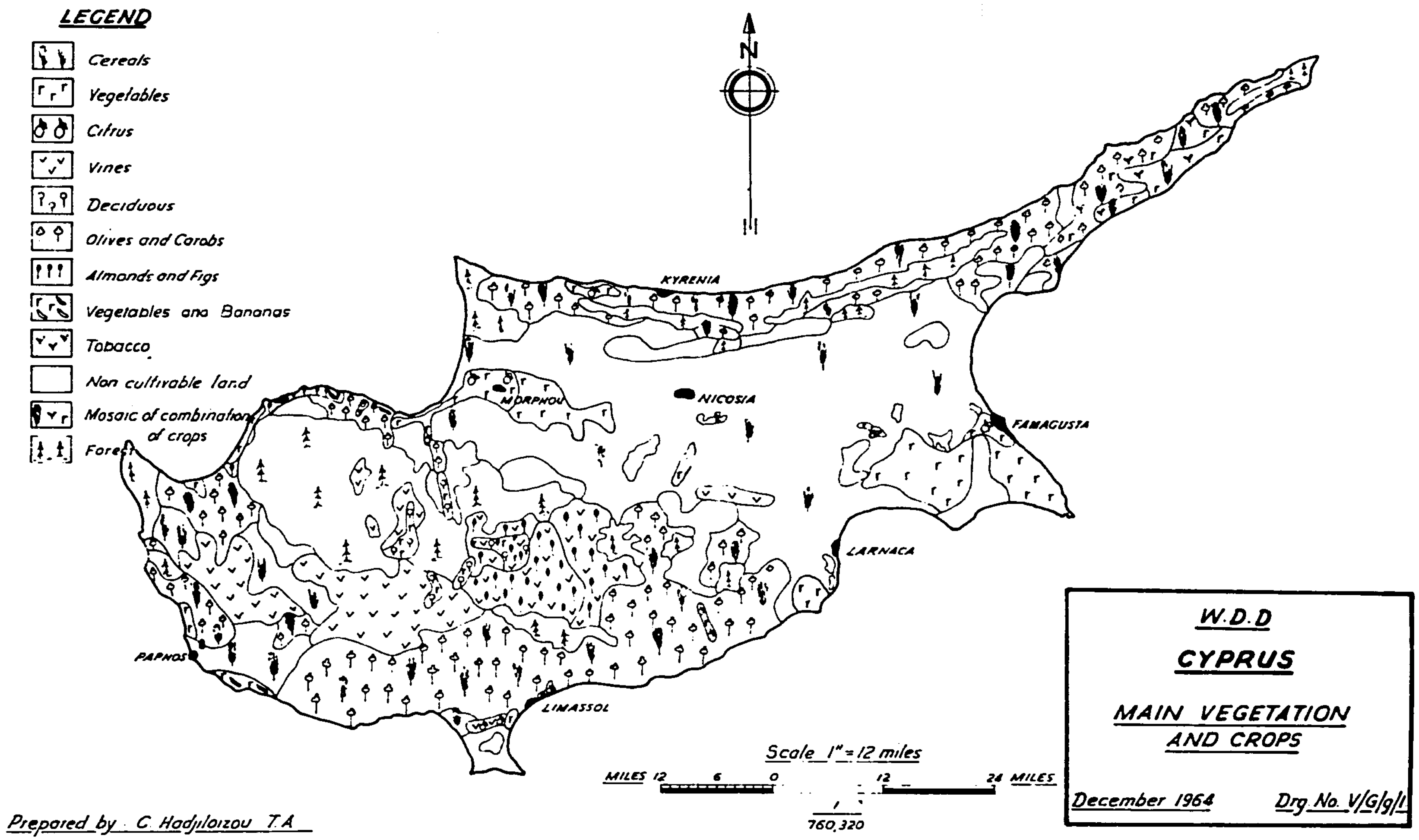
D- 1965 Projects

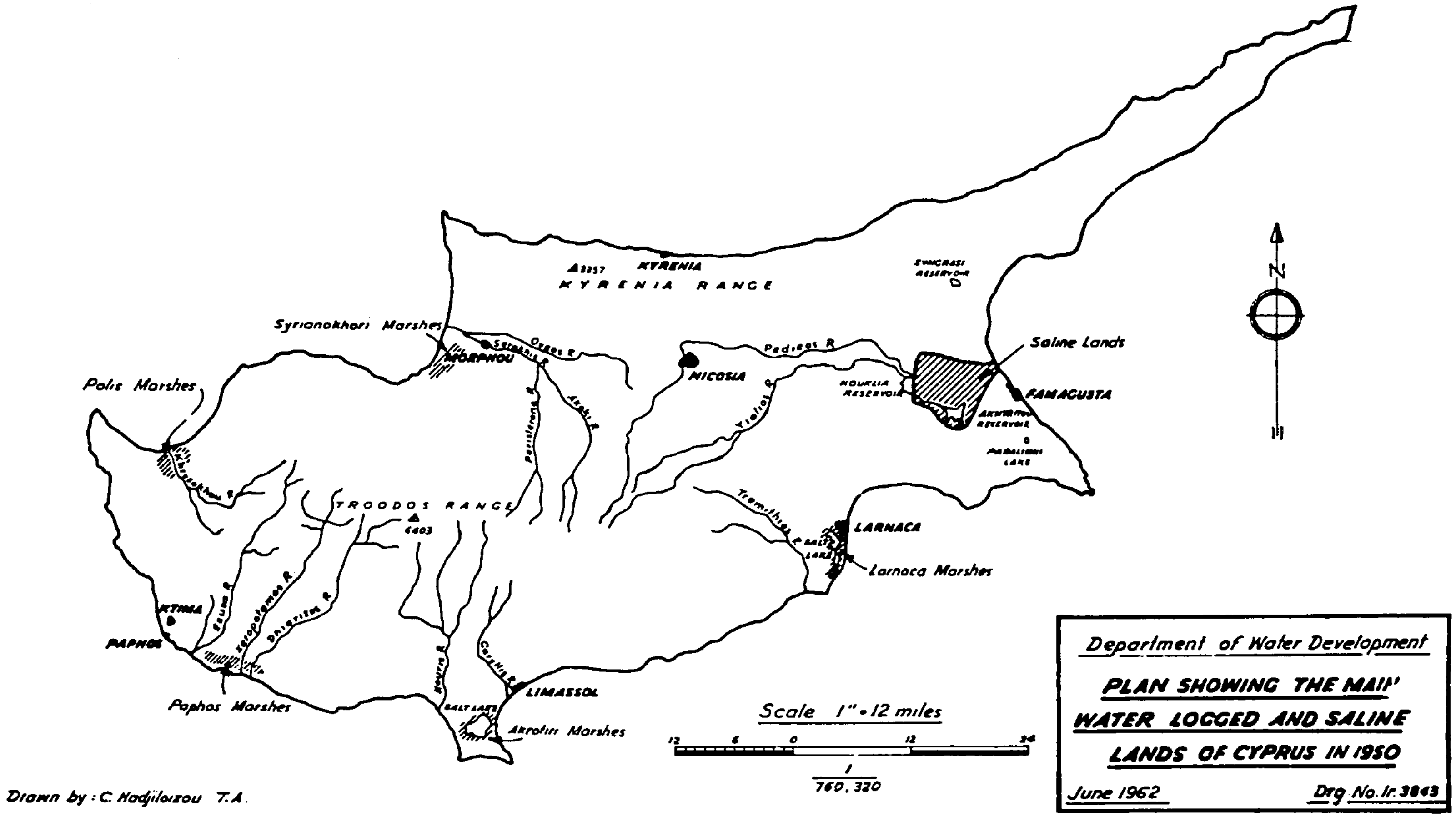
No	NAME	TYPE	HT.	MG
43	Yermasoyia	Earth	150	3000

HT refers to height in ft from foundation.
MG. means capacity of water in million gallons.
YEAR is the year of construction.

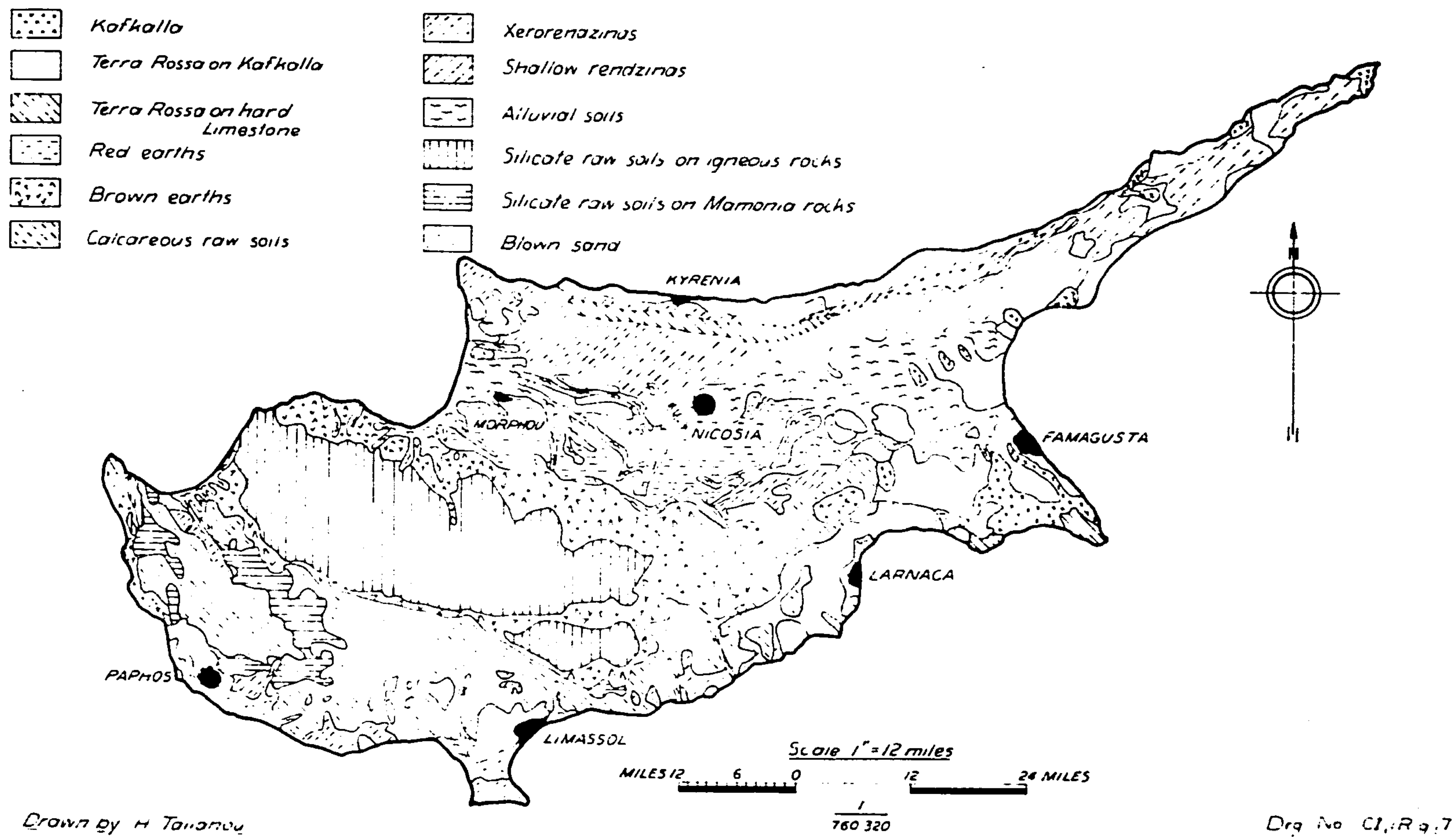


Drawn by C. Hadjiloizou T.A.


LEGEND
Cereals
Vegetables
Citrus
Vines
Deciduous
Olives and Carobs
Almonds and Figs
Vegetables and Bananas
Tobacco
Non cultivable land
Mosaic of combination of crops
Forest
N
KYRENIA
MORPHOU
NICOSIA
FAMAGUSTA
LARNACA
PAPHOS
LIMASSOL
Scale 1" = 12 miles
MILES 12 6 0 12 24 MILES
1/760,320
W.D.D
CYPRUS
MAIN VEGETATION AND CROPS
December 1964
Drg. No. V/G/9/1
Prepared by C. Hadjiloizou T.A.


KYRENIA
KYRENIA RANGE
Syrianokhori Marshes
MORPHOU
Ovgos R.
Pedieos R.
NICOSIA
Yialias R.
KOUKLIA RESERVOIR
Saline Lands
FAMAGUSTA
Polis Marshes
TROODOS RANGE
6403
Tremithos R.
LARNACA
SALT LAKE
Larnaca Marshes
KTIMA
PAPHOS
Ezousa R.
Xeropotamos R.
Dhiarizos R.
Paphos Marshes
Kouris R.
Garyllis R.
LIMASSOL
SALT LAKE
Akrotiri Marshes
Scale 1" = 12 miles
12
6
0
12
24
1
760,320
Drawn by : C. Hadjiloizou T.A.
Department of Water Development
PLAN SHOWING THE MAIN
WATER LOGGED AND SALINE
LANDS OF CYPRUS IN 1950
June 1962
Drg. No. Ir. 3843
N

RECONNAISSANCE SOIL MAP OF CYPRUS



Appendix I

SOILS OF CYPRUS

by

C. Soteriades*

Although Cyprus is a small island, it nevertheless has a large variety of soils. This may be attributed to its rather complex and varying geology as well as to climatic factors. The annual precipitation ranges from just over ten inches in some parts of the plains to over forty inches on the highest peaks of the Troodos mountains (elevation over 6,000 feet above sea level).

In their natural state the soils of Cyprus are very poor in nitrogen and phosphorus, while generally rich in potash. The imports of nitrogenous fertilizers amount to around 50,000 tons of fertilizers per annum. Phosphatic fertilizers as well as mixed fertilizers of 35,000 and 25,000 tons per annum respectively are also being imported.

A reconnaissance soil map of Cyprus, in the scale of 1:125,000, was published in 1961. Detailed soil surveys in the scale of 1:10,000, making use of soil series, types and phases, are now in progress in various parts of the island. One such sheet, with an area of nearly one hundred square miles, was published in the scale of 1:25,000 in 1965.

A brief account of the soils of Cyprus on the basis of the reconnaissance soil map is given below.

(1) *Kafkalla*

The term "kafkalla" refers to the hard, calcareous crust which occurs as an outcrop on most of the plateaus and mesas of the island. It is very rich in lime ($CaCO_3$ content around eighty percent), and very hard. The relative hardness depends on the degree of interlocking of the calcite crystals. Softer material, locally called "havara," underlies kafkalla, which from the petrographic point of view, may be considered as hardened recrystallized havara. Havara and kafkalla are thought to be terrestrial deposits of post-Pliocene or Pleistocene age.

Two types of kafkalla are distinguished. The fairly level type usually implies that havara underlies kafkalla. In many such cases it is possible to reclaim these large expanses of land by ripping, which breaks the surface crust and exposes the havara or the softer underlying calcareous material. On ripping, such lands become suitable for tree crops, mainly carobs or barley and fodder crops. The moderately sloping type usually indicates that the crust (kafkalla) is merely a cap on another rock and therefore ripping is impractical. The usual rocks that are limestone capped are the Nicosia or Athalassa sandstone and the Koronia limestone.

(2) *Terra Rossas on Kafkalla*

Terra rossas occur extensively along all the coastal plains and on the mesas and plateaus of the central plain. These are always associated with or overlie kafkalla. Terra rossas are generally shallow, although very deep soils, up to ten feet, exist in places. Such soils are colluvial accumulations and occur either in depressions, low lying places or along old water courses. Shingle beds, havara or other solid geological formations, instead of kafkalla, usually underlie such deep soils.

Terra rossas generally have a good red color, with a 10R or 2.5YR hue and chroma six or

* Department of Agriculture.

higher. These have little or no horizon differentiation. The soil is calcareous or slightly so on the surface but always calcareous in the subsoil. Lime-free soils on the surface can be found in certain areas.

Their texture is that of a clayloam to clay on the surface, but always clayee in the subsoil. Crumb or granular structure on the surface and subangular (rarely angular) blocky in the subsoil are characteristic. The soil is friable when dry but somewhat plastic and rather difficult to dig when wet. Few cracks appear on the surface upon drying and these only where the soil is very deep. Swelling and shrinking on wetting and drying are not considerable. Terra rossas are generally well drained, base saturated, easy to manage and very productive when deep.

"Immature" terra rossas represent soils of non-red color associated with or overlying kafkalla. These soils are always calcareous, with fragments of crust, calcareous nodules and grits throughout the profile. A whole range of colors, from pale grey brown to pale brown, brown and reddish brown, exist, and soils with such varying colors are so intermingled among themselves and the red terra rossas, that it occasionally proves difficult to separate these soils even in detailed surveys. The "immature" terra rossas can be regarded as juvenile soils which have not yet attained maximum development. Apart from differences in color and lack of advanced chemical weathering, these are in all other respects similar to the true terra rossas. Given time and protection from erosion, these will develop the red color required and also become decalcified. With this view in mind, the term "immature terra rossa" has been introduced to show their similarities and the direction of future development.

(3) *Terra Rossas on Hard Limestone*

These soils do not occur very extensively. The St. Hilarion limestone, on the northern range and the Koronia reef limestone on the south and south-east of the island, form good parent materials for the development of these terra rossas. These soils resemble very closely those described above, but are usually decalcified, especially those on the northern range. As these occur on steep topography, the soil is usually limited to certain pockets only, while the underlying limestone is mostly exposed.

(4) *Red Earths*

Soils of this group are mainly found on the northern foothills of the southern range and along the central plain at altitudes of 200 to 700 feet O.D., with a rainfall of fourteen to eighteen inches per annum. These are developed mainly from the weathering of igneous pebbles and overlie loose igneous pebbles, or igneous conglomerates mixed with very calcareous deposits (havara) occasionally cemented. These soils resemble the terra rossas in that these both have a red or reddish brown color but differ in profile development and characteristics. The "A" horizon has a clay or clayloam texture, but the "B" horizon has a moderately heavy clay texture and a prismatic or tendency to prismatic structure. These soils have a slightly calcareous or non calcareous "A" horizon, but their "B" horizon is always calcareous. A "BCa" horizon with a lime content of twenty to thirty percent is characteristic of some of the soil series belonging to this group of soils.

The typical red earths can be considered as more mature soils than the terra rossas, for they show a good profile development. Another important difference between these two groups of soils is the considerable swelling and shrinking on wetting and drying of the red earths, attributable most probably to differences in clay minerals.

The term "immature" has been used for the red earths with the same meaning as for terra rossas to indicate a lighter soil of brown or grey brown color and a higher proportion of igneous pebbles and lime. Another subdivision in this group are the "degraded" soils which occur at higher elevations and result from the washing away of the top soil by erosion, thus exposing the "B" or the "BCa" and "C" horizons in most instances. Such soils undergo now a new cycle of weathering.

(5) *Brown Earths*

This group is restricted to soils developing or overlying pillow lavas. Because of the steep or rolling topography of the pillow lavas, soils are generally shallow and are approaching the brown rankers. Deeper soils are colluvial accumulations exhibiting a certain degree of profile development. Soils are generally non-calcareous, although some calcareous soils may be found near the contact with the Lapithos chalks and limestones.

(6) *Calcareous Raw Soils*

These are mainly mechanically weathered soils lacking in soil development, and occur on the Lapithos or Pakhna limestone formations. Most of the vineyards in the Limassol and Paphos district are on these soils which, in spite of their steep topography, have survived complete destruction from erosion through extensive terracing. In essence these are man-made soils created because of the softness of the parent rock with the aid of the pick and the plough. The whole profile can still be considered as that of the "C" horizon, as the original "A" has been washed away and is just now being reformed. A very pale color (almost white in the majority), a very high proportion of limestones and slabs from the underlying rock, as well as excessive lime content (sixty to eighty percent) gritty texture and lack of organic matter are the characteristics of this group.

(7) *Xerorendzinas*

The Xerorendzinas, in contrast to the calcareous raw soils, are chemically weathered "A/C" soils showing some profile development and occur on limestones, marls, or other very calcareous deposits. On the basis of the parent material the Xerorendzinas were mapped as below:

(a) *On the Kythrea beds.* The parent material in this case is an interbedded sandstone and marl highly folded and tilted. These rocks give rise to a hummocky topography with the sandstone beds vertically exposed and the marl weathers down to give an "A/C" soil with some lime accumulation. Such soils are usually heavy, calcareous, humus- deficient and have a grey brown or yellow brown color.

(b) *On limestones, chalks and very calcareous deposits.* These are mostly deep soils of pale color derived mainly from colluvium of the Pakhna and Lapithos limestones and chalks. "A/C" soils are extremely calcareous even in the "A" horizon with low organic matter.

(c) *On Pliocene marls.* These soils are similar to those developed on the Kythrea beds, but occur mainly on the Myrtou and Pissouri marls. They are essentially "A/C" soils having occasionally a "B" horizon; usually shallow clays to heavy clays having an impeded drainage when on level land or depressions.

(8) *Shallow Rendzinas with Hard Limestone Outcrops*

These soils are found on the eastern half of the northern range where the soft Lapithos limestone occurs extensively. Soils with a northern aspect have a dark "A" horizon, rich in organic matter, while those with a southern aspect are less rich. These soils develop under low scrub woody deciduous vegetation.

(9) *Alluvial Soils*

Apart from some narrow patches occurring alongside certain rivers there are two main extensive alluvial regions. The one on the central part (Eastern Mesaoria) consists mainly of heavy soils highly influenced by the Kythrea marls lying to the north. The other region, around Morphou Bay, consists mainly of lighter soils from the southern range. Generally speaking, the alluvial soils of the west are less calcareous than those of the central region. All alluvial soils, however, are recent sediments and show no profile development.

Among the alluvial soils one finds saline and marshy soils formed under the influence of a high water table. These were mapped separately. Soil salinity varies from 0.1 to two percent total salts, the majority of salts being chlorides of sodium. The salinity of the underlying water table is still higher, and may reach two or three times that of the sea. Saline alkaline soils rarely exist, the least saline ones being usually alkaline in the surface horizons.

Reclamation of the saline and/or alkaline soils is feasible when an adequate system of artificial drains is established and gypsum applied where necessary.

(10) *Silicate Raw Soils*

These are mainly mechanically weathered soils occurring on the basic igneous rocks or on the very old rocks of the Mamonia formation and which have suffered severe erosion.

(a) *On igneous rocks.* The majority of soils on igneous rocks are raw, consisting of rock fragments mechanically broken down, showing little or no profile development. Steep slopes and erosion are the two factors in the exposure of the "C" horizon. In protected areas or under coniferous forest some profile development can be seen. Underneath the pine needle littre, there is a dark loamy "A" horizon with neutral or slightly acid reaction overlying a thin "B" clayloam horizon. The "C" horizon is occasionally quite deep, especially where the underlying rock is soft. Such soils may be termed as rankers. Red or brown "ABC" soils of heavy texture similar to the red earths can be found also on the southern range especially on ultrabasic rocks. Grey brown Podsolic soils with a weakly developed "A_2" horizon occur at altitudes of over 5,000 feet and an annual rainfall of thirty-five inches or more.

(b) *On Mamonia rocks.* The so-called Mamonia formation is the oldest geological formation and dates back to the Jurassic-Triassic age. It includes a wide range of rocks, such as limestones, sandstones and marls on one hand, and basic and ultra-basic rocks on the other. The most extensive, however, is a red marl giving rise to a heavy red soil with bad structure and impeded drainage. These soils have not yet been studied in any detail. In view of their bad physical properties, however, these soils are considered generally unproductive.

(11) *Blown Sand*

These are Aeolian deposits of many feet thickness consisting entirely of beach sand and occur in isolated places north of the Morphou Bay and along the Kyrenia, Famagusta and Karpass peninsula coastlines. Many of these have not yet been established.

Appendix II

IRRIGATION IN CYPRUS*

Irrigated crops form the very backbone of the Cyprus economy, and they always have; recently, however, even more so, and with a difference.

Through all of history, up to and including World War II, "irrigation" here meant wild flooding of unleveled lands for cereal production, utilizing spate waters diverted from the rivers when swollen by rains. Understandably, the extent of this type of irrigation varied considerably from year to year, and efficiency of water use was extremely low. However, on the average, large areas were irrigated and the overall production was a sustaining force in the economy. Dry season, or year-around irrigation was relatively unimportant because such water supplies were very scarce. They were comprised of a few good springs and the small quantities which could be lifted from shallow aquifers by such devices as windmills and Persian waterwheels. Life in the villages was difficult, and dry years could spell disaster, but wet years always came along to restore the production balance, and the standard of living to its normal level. The point is, there were no basic water supply problems, or threats to the way of life. Water, while a wasted asset, was not a wasting asset. One might mourn the annual runoff of huge supplies of surface waters to the sea, or the fact that large, untapped reserves existed in the deeper aquifers of the Island, but taken in context, the overall irrigation picture was one of stability. Despite the extreme inefficiency of the system, one cannot complain that spate waters were "misused." These were, after all, waters which if not diverted, would be wasted to the sea. The costs of diversion were insignificant, and the gains therefrom relatively high. It simply was not feasible to level the land or to take other measures for the improvement of irrigation efficiences for such a crop as cereals, not to mention the additional problems of shallow soils, land fragmentation, crop rotations and fallowing, highly variable water supply, etc., all of which compound both the difficulties and the costs beyond practicability. It should be added that the same holds true even today.

Today, although spate irrigation goes on just as always, its relative importance in the overall irrigation picture is greatly diminished, due to the appearance on the scene of the deep bored well and the deep well pump; essentially a post-World War II phenomenon in Cyprus. For the first time in history we have been offered a large and dependable supply of water for year-around irrigation. Is it any wonder that farmers went all-out to tap this unprecedented source of prosperity, or that government encouraged them to do so? I think not. As a result the Island today produces a great quantity and variety of fruits and vegetables, much of which is for export, comprising fully three-fourths of the total value of agricultural exports, and this in a country which exports essentially only minerals and agricultural products. Chief among the exported crops are citrus fruits, potatoes, and carrots, but many other irrigated crops are exported also, for the climate and soils are suited to virtually all crops. Only water is lacking. A measure of the value of irrigation to Cyprus is the fact that the mere five percent of cropland which is irrigated year around (the overwhelming majority of which is irrigated with groundwaters developed in the last twenty years) yields one half of total crop production, or one third of the total agricultural output. Donum for donum, the irrigated lands are thus seen to produce nineteen times the value of the drylands (which include the spate irrigated lands). In 1946, spate water use was 25,000 million imperial gallons (note that figures on irrigated acreages, water use, etc., can best be described as rough approximations), and the value of the cereals, etc., produced was *Cyprus* $9,800,000. Groundwater use was 8,600 million gallons and produced a gross income of *Cyprus* $8,400,000.

* Produced by the Water Use Section, Department of Agriculture.

In 1966 spate water use and income should be the same as before, but groundwater use should have risen to 57,500 million gallons and should produce a gross income of *Cyprus* \$58,800,000; in other words a seven-fold increase in twenty years. Present groundwater use appears to be rising by 4,500 million gallons per year, and the income from this use at a corresponding rate.

However, the blessing is decidedly mixed, because groundwater development had already become *over-development* in some aquifers more than a decade ago. In 1956 when groundwater use was a mere 20,000 million gallons, a large portion of the Famagusta aquifer was already destroyed by the intrusion of sea water, due to over-pumping along the coastal strip, a rich citrus belt. The same process had begun in small areas near Limassol and Morphou.

Controls were ordered by the then Colonial Government, but you will recall that this was the period of struggle which culminated in independence in 1960. Controls were unenforceable, and few people were fully alerted to the dangers of the situation anyway. As for proper water use, it had never been of concern, and there were no trained people on the Island.

Since 1960, the Government of Cyprus, realizing the importance of all-season irrigated agriculture to the economy, has given its full support to the development of surface sources presently wasted to the sea, to the improvement of water use efficiencies at the farm level (see separate paper on the "Water Use Improvement Project"), and to various investigative programs to determine the true status of water supply and use. Meanwhile it has striven to formulate and pass legislation to enforce necessary controls on water use. I am pleased to report that this legislation has now been passed, and enforcement procedures are being formulated.

The sobering fact is that all possible measures must be taken if the present high income from irrigated agriculture is to be maintained, much less increased:

(1) Unauthorized drilling of wells must cease.

(2) All groundwater sources must be fitted with water meters or other accurate measuring devices.

(3) Extraction Quotas must be set and enforced for each well.

(4) Every effort must be bent, and every facility made available, to effect the highest possible efficiency of water use at the farm level.

(5) Water must be transferred from areas of plenty to threatened areas.

(6) New sources of water, both surface and subsurface, must be developed to supplement present sources.

(7) Likely a charge will have to be put on the extraction of groundwaters.

(8) Quite possibly there will have to be planting controls which could restrict or halt new plantings, with cropping patterns to favor low water requirement crops, or in grave cases, to reduce the irrigated area.

Some of these measures are already being taken, others soon will be, and the rest are under consideration.

There is a bright spot on the horizon which is now looming larger daily. It happens that the returns from fruit and vegetable crops, per unit volume of water they require, are very high. We can afford to pay a high price for a dependable supply of year-around water. So we are pleased to note the results of the latest feasibility studies for a large scale (150×10^6 US gallons per day) desalinization plant in the USA, which indicate unit costs comparable to those we are presently expending for development of surface supplies which are not dependable in Cyprus, and which projects are further complicated by problems of water rights and land fragmentation. We submit that it is time for Cyprus to begin seriously considering desalinization of sea water as a very possible answer to our water supply problems in the not too distant future.

Appendix III

RESEARCH IN IRRIGATION

by

Mr. Y. Stylianou

In the summer of 1962, after an agreement between the Cyprus Government and the Special Fund of the United Nations and the FAO, the Agricultural Research Institute was established.

Among other sections, the Soils and Water Use Section is one of the most important.

Since water is one of the most precious commodities in Cyprus, priority was given to the finding of the exact water requirement of the main irrigated crops and particularly citrus. This detailed information is necessary for raising the irrigation efficiency. It is also of utmost importance to the government in its effort to enforce strictly any legislation designed to balance the extraction of groundwater with the replenishment.

The experimental trees are irrigated by the "hose-basin" method. The moisture is followed by regular samplings and by the use of tensiometers. The frequency of irrigation is another objective of the experiments, side by side with the water requirement. Four points on the scale of the available moisture (1 - 5 - 9 - 13 atmospheres average tension in the root zone) are under, and no difference in the trees' growth or production has as yet been observed. This means that we can grow the trees without any damage, with fewer irrigations and less total water, since the efficiency of application can never be 100 percent.

This coming irrigation season the data to be collected will include evaporation records for the first time in Cyprus. Evaporation records will also be used to determine the water requirements of crops such as potatoes, since the soil samples are not reliable, due to the sparse root system. An important part of the work in 1966 is the testing of waters of various salinity levels for sprinkling alfalfa. Also for raising the efficiency, we will try to determine the optimum length of furrow for a given soil type, slope and head of water.

The work of the Water Use Section of the Research Institute is therefore "applied" research on problems raised by the farmers or by the Extension Irrigation experts of the country.

* Agricultural Research Institute

Appendix IV

SOIL CONSERVATION SCHEMES

by

Kyros L. Sarrides*

Soil conservation has been a serious problem in Cyprus, and as the government realized it a specialist service of Soil Conservation was established under the Department of Agriculture to deal with both dry and irrigated land. The following schemes are now in operation for promoting soil conservation works:

(1) *Organization of Soil Conservation Divisions*

According to the Soil Conservation Law, legal power is given to the government for the establishment of Soil Conservation Divisions on compact areas, provided this is decided by the majority of the land owners and the scheme prepared by the Soil Conservation Service is approved. The administration and application of the scheme are the responsibility of a local committee of land owners, elected by the farmers affected, with the Director of Agriculture or his representative as chairman.

In addition to the technical assistance, the government gives financial help, which now amounts to fifty percent as subsidy and the remaining fifty percent as a long-term loan.

The major obstacle in the economic planning of such divisions has been the scattered holdings in small plots, the average size of each plot being about one acre. This problem is expected to be solved by the enactment of a Land Consolidation Law in the near future.

(2) *Soil Conservation Minor Works Subsidy Scheme*

According to this scheme a subsidy of twenty-five percent of the cost is given to the farmers of joined villages for certain soil conservation measures applied by them according to the instructions of the specialists. Such measures are: bench terraces, leveling, masonry structures, ripping, etc.

(3) *Earth-moving Equipment*

The use of such machinery was initiated by the government by making fifteen crawler tractors, with scrapers, bulldozers and rippers, available to farmers at very low prices in the beginning but now at cost price. Meanwhile, individual contractors have increased sufficiently in number so that their services are obtained at reasonable prices.

(4) *Technical Assistance*

Technical assistance is given to individual farmers by the Department of Agriculture and plans are prepared for proper land preparation and usage.

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GREECE

The total irrigated area of Greece (1964) amounts to 540,000 hectares, fifteen percent of the cultivated surface. The area that can be irrigated in the future, by the existing possibilities, is estimated to be 1,600,000 hectares.

Methods of Irrigation

Furrow irrigation is widely used, chiefly for cotton, corn, sugar beets and vegetables, and covers about eighty percent of the irrigated area in northern Greece and a smaller percentage in other regions of the country.

The main reasons for adopting furrow irrigation in northern Greece are: (a) the increasing acreage cultivated with row crops; (b) the small rates of discharge, which are very easy to handle; (c) the use of small siphons to supply water from laterals to furrows that facilitate considerably the application of irrigation.

In southern Greece the most widely used method of irrigation, especially in orchards, is irrigation by basins. This method is preferred in order to prevent excessive water losses and to increase the water distribution efficiency.

Sprinkling irrigation by portable individual sets is applied in areas where collective surface irrigation projects are under construction.

The irrigated area by sprinkling (individual installations) amounts to 34,300 hectares.

A project for collective irrigation by sprinkling on demand is under construction to serve 2,100 hectares and an additional area of 51,700 hectares is being studied. A comparison between surface irrigation and sprinkler irrigation is also being made.

From an analysis of the general and annual costs of the two systems the following conclusions have been made: (a) The total cost of construction of surface irrigation systems, including the cost of land grading, is $905 per hectare. The comparative cost for sprinkling systems amounts to $1,474 per hectare, or $569 per hectare more than surface irrigation; (b) The annual cost for surface irrigation is $95.50 per hectare, while for sprinkler irrigation the annual cost is $169 per hectare. In other words, surface irrigation gives a net profit of $73.50 per hectare more than sprinkling; (c) In general, irrigation by sprinkling should be adopted when special soil and water conditions make surface irrigation impossible.

Field experiments are conducted by the Land Reclamation Research Station on the amount of water applied, length and width of borders, length and spacing of furrows, land slopes and sprinkler irrigation designs.

Field irrigation efficiency studies have been made only on the methods of furrow and border irrigation.

In newly constructed projects land leveling is applied by the Land Reclamation Service, on the basis of careful studies carried out by the specialized agronomists.

Improved Irrigation Systems

Due to the high cost involved, irrigation canals were constructed unlined a few years ago, but since 1957 all systems are concrete lined.

Flumes (canaletti) of a length of five meters each have been used since 1960 in all major irrigation projects, where land slope is very small. Concrete lined canals (mostly rectangular) and more recently pipelines are used in irrigation works constructed on hilly areas. In all large irrigation projects Neyrpic discharge measuring devices equipped with Neyrpic (Amil, Avio, Module a Masque) regulators are installed in every canal.

The continuous flow delivery system is most commonly used.

Water Quality

A serious water quality problem developed recently in the coastal areas, where overpumping from shallow or deep wells caused intrusion of sea water.

In making soil survey studies for the construction of irrigation projects, quality of waters to be used for irrigation is always examined by the soil laboratories of the Ministry of Agriculture and waters are classified in various classes of salinity and alkalinity, according to the USDA Salinity Laboratory Diagram.

Under our conditions we consider the water quality classification applied by the USDA Salinity Laboratory as very strict and therefore, in Greece, waters beyond the upper limits are still accepted as suitable for watering the respective crops to a certain degree.

Leaching of Saline and Alkaline Soils

Saline and alkaline soils cover a relatively large irrigable area, estimated at 110,000 hectares, out of which 50,000 hectares are coastal soils and 60,000 hectares are continental. An additional 40,000 hectares will be reclaimed from lagoons, swamps, etc.

Some work has been done with leaching of saline soils in combination with rice cultivation and with application of gypsum. Good results were obtained in the case of permeable (more or less sandy or organic) soils when well drained.

A systematic investigation of leaching requirements of saline soils, and of the proper amount and nature of soil amendments to reclaim alkaline soils, has been included in the program of the Land Reclamation Research Station. More especially, the investigation will aim at determining quantities of water, time of flooding and soil amendments needed to improve saline, non-saline-alkali and saline-alkali soils, and also plants to be grown, until full reclamation is achieved.

Drainage of Irrigated Land

Drainage is extensively applied in Greece: (a) on areas reclaimed out of lakes or marshes; (b) on bottom lands suffering from high water table, and (c) in irrigated areas, where it is generally combined with the irrigation network, except in sloping areas.

Drainage ditches are usually located parallel to the irrigation laterals. Thus spacing of drains depends largely on the spacing of irrigation laterals. In some irrigated areas, however, a high water table may occur.

The areas where closer drainage spacing is necessary are those of impermeable soils or those containing an excessive amount of salts. Practically all drainage projects consist of open ditches. A very small area, with an impermeable layer at a depth of sixty to seventy cm. is drained by mole drains for experimental purposes.

Methods Used for Determining Consumptive Use of Water by Crops and Frequency of Irrigation

Systematic studies for determining the consumptive use of water by crops have been undertaken recently by the Land Reclamation Research Station, using direct and indirect methods. The direct methods applied are: (a) measuring the moisture of soil samples, and (b) the use of bouyoucos blocks. An indirect method recently used is the atmometer method. Studies have also been conducted to determine ideal irrigation frequencies. Results indicate that a decrease in the available moisture in cotton fields below twenty-five percent for a certain period may cause a considerable reduction in yields.

Assuming soil moisture constantly over twenty-five percent of the available moisture on medium textured soils, the best irrigation frequency for cotton would be fourteen to nineteen days during August, which may be considered as the most critical month for conditions prevailing in Greece.

Extension and Training of Farmers

The agency having the overall responsibility for the application of irrigation in the field and the training of farmers in modern methods of irrigation is the Land Reclamation Service of the Ministry of Agriculture, working in cooperation with the Extension Service of the Ministry of Agriculture as well as the general and local organizations administering the irrigation works.

Field demonstrations are organized by the Land Reclamation Service, to train farmers in modern methods of irrigation, handling of sprinkler systems, conservation through land leveling, etc. Special courses also are undertaken for supplementary education of scientific personnel.

INDIA

by

Jagat Kishore Jain *

The sub-continent of India lies partly in a tropical and partly in a sub-tropical region with land elevations varying from sea level to very high mountains. Physiographically the sub-continent may be divided into four regions of varying characteristics: (1) the Peninsula of Deccan, largely composed of most ancient rocks; (2) the Himalayas; (3) the Thar Desert and (4) the Indo-Gangetic alluvial plains. The Indo-Gangetic plains constitute one of the most fertile tracts in the country.

The main problem in water utilization in India is the great diversity in seasonal and annual distribution of rainfall. Floods may be causing havoc in some parts of the country while other parts are suffering from drought. The rainfall varies from five inches (127 mm) in the deserts of the northwest to over 100 inches (2540 mm), leaving out Chirapunji in Assam, which gets an average annual rainfall of 500 inches (12,700 mm). Most of the rainfall is due to the southwest monsoon and occurs in the months of June to September, except in the southeast portion of the peninsula, where the rainfall is heavier from October to December. Even from year to year the rainfall is subject to wide variations, both in regard to quantity and time. Due to these irregularities in rainfall, widespread need for irrigation is recognized in most parts of the country.

Soils. The soils of India can be classified into four major types: (1) alluvial soils of the Indo-Gangetic plains and the coastal areas; (2) black cotton soils of the Deccan tract; (3) red soils and (4) laterite soils.

Agricultural acreage. The geographical area of the country is 809.6 million acres,[1] of which about 337 million acres (net) were under cultivation in 1962-63. The gross area under different crops was 386 million acres. The major food crops are: rice, jowar, wheat, bajra, gram and pulses. Cotton, groundnut and sugarcane are the cash crops which occupy the maximum area. The area actually receiving irrigation during 1962-63 was 63.5 million (net) acres and 72.6 million (cropped) acres. This is only nineteen percent of the area. There is thus an evident scope for further development of irrigation.

Water resources. The utilizable surface water resources of the country are estimated to be about 450 million acre-feet,[2] of which about one-third is expected to be developed by the end of the Third Five-Year Plan, i.e., the end of March, 1966. A reliable estimate of the country's groundwater resources is yet to be made. The longterm potentiality for irrigation development in the country is tentatively placed at 187 million acres, comprised of about 142 million acres from surface water sources and about forty-five million acres from groundwater sources.

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[1] One acre equals 0.40 hectare.
[2] One acre-foot equals 1233.48 cubic meters.

Irrigation facilities. Since the beginning of the First Five-Year Plan in 1951-52, concentrated efforts have been made to develop irrigation facilities in the country through all feasible types and sizes of schemes. During the three Five-Year Plans, about 500 major-medium irrigation projects have been constructed. They are expected to create an irrigation potential of about nineteen million acres, with an expected outlay of Rs.13,-100 million[3] during the fifteen years' period. In minor irrigation, the salient achievements during the last fifteen years are: construction and restoration of 900,000 dugwells; boring and deepening of 300,000 dugwells for augmenting their yields; construction of 30,000 shallow tubewells; and construction of 9,500 deep tubewells; installation of 125,000 diesel powered pumps and 375,000 electrical driven pumps; construction for repairs of about 55,000 tanks. A large number of small diversion, drainage and embankment schemes have also been developed. The net additional irrigation potential expected to be created by the end of the Third Plan is 13.8 million acres, with an outlay of about Rs. 5800 million.

Administration. The primary responsibility for implementation of all types of irrigation schemes rests with the state governments; the central government mainly plays an advisory and coordinating role. The major-medium irrigation-schemes are handled by the Ministry of Irrigation & Power. The schemes are scrutinized from the planning and technical angle by the Central Water & Power Commission under that ministry. The minor irrigation schemes are handled by the Ministry of Food, Agriculture, Community Development & Cooperation. The coordination among various ministries in regard to agriculture, including irrigation and drainage, is achieved by the Agricultural Production Board, which is a high-powered coordinating body, including representatives from all the concerned ministries.

Floods and drainage. The problems of floods and drainage are fairly acute in the country. On an average, the floods annually affect an area of sixteen million acres, including about five million acres under crops. The total annual direct and indirect loss amounts to Rs. 1000 million. It is tentatively estimated that the longterm outlay required for flood protection and drainage works would be of the order of Rs. 10,000 million. The investment actually made by the end of the Third Five-Year Plan was some Rs. 1500 million.

[3] One rupee equals 0.213 U.S. dollar.

I. Accomplishments Since Last Seminar

(A) Execution of Works

The work on irrigation projects has continued vigorously. The emphasis has been on completion of those major-medium irrigation projects which were in advanced stages of construction so that benefits could start accruing quickly. Under minor irrigation, emphasis has been on increasing groundwater utilization through construction of dugwells, dug-cum-bore wells (dugwells which are deepened by drilling to increase discharge) and power driven pumps. Priority has also been given to renovation of existing irrigation sources which had previously been owned by the absentee landlords and were in disrepair due to long neglect.

(B) Maintenance and Operation of Works

The responsibility for maintenance and operation of irrigation projects irrigating more than 200 to 250 acres rests with the State Irrigation Departments. Irrigation charges are realized by the government from the beneficiaries on a crop-area basis. In some cases there is a two-part charge comprising a fixed charge on the entire commanded area irrespective of whether irrigation is carried out or not, and the other is a variable charge on the basis of the actual crop-acres irrigated. Adequate maintenance grants for these projects are ear-marked specifically in the annual budget of the states. For some smaller projects, the grants earmarked in the annual budget were not adequate. During the last two years these grants have been increased in many states.

The responsibility for operation and maintenance of irrigation works irrigating less than 200 to 250 acres has continued to be entrusted to the village *panchayats* (local self-government) in all the states. Rural engineering departments have been established in the states to provide technical supervision and guidance on the maintenance works and other rural jobs executed by the panchayats. Specific grants for maintenance are made available by the government to panchayats.

(C) Irrigation Water Management

Many positive steps have been taken since the seminar in 1964 for improving irrigation water management on the projects at the farm level. These are described subsequently in the report.

(D) Drainage, Waterlogging, Salinity and Alkali Problems

(1) The problems of waterlogging, salinity and alkalinity relate closely to drainage. As a first step, therefore, emphasis is being placed on improvement of drainage. Technical committees have been appointed to examine the problems of drainage and flooding in all badly affected regions. Longterm master plans have been prepared on the basis of the recommendations of these committees. The program is being executed in a phased manner, first the main drains then the laterals and subsidiary drains. Maximum progress has been attained in the State of Punjab which was badly affected by waterlogging and salinity. Of the longterm Master Plan, involving a total cost of above Rs. 610 million, works covering about twenty-five percent of the total are expected to be completed by the end of the Third Five-Year Plan.

(2) The work of surface drainage improvement is being accompanied by a vigorous program of groundwater pumping through construction of dugwells and tubewells in the affected areas. This groundwater pumping not only provides added irrigation (in case the quality of water is good) but also helps depress the water table and thus relieves waterlogging.

(3) A land reclamation organization has been set up in the state of Punjab for bringing saline and alkaline areas under cultivation. A discharge of about 1,000 cusecs[4] of water is being utilized for leaching the salts and raising crops. Reclamation work is also being conducted in the states of Maharashtra, Rajasthan and Uttar Pradesh. Up to March, 1964, a total of about 52,000 acres was reclaimed in these states. Since the last seminar an estimated 60,000 more acres have been reclaimed.

(4) To promote a program of saline-alkali reclamation on a large scale during the Fourth Five-Year Plan, the government of India initiated three centrally sponsored pilot demonstration projects. These projects are located in the affected areas of Punjab (1,000 acres), Gujarat (600 acres), and Madras (300 acres). The project areas have been selected and preliminary investigations as to salinity and alkali reclamation needs have been completed. Necessary reclamation works are in progress. The project in Punjab consists of laying of tile drains, leaching of saline soils, and treating alkaline soils with gypsum applications. The project in Gujarat is intended to determine the efficiency of open, pipe and rubble drains with and without application of gypsum to reclaim coastal saline lands which have already been protected against ingress of sea water by construction of suitable embankments. The project in Madras will work on an open field drainage system and the application of amendments for reclamation of saline-alkali lands in rice fields. The results of these projects are expected to be available within the next two to three years.

(E) Field Irrigation Drainage Research

After the last seminar, the government of India appointed a committee to study the needs for research on irrigation and drainage and make suitable recommendations for intensification of the programs. The committee strongly emphasized the need for undertaking coordinated projects on items connected with field irrigation and drainage. Under each coordinated project, the work is envisaged to be conducted at different research institutes in the country. There would be a coordinator for each project to control and integrate the work. These coordinated projects would be de-

[4] One cusec equals 0.03 cubic meter per second.

veloped in the Fourth Five-Year Plan. Meanwhile, the work on irrigation and drainage already being conducted at the various research institutes is being intensified. There is a coordinated scheme for research on minor irrigation and water use under which research work is being conducted on irrigation methods suited to different crops under variable conditions of soils, topography, etc. The work of determining water requirements of crops according to the soil-moisture regime method has been intensified at various research institutes. Some work has also been initiated on determination of water requirements of crops based on climatological approach.

Five irrigation research centers have been established in five major project areas. The work on field irrigation and drainage is being speeded up at these research centers.

(F) Education and Training

(1) *Professionals.* Since the last seminar the central government arranged two training courses for the professionals on the subject of minor irrigation and water use — one during February-March, 1965, and the other during January-February, 1966. About forty technicians from different states were trained during these two courses. The training provided was sufficiently comprehensive and included lectures on theory as well as field practice. It is proposed to conduct one such course every year in the future.

(2) *Sub-Professionals.* A training program for sub-professionals on the subject of minor irrigation and water use is already underway in thirteen of a total of sixteen states. The program has made good progress in several states and the others have been catching up.

(3) *Village Extension Workers and Farmers.* Training of village extension workers and progressive farmers is being provided on a regular basis. The village extension workers are provided pre-service as well as in-service training. The curriculum of training includes different aspects of irrigation and water use depending on the requirements.

II. Plans for New Water Supply Development

(A) Development through execution of major-medium and minor irrigation schemes in close coordination is proposed. The Fourth Plan (1966-71) is yet to be finalized. It is, however, hoped that sufficient allocations will be made in the Irrigation Sector to enable creation of an additional irrigation potential of about twenty to twenty-five million acres.

(B) For accelerating the creation of potential major-medium irrigation, it is proposed to give priority to those projects which are continuing from earlier plans.

(C) Under minor irrigation, emphasis is on groundwater development along scientific lines. A program for groundwater investigations executed by the Exploratory Tubewell Organization of the government of India has been underway since 1955. This program, however, has confined its activities mainly to more favorable groundwater-worthy areas for deep tubewell construction. There are, however, many tracts in the country which offer possibilities for increased groundwater utilization through construction of dugwells and shallow tubewells. A centrally sponsored program of groundwater surveys to be implemented by the States has been initiated recently to cover these tracts.

(D) The existing organzation in the states for conducting drilling work and for undertaking deepening of dugwells by means of pneumatic blasting is being strengthened. For facilitating lifting of water from dugwells and also from other sources such as ponds, lakes, streams, rivers, etc., a program for the installation of power pumps, both electric and diesel, is underway. The program is proposed to be intensified further during the Fourth Five-Year Plan. For this purpose many incentives have been introduced. Until recently, only financial assistance in the form of loans was available to cultivators for purchase and installation of pumps. However, he is now eligible for a substantial subsidy amounting to twenty-five percent in the case of electrical pumps and up to fifty percent (varying according to the

H.P.) for diesel powered pumps. It has also been decided that the rate of electricity supplied for irrigation pumping over and above Rs. 0.12 per unit would be subsidized. In the case of the pump units as well as the electricity supplied, the subsidy is to be shared half and half between the central government and the state governments.

(E) Under the Rural Electrification Program, emphasis is on providing motors and power for as many pumps as possible within available finances.

(F) Under the new strategy of development of irrigated agriculture in conjunction with such other basics as improved seeds, fertilizers, etc., emphasis is on providing more dependable and intensive irrigation. Major-medium and minor irrigation schemes have been playing a complementary role in this regard. Construction of dugwells, dug-cum-bore wells and tubewells in major-medium irrigation projects is increasing. Besides increasing the intensity of irrigation this is also expected to reduce the hazards of waterlogging, salinity and alkalinity, etc., in the controlled area. The program is proposed to be intensified during the Fourth Five-Year Plan. Integrated utilization of major-medium diversion and storage schemes and minor tanks is also planned wherever feasible by diverting the surplus supplies, if any are available during the monsoon season, and storing them in small tanks for irrigation.

(G) On some storage schemes the existing practice is to grow only one long-duration crop of paddy. It is proposed to replace this crop by a high yielding short-duration variety and then follow it up by a second crop during rabi (winter season) within the same amount of available storage water. With simultaneous introduction of improved irrigation practices in the distribution and application of irrigation water, this arrangement is considered to be workable on many storage schemes.

III. Development of Institutions and Procedures for Improving Irrigation and Drainage at the Farm Level

(A) It is now well recognized that the full impact of irrigation potential on increasing food production cannot be obtained unless irrigation and drainage at the farm level are planned scientifically. In fact, a single program which is expected to yield spectacular results in the agricultural field today at a minimum cost is considered to be the promotion of irrigated agriculture. The question has been how to achieve this important objective, particularly in the face of many difficulties such as: fragmented and scattered land holdings; subsistence level of farming; lack of incentive on the part of the cultivators for increasing production; lack of technical know-how; shortage of basic supplies and services, and scarcity of credit at the disposal of the cultivators.

During the last few years the problem has been discussed in detail by various working groups appointed, and at various seminars convened for the purpose. Consequently, there has been some crystalization of thought on the issues involved and as a result positive steps have been taken by way of: (1) intensification of the research on field irrigation and drainage; (2) undertaking training programs in the modern techniques of irrigation and drainage; and (3) strengthening action programs in the field. Details about (1) and (2) have already been given earlier in the report.

(B) In regard to strengthening action programs, a composite approach seeking coordination of all basic inputs and practices along scientific lines should be the basis of any action. Consistent with this principle, the essential ingredients of the action program (although the program would vary in details from region to region and project to project) are considered to be as follows:

(1) Crop planning and regulation of irrigation supplies — providing supplemental irrigation wherever necessary and feasible.

(2) Proper distribution and application of irrigation water and provision of adequate drainage facilities.

(3) Land shaping and consolidation of holdings.

(4) Soil surveys for efficient crop and water use planning.

(5) Arrangements for supplies and complementary inputs.

(6) Extension and demonstration.

(7) Financial arrangements to meet the credit needs of the cultivators.

(8) Cooperative storage and marketing facilities.

(9) Communication and agro-industrial development.

Several measures have been undertaken to strengthen the action program:

(1) A special program called the *Ayacut* (Command Area) Development Program to cover the integrated activities of the type mentioned above has been initiated. The program envisions a concerted and coordiated effort on the part of various departments in selected compact areas. It is planned to begin the program in limited areas only, because of the limitations of resources such as trained men, supplies, cooperative credit, etc. The state departments involved would be those of Irrigation, Agriculture, Community Development and Public Works. A broad indication of the specific responsibilities of different departments is as follows:

Irrigation Department

(a) To fix the alignment of the field channels and supply the maps showing the command area and the alignment of field channels for each village to the block development staff panchayats.

(b) To construct the water courses and field channels departmentally where the cultivators so desire or have not been able to construct these themselves.

(c) To help the Agriculture Department and the ayacut development program project staff in crop planning in relation to irrigation supplies.

(d) To review the existing practices in regard to duty of water, water allowances, outlet factors, restoring of channels, etc., and to introduce such adjustments as may be feasible for accommodating the cropping program.

(e) To forecast the availability of supplies so that the plantings can be planned accordingly.

(f) To construct and improve the drains of the tract.

(g) To construct such supplemental works as may come under the purview of the department.

Agriculture Department

(a) To make a detailed soil survey of the area.

(b) To plan cropping in the area in relation to the irrigation supplies, in consultation with the Irrigation Department and the project staff of the area program.

(c) To organize departmental mechanized units for carrying out leveling work; and to provide implements and technical guidance to the cultivators.

(d) To arrange for improved seeds, fertilizers, manures, insecticides, fungicides, etc., for the area.

(e) To arrange consolidation of holdings on a priority basis within the program.

(f) To actively participate in the extension and demonstration work of the area in collaboration with the extension staff of the blocks.

Community Development Department

(a) To persuade the cultivators to construct field channels and prepare their fields properly.

(b) To plan and carry out the extension and demonstration work required under the ayacut development program.

(c) To stimulate and direct activity for road construction and improvement in the area.

(d) To carry out all the normal community development activities.

Cooperation Department

(a) To arrange for the requirements for long, medium and short-term credit for the cultivators under the program.

(b) To revitalize the existing cooperative societies and to organize additional societies for cooperative storage and marketing.

(c) To establish cooperative units for processing the main agricultural produce of the area.

Public Works Department

(Buildings and Roads Branch)

This department is to expand communications in the area covered under this program on a priority basis.

(1) As indicated above, the entire country has already been brought under the community development program with the establishment of 5223 blocks covering 558,000 villages of India. Each block is staffed by extension officers who are specialized in different disciplines such as agronomy, soils, fertilizers, crops, engineering, etc., and by village-level workers. All this staff is trained in extension methods.

As mentioned in the country report of the last seminar, a cooperative credit organization has also been established in the country to assist the cultivators in activities connected with agriculture. This cooperative organization is expected to meet the short-term as well as the long-term credit needs of the farmers in regard to development of irrigated agriculture. The organization makes available short-term loans for seasonal requirements for improved seeds, fertilizers, etc. For construction of field irrigation and drainage channels, land preparation, purchase of bullocks, implements, etc., medium and long-term loans are made available by the organization. Special efforts are planned under the cooperative sector to meet the requirements of the cultivators under the coverage of the ayacut development program on a priority basis.

The program of ayacut development has already made good progress on certain projects in Maharashtra and Andhra Pradesh. Other states have also initiated the program in selected areas.

(2) As detailed in the last country report; an intensive agricultural development program is in progress in several districts. In some of these districts, the practical methods of efficient water use have been demonstrated to the farmers. The program of demonstrations includes: (a) the establishment of proper farm irrigation distribution systems, including construction of field channels and simple structures for control and distribution of water; (b) proper grading and preparation of fields for uniform water application according to sound irrigation methods, and (c) provision of suitable drainage arrangements for excess water.

The demonstrations are arranged in the fields of cultivators. This program has brought excellent results. In the beginning the farmers were apprehensive and reluctant. However, the spectacular increase in the yields of crops as a result of improved practices and proper fertilizer application has made noticeable impact on their minds.

Experience with the demonstrations, on the other hand, has also revealed that the work involved in construction of field channels, distribution structures and land leveling and preparation in relation to the topography, soils, crops, etc., requires specialized knowledge and must be done by a staff specially trained in the subject. Moreover, the farmers, even after they have carefully watched the demonstration cannot do this work themselves unless they are provided with further technical guidance and supervision.

(3) It has been felt necessary that the irrigation codes be revised and updated. These cover practices in regard to water allowances, duty of water, rotation of channels, etc. In several cases they were prepared a long time ago. Consideration should be given to the changing needs and the cropping patterns of the high yielding strains of crops. These involve changes in water requirements as a result of increased use of chemical fertilizers and other factors. The government of India has appointed a technical committee to ex-

amine these codes in the light of modern developments and suggest suitable modifications. The committee is expected to give its recommendations within a year.

(4) The state governments have been advised to set up a special organization for handling development of irrigated agriculture according to modern techniques. The responsibility for implementation of the ayacut development program would also rest with this organization. On new irrigation projects this organization would evaluate the project from the agricultural point of view during the planning phase. The states have been taking steps for setting up this organization.

(5) A country-wide drive is being organized to expedite construction of field channels on new irrigation projects. Technical guidance in this regard is being provided by the project authorities. Legislation has been introduced in nearly all the states, empowering the state governments to undertake the construction of field channels themselves in case of default and charge the cost to the beneficiaries.

(6) For lining field channels, some state governments have decided to extend financial assistance in the form of loan and subsidy to the cultivators who are prepared to carry out this work. Field channels in the form of underground pipes manufactured locally have become popular on well and tubewell irrigation in many states such as Maharashtra and Gujarat. The state of Uttar Pradesh, where there exists the largest number of deep tubewells (about 8,000), has decided to line the field channels to a total length of three miles instead of the older practice of lining only two miles per tubewell.

(7) The soil conservation organization in some states has begun a program of constructing and lining field channels and of leveling and preparing fields. The program has become very popular on well irrigation in the state of Punjab. It is proposed to extend this activity to other states.

IRAN

by

Asghar Azzarnia*

General information about the geographical condition, climate, water resources, agriculture, and the main farming methods in different areas of Iran and also different procedures of getting water have been noted in the country reports of the Fourth and Fifth Irrigation Practices Seminars.

I have tried to avoid any repetitions and will therefore, only mention a summary of activities in agricultural development, utilization of available water resources and improvement of irrigation during these past two years in Iran.

Before explaining the said activities I would like to state that the implementation of the Land Reform Law has had excellent results and has caused many changes in the social conditions of the rural areas in different parts of Iran. These changes resulted largely from the approval of six national principles proposed by H.I.M. Arya Mehr, followed by organizing and activating thousands of army draftees for education, health and extension work in the villages. This added manpower has speeded the rural development programs far more than expected.

I. Education and Training

(A) *Professionals.* Equipment for the agricultural colleges of Tehran, Pahlavi, Ahwaz and Tabriz Universities has been essentially completed and thus it was possible to double the number of students in the year 1965-66. A new agricultural college has been established in Rezaieh in northwest Iran. Since September, 1965, with the cooperation and help of French and Iranian experts, a hydro-geology postgraduate course has been started in Tehran University.

(B) *Sub-Professionals.* In addition to the professional and sub-professional agricultural training, mechanized irrigated farming methods and proper use of soil and water are being taught to farmers' sons in twenty-one practical training centers in different areas of the country. His Imperial Majesty Arya Mehr's order establishing the Extension and Development Corps was issued on September 21, 1964 (Farmer's day), was approved by the parliaments in January, 1965, and was announced to the Ministry of Agriculture immediately after the signature of His Majesty was obtained.

The Extension Corps trains farmers and small landowners in remote rural areas in agricultural methods and proper use of soil and water. To date, over 1,000 young men, all graduates of high schools or technical colleges, have been sent to special practical training courses in irrigated farming and then sent to live in the villages to train farmers and small land owners in better farming and rural development, under the general guidance of the regular government Extension Service.

* General Director, Agricultural Engineering Dept., Ministry of Agriculture.

(C) *Training of Farmers.* During the two past years over 1500 farmers and small land owners have become acquainted with methods of mechanized agriculture and proper use of water and soil at demonstration farms.

The Agricultural Extension Service, together with the Agricultural Engineering Department, has established demonstration and training farms in the provinces of Azarbayejan (east and west), Gillan, Mazandaran, Esfahan, and Fars. These farms are a minimum of 200 and a maximum of 500 hectares.

The extension men can train at least 250 farmers at a time. Since the farmers' training courses are short, it is expected to acquaint 10,000 to 20,000 farmers with new methods of farming each year.

To acquaint farmers and small land owners with mechanized sugar beet planting and proper irrigation, and to encourage them in mechanized sugar planting, mechanization working task forces have been established in four ostans.[1] They perform agricultural activities with agricultural machinery, charging the farmers very small and reasonable prices for the work.

This year demonstration farms will be established in the areas of activity of sixteen governmental factories to show the sugar beet farmers and the small land owners the methods of mechanized sugar beet planting and the advantages of this kind of farming. Meanwhile the Agricultural Engineering Department, with the help of tractor dealers, has arranged two-month training courses for tractor drivers in the provinces.

These courses started in the year 1965 and in nine months a total of 425 drivers have been trained for mechanized agriculture.

II. Operation and Management of Irrigation Projects

Water management of individual rivers is by relevant groups of land owners under the technical supervision of government water masters. Since the execution of the Land Reform Law the rural coops have replaced the previous land owners and the local Water and Power Organizations, as recommended by previous seminars. These coops are responsible for the management and maintenance of the dams, irrigation establishments and the hydraulic units. In the areas where irrigated farming was not practiced and the farmers were not acquainted with irrigated farming, some irrigation organizations were established, but irrigation management will be done by government organizations until the farmers get acquainted with the irrigation operations.

III. Field Irrigation and Drainage Research

During the past two years three laboratories for drainage research have been established and the equipment for previous laboratories has been completed. Irrigation research for indicating the amount of water needed for sugar beet, cotton, wheat, rice and alfalfa is being continued according to the previous program. Within the past six months a commission of experts in irrigation and drainage has been established, with the guidance of professors at the agricultural college of Tehran University.

The commission will make recommendations regarding the amount of water needed for different plants, the size of basins (or the length of the furrows in mechanized irrigated farming) and make economic comparison of different methods of irrigation (border irrigation, furrow irrigation and sprinkler irrigation). It will also indicate the effect of different chemical fertilizers on the amount of irrigation water used. The depth of drains, spaces between the drains, the climatic conditions, and the soils of different areas of the country for various farming products, the effect of soil leaching in saline soils and the need of water for this purpose are under study. This study is expected to be completed in the next two months.

IV. Waterlogging, Salinity and Alkali Problems

The recommendation of the Fifth Seminar for training agricultural engineers has been considered and the drainage and reclamation of saline areas

[1] Ostan means region or state.

have been included in the training course program, since it is so important for the southern and southeast areas of Iran. It has also been included in the program of the agricultural machinery and soil conservation center in Karaj.

V. Farm Irrigation and Drainage Systems

The necessity of research and preparation of agricultural development plans and irrigation networks has been more noticeable since the implementation of the Land Reform Law and the farmers' awareness of improvements in the condition of farming.

The local irrigation organizations, with adequate budget and funds, are modernizing farming conditions. Executive and study groups of the Agricultural Engineering Department, following the special regulations of assistance to farmers, are responsible for land leveling and rural irrigation and drainage networks. The Department also carries out reclamation and canal lining activities at a very low price to farmers and small land owners. Excellent results came from these activities and programs are underway for the development of 50,000 villages throughout the country, which will be performed by these groups. Work is planned so as not to interfere with individual private farming but to encourage and guide farmers in their activities.

VI. Standards for Irrigation and Drainage Investigation

The recommendation of the Fifth Seminar concerning the standard for irrigation and drainage has been considered and observed by the Ministries of Agriculture and Water and Power, and it is always regarded in preparing preliminary study plans, feasibility reports and project designs.

It is hoped that by sincere cooperation of the two said ministries Iran will be able to carry on relevant projects without the assistance of foreign advisors and organizations.

VII. Activities in Agricultural Development and Use of Water Resources

The Ministry of Water and Power was established on March 1, 1964, and all the irrigation organizations, such as Khuzestan, Sefid-Rood, Karaj and Tehran Water and Power Authorities, were centralized in this ministry. The Independent Irrigation Bongah[2] (Independent Irrigation Department) also was separated from the Ministry of Agriculture and attached to the Ministry of Water and Power. Thus there is more coordination among the various organizations in performing the reclamation plans and use of water resources.

With the separation of the Irrigation Bongah from the Agricultural Ministry, the Agricultural Engineering Department and the Soil Institute were separated from the Bongah, remained as two departmental units in the Ministry of Agriculture, and are being managed with more authority and better facilities. The following activities have been implemented during the past two years:

(A) *Topography.* Through the Topographic Institute, topographical maps with scales of 1/5000 have been prepared with photogrammetry, for the province of Khuzestan, ports and islands of the Persian Gulf, ports and islands of Oman Sea, Sistan, Baloochestan, Esfahan, Gillan, Mazandaran, Tehran, and a part of Azarbayejan and Khorasan. The contour lines in the plain areas are shown at intervals of one meter, and in mountainous areas five meters, with a scale of 1/50,000.

(B) *Hydrology.* During the past two years seventy more hydrologic stations have been established for measuring the amount of river waters and recording related statistics. The number of such stations has thus increased from 260 to about 330. Furthermore, due to reconsideration of the organization and completion of the technical staff, the analysis of the investigations is accomplished more effectively and the results are more satisfactory.

(C) *Hydro-geology.* The organization of a Hydro-geology Institute was completed in 1964. About eighty geologists who specialize in hydrology were employed. At present 160 geologists

[2] Bongah means office, corporation or department.

and technicians are working on the underground water project. Research for underground water has been done in an area of fifteen million hectares, and the quality and amount of available underground water have been determined.

(D) *Meteorology.* During the past two years twenty new meteorology stations and 100 rain gauging stations have been established, making a total of 500 stations managed by governmental agencies (forty stations are synoptic). Since statistical information of the atmosphere is of great importance in irrigation, a program is being studied to increase the number of second class meteorology stations to 1,600 and rain gauging stations to 6,400, with Army Education Corps draftees to manage them. Also, with the help of UNESCO, in the very near future secro-climateology and agro-climateology stations will be established with adequate staff and equipment in Karaj.

I hope to be able to announce to the honorable delegates of the Seventh Seminar all of the progress achieved from this center.

(E) *Soil Studies.* The Soil Institute, after being separated from the Independent Irrigation Bongah, started its activities as an independent institute. It has established soil laboratories in Tabriz and Shiraz during the past two years. Drainage research laboratories of the Agricultural Engineering Department have very intimate cooperation with the Soil Institute. Altogether ten laboratories are working for soil and land reclamation studies. Six laboratories are completely equipped.

During the past two years detailed studies have been made in an area of 30,000 hectares, and semi-detailed studies in an area of about 1.2 million hectares.

The technical staff has been increased and at present thirty engineers and chemists, forty technicians and six administrative employees are working for the Soil Institute.

(F) *Agricultural Research and the Economy of Water.* In the new organization of the Ministry of Water and Power a unit has been established to do research for agriculture and to deal with economic problems of irrigation. It also supervises the relatively small irrigation projects, large water resource projects, and dams such as Shah Abas Kabeer (Zayande-rood Esfahan) Daryush Kabeer (Kor River in Fars) and Kurosh (Zareenerood west Azarbayejan).

(G) *Irrigation Development.* The following activities have been performed for development of irrigation and agriculture during the past two years:

(1) In the area of Mohamad Reza Shah Reservoir Dam, the first unit of the Sad Dez irrigation canal network, serving an area of 22,000 hectares, has been completed in every phase including drainage. Khuzestan Water and Power organization has agreed to do the land leveling and land reclamation in the irrigated and farmed area, with a grant of fifty percent of the cost, and the balance on a long-term loan.

(2) In the irrigated area of Shahbanoo Farah Reservoir Dam (Sefid Rood) the production of rice has risen tremendously and the yield in 1964 was over three and a half tons per hectare as a result of providing the necessary water.

(3) The seventeen kilometers thirty m^3/s irrigation tunnel from the Sefid Rood River to the Fuman plain of Shahbanoo Farah Dam is excavated and construction is nearly complete. It is expected to be in operation during the coming year.

(4) The two diversion dams on the Sefid Rood are already constructed and the main canal of Sangar (which together make 307 kilometers having the capacity of thirty-five $m^3/sec.$) is completed.

(5) The network of main irrigation canals which are fed by Amir Kabeer Reservoir Dam (Karaj) have been reconstructed and their beds lined with concrete. The overall length of canals is sixty kilometers.

(6) During the past two years more than 3500 deep wells have been dug for small farming purposes and thus about 140,000 hectares of land developed. The funds have been provided by the Plan Organization and Investment Bank of Agriculture and Rural Development.

(7) Through the execution of the Land Reform Law and the interest of farmers and small land owners in proper use of soil and water, there was an increase of over ten percent in crop yields, although the year 1964 was a drought year. Contributing factors were: improved farming methods, the availability of more land, investment in rural roads, financial and technical assistance, and activities of army draftees serving in education, health, extension and rural development.

Altogether in the last two years the Rural Agriculture Development Bank has made 922,000 loans amounting to seven and a half billion rials, for providing water, land, nursery, seeds, chemical fertilizer, implementation, etc., and thousands of army draftees for education, health and extension were working with great interest on remote farms and villages. The improvement in farming, health and training services is being felt all over the country.

JORDAN

Jordan has a total area of about 100,000 square kilometers, and supports a population of about 1,800,000 people. About eighty-seven percent of the total area receives less than 200 millimeters of rainfall per year. The need to improve the water resources of the country, in order to increase the agricultural production as well as the standard of living, is the major concern of both private and governmental agencies. This report deals with the progress of each of the following agencies:

East Ghor Canal Authority

(1) *Construction*: 186 kilometers of lateral were constructed to serve 52,000 additional donums of land in section three. This brings the total length of laterals to 398 kilometers and the total area served to 117,000 donums. Eleven kilometers of surface drains were completed in section three. A pilot sub-surface drainage network of about two kilometers of tile drains in an area of 2000 donums was also constructed in section one. Measurements of water table levels and the amount and quality of drainage effluent are being continually made.

(2) *Small Dams*: Sixty percent of the total work in Wadi Ziglab Dam, including 100 percent of the foundation work and forty percent of the compacted earth fill work, was completed. This dam is being constructed to store five MCM of water.

Design was finished for the 30,000m^3 compacted earth fill Wadi abu Ziyad flood control and water regulation dam. This will also be used for the future groundwater recharge activities.

Construction was completed in Wadi Jurum cutoff curtain and water regulation and control structure to improve Wadi Jurum springs.

(3) *Land Distribution*: 900 farm units were distributed to new owners in sections two and three, bringing to 2868 the total number of distributed farm units.

(4) *Operation and Maintenance*: The Water and Maintenance Division increased in personnel and responsibilities with the expansion of the area served by the project. Training of employees and of farmers on procedures and regulations of water distribution continued. New water regulations for the project were passed by the Cabinet of Ministers. Refinement in techniques and ways of operation and maintenance continued.

East Ghor Rural Development

One of the major goals of the East Ghor project has been to make available to farmers facilities that will improve living conditions and increase productivity; also, the improvement of roads, marketing facilities, veterinary services, health centers, agricultural credit, cooperatives, and packing facilities. The following facilities are completed or are under construction and will be completed soon:

	Costs, J.Ds
(1) Agricultural Extension Buildings and Furnishings	10,714
(2) Agricultural Extension Training and Demonstration Commodities, etc.	16,775
(3) Health Center at North Shouneh and Wadi Yabis	17,500
(4) Citrus Packing Plant and Machinery at North Shonneh	45,357
(5) Vegetable Packing Plant at Wadi Yabis	22,500
(6) Grants to ACC for Loans to Farmers	55,000
(7) Farm to Market Roads	146,420

Ministry of Agriculture, Department of Agricultural Extension and Research

Farmers are still in need of advice on agricultural practices. Therefore, research and extension activities should go hand in hand with the different agricultural projects in order to maintain the development and progress of agriculture in this country.

The Incentive Payment Program: Under this project money has been allocated for development of farm units. The owner of the farm unit can receive up to one half the cost of the unit land development, providing these costs do not exceed J.D 200. As a cooperative member, the farmer is responsible for the remaining required costs.

The following table shows that the farmers benefitted from the program in the East Ghor Canal Area 1964-1966:

Purpose of Incentive Payment	No. of Units	Areas in Donums	Money spent by Farmers J.D	Incentive Payment J.D
Land Development	70	2100	10,223	6242
Alfalfa Planting	13	114	farming	228
Total	83	2224	10,223	6470

Demonstration by Extension in other parts of Jordan 1965-1966:

Type of Demonstration	No. of Farms	Areas in Donums	Length of dikes - Mts	Amount spent J.D
Topographic study	6	3250	—	—
River Flood & Erosion control	2	1950	10,000	15,00
Irrigation Plan	6	3250	—	29,00
Total	6	3250	—	44,500

The Research Department has conducted studies on cotton, rice, sunflowers, caster beans and ground nuts, providing needed information for initiating an agricultural industry. The findings have not yet been published.

Central Water Authority

(A) THE SANDSTONE PROJECT

This project was undertaken in 1965 by the government of Jordan and the Food and Agriculture Organization (FAO) of the United Nations, to determine areas where groundwater can be economically exploited for stock water, irrigation, industrial and domestic uses. It is also planned to estimate the rate of recharge and safe yield as well as to investigate the feasibility of mining the groundwater.

The project area covers about 60,000 square kilometers of East Jordan, delineated to the south and east by the Saudi Arabian border, to the north by a line through H5 and Jerash, and to the west by the escarpment of the Jordan Valley. Technical activities of the project that have been carried out are summarized below:

(1) Geological mapping and stratigraphic studies were completed this year.

(2) Geophysical Surveys are being carried out by a UN sub-contract in March, 1966.

(3) Drilling of a total of 5,375 meters in exploration, in fourteen wells, has been completed.

(4) Isotope investigations have been supplied to the International Atomic Energy Agency, Vienna, to provide data on recharge characteristics in various aquifers.

A hydrochemical analysis has been conducted by the laboratory of this authority in order to determine the quality of the produced water for irrigation use.

(5) A water balance study of the Wadi Utum groundwater in the southern desert has been started.

Preliminary results are as follows:

Southern Desert. Groundwater of high quality occurs in the Wadi Utum basin and high yielding wells can be constructed. Aquifer thicknesses are great, ranging from 200 to 900 meters, and a large quantity of water is held in storage. A water mining operation seems feasible. However, it appears that some recharge does occur. Water quality is high, ranging from 200 to 650 ppm. Pumping depths in some areas are less than 100 meters. Soil suitable for irrigation is found in the area.

Jafr Basin. Three wells have been drilled to test the sandstone aquifers in this area. At Jafr one sandstone aquifer has been shown to be under high pressure and is capable of high yields from economic pumping depths.

Northern Plateau. Eight wells have been drilled. In Baga Valley, good quality water is present in the kurnub sandstone at economic pumping depths. The drilling also has proved the presence of deep limestone aquifers under artesian pressure and containing good quality water which can be exploited.

(B) Utilization of Surface Water

It has been thought that surface runoff in the desert can be used for irrigation purposes if storage facilities are provided. Three dams were constructed for this purpose.

(1) *Sama Sadud Dam.* A rock-fill dam eight meters high with a storage capacity of 1,500,000 cubic meters of flood water, which will be used to irrigate about 3,000 donums.

(2) *Buweida Dam.* A concrete dam nine meters high with a storage capacity of 250,000 cubic meters, which will irrigate about 1,000 donums.

(3) *Sumeiya Diversion Dam.* A concrete diversion dam which was built to divert flood runoff, to irrigate about 2,000 donums without storage.

(C) Groundwater Development for Irrigation Purposes

Drilling of a total of 2,840 meters, in twenty-five irrigation wells, has been completed. The salinity contents of the produced water ranged from 205 to 832 ppm.

(D) Soil Studies and Land Protection

(1) Semi-detailed soil classification for irrigation use of about 300,000 donums of Wadi

Dhuleil area has been carried out. Five thousand donums of this area were reclassified intensively. Results showed that more than 10,000 donums of the area studied are arable and suitable for irrigation.

(2) A detailed soil classification of about 50,000 donums of Gaa El-Desi is still under investigation.

(3) Land protection: The authority carried out some controls on floods which had caused an excessive damage to about 10,000 donums of the irrigated lands in the southern Dead Sea area.

The Jordan River and Tributaries Regional Corporation

The following shows the work progress since May, 1965:

(A) *Construction.* The following construction was completed:

(1) Raising of main canal, tender* one, from station 2+072 to station 37+339 (about thirty-five kilometers).

(2) Mukheibeh Scheme, tender one, colonies at the dam site and North Shuneh.

(3) Tender Zor one (Jiftlek colony) part of the whole tender.

(B) *Tender award*: The following tenders were awarded:

(1) Tender Zor one, east canal, west canal, Zerqa Zor canal.

(2) Mukheibeh scheme, tender two, tunnel.

(3) Mukheibeh scheme, tender three, dam.

(4) Raising of main canal, tender two, from station 37+339 to station 70+085 (about thirty-three kilometers).

(5) Tender Zor two, west Zor north canal.

(C) *Tender offer*: The following tenders were offered:

(1) Mukheibeh scheme, tender seven, hydraulic steel structures.

(2) Mukheibeh scheme, tender eight, turbines, generators and cranes.

The Agricultural Credit Corporation

The Agricutural Credit Corporation issues medium and long-term loans to individuals and groups of farmers to enable them to embark on a larger number of agricultural projects and make better use of water for irrigation. Loans given to farmers are strictly supervised and paid in installments according to the progress of the work done in each project. Cost of engines, pumps and pipes are paid to selling firms, to ensure the proper use of the loan. Cost of building concrete channels, power houses, digging of cisterns and artesian wells, construction of reservoirs, etc., are paid in installments to the borrower according to the progress made and under effective supervision.

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* Tender means section or unit.

Activities of the corporation in the development of water resources during the period 1960-61 to 1964-65 are shown in the following table:

Irrigation Projects	1960-61 No. meters	1961-62 No. meters	1962-63 No. meters	1963-64 No. meters	1964-65 No. meters
Artesian wells	6	1	5	6	7
Cisterns	88	92	234	726	214
Reservoirs	16	18	29	59	0
Engines	16	26	16	49	48
Pumps	15	25	17	45	40
Pipes	4666	5754	13439	23534	26665
Concrete channels	23984	26751	28176	45335	17425
Non-concrete channels	..	3285	955	2520	1580
Spring improvements	..	..	2	..	..
Dams	..	..	1	..	..
Power houses	..	11	21	27	34

During the period 1960-61 to 1964-65 ACC issued loans amounting to 3,700,462 dinars for different agricultural projects, of which about 684,018 dinars were invested in irrigation projects. Figures are shown in the following table:

	Total Agricultural Loans	Irrigation Loans	Percentage of Irrigation loans to the total loans
Years	J.D	J.D	Percentage
1960-61	457,680.515	66,124.000	13.13
1961-62	470,196.786	83,622.000	17.78
1962-63	1,036,306.079	104,251.000	10.06
1963-64	902,807.002	275,024.987	28.47
1964-65	833,471.715	160,996.090	19.32
Total 1960-61 up to 1964-65	3,700,462.097	684,018.077	

Several village irrigation projects and group irrigation schemes have also been accomplished, during the last five years, by long-term loans. Loans issued for such purposes amounted to 29,605 dinars and have been allocated for construction of concrete channels in Jerash, Souf, Karak, Salt and Ma'an.

Farmers have responded readily to such economic activities. They are convinced that the expansion of irrigated lands, by digging artesian wells, and utilization of underground water, is an important factor in the increase of agricultural production.

NEPAL

The Kingdom of Nepal is completely land-locked. It is somewhat rectangular in shape, extending 550 miles in length along the southern slopes of the base of the Himalayan Mountains. The average width of Nepal is 100 miles and it has a total area of 54,362 square miles.

Nepal can be divided geomorphologically into four main zones:

(1) The Tarai Plain.

(2) The Bhabar or Churia Hills (also called Inner Tarai).

(3) The Mahabharat Hills.

(4) The Main Himalayan Range.

Topography

The Tarai area is between 250 and 600 feet above sea level. The estimated cultivated area in this zone is 1.75 million acres.

The Bhabar zone has an elevation of 600 to 1000 feet above sea level, and forms an almost continuous band about eight miles wide in the north-south direction and 550 miles long in the east-west direction. It is a transition zone between the Churia Hills and the Tarai belt.

To the north of Bhabar the Churia Hills rise sharply to heights between 2,000 and 4,000 feet above sea level.

The Mahabharat is the main part of the country, having a width between forty and fifty miles running along the entire length of the country up to about 15,000 feet above sea level. In this zone, there are a few plains, such as Kathmandu Valley and Pokhara Valley, having an area of about 250 square miles and seventy square miles at elevations of 4,500 feet and 3,000 feet respectively above sea level.

In the north there is a main Himalayan range of granite and limestone in parallel folds above 15,000 feet.

The following gives the approximate percentage and land pattern distribution of the country:

Table 1

Land under forest	32%
Land under perpetual snow	16%
Alpine meadows	8%
River, villages and towns	13%
Waste land reclaimable	17%
Cultivated land	14%
	100%

Climate

Though Nepal is a small country, she has almost all types of climate: tropical in the Tarai and Bhabar regions, sub-tropical and sub-alpine in the central region, and alpine climate in the mountainous region.

Water Resources

As Nepal is situated in the monsoon range and lies between the high Himalayan range with perpetual snow in the north and the Gangetic plain in the south, there is no problem of scarcity of water in this country. There are more than 6,000 rivers in Nepal. Of these, 960 are ten kilometers or more in length. Of these 960 rivers, 93.7 percent are between ten and fifty kilometers in length; 5.4 percent are between fifty and 200 kilometers, and 0.9 percent are more than 200 kilometers.

There are 119 rivers having a watershed area of more than 300 square kilometers; 39.5 percent between 300 and 500 square kilometers; 31.9 percent between 500 and 1,000 square kilometers; 22.7 percent between 1,000 and 10,000 square kilometers and 5.9 percent more than 10,000 square kilometers.

Almost the entire rainfall in the country is from the southeast monsoon and is received during the four months of June through September. The distribution of rain is not equal, and apart from the monsoon the rainfall shows variation from year to year.

In the Tarai region the average rainfall varies from sixty to 100 inches, but at the western end of the country the average rainfall is only about forty percent of that in the east. The temperature in this region varies from 40°F. to 105°F. (minimum in December and maximum in June).

In the central region, the average rainfall is forty inches in the extreme west, 100 inches in the extreme east, and fifty-five inches in Kathmandu. The climate is sub-tropical up to 6,000 feet, and sub-alpine above 6,000 feet. The temperature varies from 38°F. to 80°F.

The mountainous region includes the high border ranges and peaks with perpetual snow, from 16,000 to 29,142 feet — Mount Everest. This region has an alpine climate.

Agriculture

The lower flat land of the Tarai and Bhabar region, constituting a part of the Indo-Gangetic plain and heavy jungles, is the hottest part of the country. Here a tropical climate prevails. Although the soil varies in fertility from place to place, the land in general throughout the tropical zone is very fertile. Rice, wheat, corn, pulses, oil seeds, sugar cane, jute, tobacco, etc., are very popularly grown in these areas. In the eastern most areas, due to heavy rainfall, two paddy crops, bhadai and agahani, are cultivated between June and December. Jute is also grown in these areas between May and December. Besides, tropical fruits such as mango, litchi, guava, banana, etc., are also successfully grown in this zone.

In the central zone (Mahabarat Hills) subtropical and sub-alpine climates prevail. In spite of the steepness of the ground, it is intensively cultivated by forming bench terraces, sometimes on incredible slopes up to forty-five percent. It is estimated that only one third of this zone is in forest. Different citrus fruits, such as orange and lemon, and varieties of temperate fruits, such as peach, plum, etc., are successfully grown in this area. The main crops produced in large scale are paddy, wheat and maize. On the hillside above an elevation of 6,000 feet there is a vast scope for expanding the apple farming.

Irrigation Development

From time immemorial farmers in Nepal, working individually or in groups, have been known to make diligent efforts to bring water for irrigation by cutting open-canals from the river banks. But such efforts have great obstacles except in the case of small brooks or streams.

The first attempt at providing scientific irrigation facilities was made in the district of Saptari in 1924. The Chandra Canal extending from a dam built across the Trijuga River covers a gross area of 20,000 hectares. In about the same year, detailed survey reports were presented on the construction of the Banganga Canal in Palimajakhanda, the Jhanja Canal in Rauthat, and the Jalad Canal in Mohotari. But no action was seen taken on these projects. Development of irrigation suffered until 1946 when the Judha Canal was built in Rahutahad to tap the water of the Manusmara

River. It was estimated to cover 800 hectares of land.

A coordinated program of irrigation projects was included for the first time in the Five-Year Plan (1956-1961). The plan target was to irrigate 11,000 hectares of land. Of the projects completed within the plan period, mention may be made of Tikabhairabe Canal, Mahadukhola Canal and Bagmati Canal in Kathmandu Valley, the Fewa Dam and the Vijayapur Canal in Pokhara, the Jhang Canal in Rahutahat; the Sirsiya Canal, the Dudhaura Canal, and the Tilawa Canal in Bara Parsa, and several other projects under construction.

On the basis of the experience gained during the previous plan, a large number of major irrigation projects, along with minor projects, have been included in the plan.

The major irrigation projects completed by the Irrigation Department within the Third-Year Plan period (1962-1965) are given in the table below:

Project	District	Irrigated Area in Hectares
Tinau	Palimajakhand	14,170
Hardinath	Mahottari	1,943
Dunduwa	Banke	1,943
Judhanahar	Rahautad	2,024
Katkhu	Kathmandu	810
Goodawari	Kathmandu	810
Bagmati	Kathmandu	314
Bosan	Kathmandu	485
Chandranahar	Saptari	4,049

Minor Irrigation Projects

To provide irrigation facilities all over the country requires considerable capital, and time will be required to construct large permanent dams and big canals. Minor irrigation projects have thus been established under the Department of Agriculture during the Second Three-Year Plan. These minor projects will start helping the farmers by providing financial and technical aids to tap water for irrigation from any source available. Minor irrigation projects are those that cost less than Rs. 30,000 and provide technical and financial aid to the cultivators to operate the projects. Fifty percent of the cost of the projects is to be provided by the cultivators, in cash or labor. Repair and maintenance of the completed projects on the land to be irrigated is the responsibility of the cultivators themselves. Heavy equipment and machines and expert technicians from foreign countries are not needed to run these projects. Local available labor and materials, such as, bricks, rocks, logs, are used for these projects. Cement must be imported.

During the Three-Year Plan, the Department of Agriculture has provided financial aid amounting to Rs. 540,000 to build and operate the twenty-eight minor irrigation projects in nine zones listed in the following table:

Of the above twenty-eight projects, eight are completed. Six of the projects have not started construction work because the cultivators have been unable to raise their share of the cost. The remaining projects are under construction.

Serial No.	Project	Estimated Total Cost of project in Rupees	Amount of Aid given by HMG in Rupees	Est. Area to be irrigated in Acres
	Zone Janakpur Villages			
1	Hardia	22,744	11,372	600
2	Bela	13,747	6,373	300
3	Sahadwa	1,600	800	..
4	Mahanarwa	29,462	14,732	2,500
5	Sakhuwa	20,570	10,285	600
6	Jadukuwa	29,395	14,697	900
7	Sindhesor	29,966	14,983	90
8	Dadhi Gurase	13,954	6,977	90
	Zone Sagarmatha Villages			
9	Belha	13,747	6,373	300
10	Basantpur	6,396	3,198	400
11	Pokharia	8,548	4,274	300
	Zone Kosi Village			
12	Govindpur	29,896	14,948	800
	Zone Bagamati Villages			
13	Sunchitar	8,933	4,466	250
14	Tadaha	12,443	6,221	200
15	Kirtipur	28,030	14,015	600
16	Harasidhi	17,500	8,750	650
17	Nalinichaur	19,554	9,777	600
	Zone Narayani Villages			
18	Rampur	19,599	9,799	600
19	Gadhal	29,993	14,996	800
20	Dhrubanagar	28,500	14,250	600
21	Manpur	25,000	12,500	600
22	Bijulpur	29,999	14,999	1,000
	Zone Gandhak Village			
23	Nuwarthok	12,755	6,377	50
	Zone Lumbini Villages			
24	Baghouli	16,231	8,115	150
25	Mukundhagadha	2,096	1,048	50
26	Kunjalapur	13,605	6,802	300
	Zone Rapti Village			
27	Sulichaur	12,962	6,481	40
	Zone Bheri Village			
28	Narinapur	29,969	14,984	1,000

NOTE: U.S. $1 equals Rs. 7.75 (approx.).

PAKISTAN

Irrigation in West Pakistan has been adapted to the natural variation in river flows and it is dependent entirely upon diversions of unregulated supplies. Low river flows during winter seasons and inadequate canal capacities during the summer seasons generally limit irrigation water application to less than the requirements to sustain optimum plant growth. Insufficient water is applied to leach down the salts from the root zone, to prevent the gradual salinization of the soil. Modern irrigation practices require a supply of water in excess of the consumptive use requirements of crops, to leach the accumulating salts down below the root zone. Waters of the Indus River are of good quality, having a salt content of about 250 ppm. Even with the low salt content of the river waters, about 37,000 million pounds are added from fifty-four million acre feet (maf) of water, irrigating twenty-four million acres annually. Thus about three-fourths ton of salt is added per acre annually. Only a small percentage of the irrigated area receives sufficient irrigation water to leach down this salt.

To make up the present water deficiency and to provide future irrigation requirements, an extensive program is planned to develop both surface and groundwater resources. The proposed use of twenty-two maf of groundwater with salinity concentration up to 3000 ppm or waters with appreciable amount of residual sodium carbonate will make irrigation practices still more complex. Irrigation practices and the patterns and intensities of cropping now followed will have to be drastically modified to suit the changed conditions.

This report has been prepared with the above complexities in view.

Land Forms and Soils

Of the total area of nearly 199 million acres in West Pakistan, about forty-two million acres are under cultivation, of which thirty-two million acres are equipped with irrigation facilities, and the cultivation of another ten million acres is dependent upon natural rainfall. An additional twenty-five million acres might be brought under cultivation if irrigation water were available. Only three and a half million acres are presently classed as forest lands. Fifty million acres are considered unsuitable for agriculture, and the remaining seventy-eight and a half million acres are principally mountainous or desert.

The soil of West Pakistan can be divided into five main physiographic divisions:

The first one, and the western most, lies along the base of the Kirthar, Sulaiman and other ranges of the western mountains. This is one of the most desolate tracts, with strips of cultivation dependent on unreliable rainfall. This zone has strong potentialities for development as it has a lot of cultivable land of high inherent fertility with adequate surface drainage.

The second major division occupies the basin between the salt range and the Himalayan foothills. It has been subjected to geological erosion on a grand scale. The land-use pattern shows an equally complex mixture of dry crop land, poor grazing lands and wild-gullied waste lands. There is not much potential for agricultural development. It is regarded as one of the least promising portions of the province, mainly due to rough and eroded terrain and shallow soils.

The third division comprises the small pediment plain deposited by torrents flowing from the Himalayan foothills. The greater part of this zone is fertile, having well drained soils. It is most suited to dry farming, due to a high and reliable rainfall.

The fourth division is the Thal tract, which occupies most of the interfluve between the Indus River and the Jhelum - Chenab system. In this zone great changes have been wrought with the introduction of canal irrigation.

The fifth physiographical division comprises the scalloped interfluve of Punjab, the level plains of recent river-laid alluvium in Punjab and Sind and small isolated outcrops of similar alluvium near Peshawar and Bannu.

In general the soils of the province are alluvial, sandy loam or loam, excepting stony hills and rocks exposed to heavy soil erosion. The soils on the whole, although low in organic matter, are rich in minerals, and are very productive if exploited thoroughly under the improved agricultural and complementary practices.

Irrigated Agriculture

Irrigated agriculture is mainly confined to the Indus Plain in West Pakistan. About eighty percent of the total food production in West Pakistan comes from twenty-four million acres of land, regularly irrigated in the Indus Plain, and the balance of the production is from 4.1 million acres, irrigated outside the Indus Plain, and from other dry farmed lands. The Indus Plain is a vast alluvial plain extending from the Himalayan foothills, the Salt range and the Potwar plateau in the north to the Arabian Sea in the south; from latitude 24° - 15′ to 42° - 45′ north.

The Indus Plain can be divided conveniently into two parts: the upper and lower plain, representing the former provinces of Punjab and Bahawalpur, and Sind respectively.

The Indus Plain is a nearly flat plain traversed by five major rivers in the upper parts and by the main stream of the Indus in the lower reach. The existing canal system in the Indus Plain commands a gross area of 36.8 million acres. Of this area, 32.8 million acres are classed as cultivable commanded: 19.5 million acres in the northern zone and 13.3 million acres in the southern zone. Some 21.4 million acres are sanctioned for perennial water supply, while the remaining 11.4 million acres are to be irrigated during the high flow season only.

Although the surface of alluvium looks perfectly flat and monotonous from one end of the Indus Plain to the other, yet careful observation will reveal that for irrigated agriculture the plain is neither perfectly flat nor uniform. The main physical problems of this tract, however, are deficient river flow during winter, severe surface salinity and poor internal drainage. About 17.2 million acres of irrigated or potentially irrigable lands are adversely affected by salinity and inadequate drainage, and each year about 100,000 acres are lost from useful production. With proper irrigation practices, drainage, and the use of fertilizers, the lands can be as productive as fertile lands in other countries.

Water Resources

The principal water resources of West Pakistan include direct rainfall on the agricultural land, surface river waters and the groundwater in the aquifer. Due to insufficient rainfall, almost desert conditions exist in most of the Indus Plain. The average rainfall is three to fifteen inches, except in the northeast, near the foothills. According to precipitation data, 66.7 percent of the whole area receives rainfall from zero to ten inches, 24.2 percent between ten and twenty inches; 5.4 percent between twenty and thirty inches, and only

3.7 percent more than thirty inches, annually. If rainfall were the only source of water, ninety-six percent of the total area of West Pakistan would be barren or sparsely vegetated.

Surface River Waters

The Indus River system is by far the most important hydraulic basin in Pakistan. The total catchment area of the basin is nearly 350,000 square miles, of which about 200,000 square miles are in Pakistan. The mean annual discharge of the system is about 164.5 million acre-feet.

The Indus River brings into the valley an average of eighty-seven maf of water per year, and another eighty maf are added by its tributaries, namely the Jhelum, the Chenab, the Pavi, the Beas, and the Sutlej. One hundred and thirty-five million acre feet is the annual flow of the three western rivers, i.e., the Indus, the Jhelum and the Chenab, which would be available for use in West Pakistan according to the recent water treaty. Of this total, eighty-three maf are in use and twenty-four maf will be used to feed the canals, and replace the water which is being withdrawn by India. After taking into account the losses, the water that will flow to the sea will be twenty-nine maf, compared to ninety-nine million acre feet going to the sea previously.

Diversions of the river flow for irrigation use, as stated above, now average eighty-three maf: about fifty-two maf in the high flow season and thirty-one maf in the low flow season. These diversions are generally limited by the operating capacity of the canal systems and in the low flow season by the available water supply.

Present aggregate operating capacity of canals of forty-three principal canal systems is 248,650 cusecs, and their total length measures to 38,000 miles. Construction of about 390 miles of link canals is in progress. These link canals will transfer water from the western rivers to replace the diversions by India.

The existing canals are almost all unlined. Conveyance losses amount to about 35 percent, from the head works to the farms. The net farm deliveries at the outlet heads are, therefore, of the order of fifty-four maf. After taking into consideration further surface and percolation losses in the farm water courses, the net crop use is estimated to be forty-one maf. Farm deliveries of surface water in the northern zone are estimated to average 2.2 acre feet per cropped acre during Kharif (May to September) and 1.6 acre feet per acre during October to April, compared to the optimum requirements of 2.7 and 2.4 acre feet in the respective seasons. In the Indus Plain the lands are generally under-irrigated. To make up the present water deficiencies and to meet future requirements, a substantial development program for the exploitation of the surface and groundwater resources is being pursued vigorously. It is estimated that about twenty-six maf of farm deliveries will be needed by 1975, over and above the present farm deliveries of fifty-four maf. To develop the twenty-six maf of water, it has been suggested to tap surface resources for four maf and groundwater resources for 22 maf of water. The increased surface supplies will encompass the surface water storage reservoirs, remodeling of existing canals, and elimination of seepage losses. Useful storage, totaling about twenty-one million acre feet, will be provided with two major dams: Mangla on the Jhelum River and Tarbela on the Indus River. Several other storage reservoirs of smaller capacity will also be built.

The Mangla Dam, now under construction, will provide useful storage of 7.70 maf, of which 4.75 maf will be provided in the initial project, to be completed in 1968, under the Indus Basin Project. Tarbela Dam, which is also a part of the Indus Basin Project, will create a reservoir with a useful storage capacity of 9.30 maf, of which 6.60 maf will be provided in the initial construction, under the Indus Basin Project, which is scheduled to be completed in 1973.

Other smaller reservoirs with an estimated storage capacity of four maf will be located in the valleys of the tributaries of the major rivers. Investigations and construction work for such dams are the responsibility of the West Pakistan Water and Power Development Authority.

S.No.	Dams	Storage Capacity	Area to be Irrigated Annually
	Completed		
(1)	Misriote Dam	560 acre feet	500 acres
(2)	Tanaza Dam	(33.15 feet in height in 0.6 square miles calculated areas)	80 acres and drinking water to a cattle farm
(3)	Sipiala Dam	568 acre feet	525 acres
(4)	Miana Ziarat	....	600 acres
(5)	Gurabh Dam	679.4 acre feet	....
	Under Construction		
(6)	Kahl Dam	....	4000 acres and 70 acres of demons: Fruit Orchard Fish Culture
(7)	Mang Dam	....	1000 acres
(8)	Chichali Dam	....	5200 acres
(9)	Bango Dam	....	85 acres

Small Dams

Small Dams Organization, under the Agriculture Development Corporation, is responsible for construction of small dams in dry and hilly tracts, for checking soil erosion and providing irrigation facilities to the rain-fed areas. The ultimate aim of this organization is to construct 500 small dams in hilly tracts of West Pakistan. Five of the nine dams under recent construction have been completed. See table above.

Control of Seepage Losses

The control of seepage losses from the big canals would necessitate lining the canals, which is a very expensive proposition. Checking of seepage losses from the farm ditches can be done without much expense. There are about 60,000 irrigation outlets which deliver water to the farm lands. Losses from the farm ditches are estimated to be about 25,000 cusecs, on the basis of ten percent losses of the diversion deliveries at the farm outlet head. Even with the reduction of losses from ten to five percent there will be a saving of 12,500 cusecs, which can be utilized to meet the existing deficiencies. From the national water conservation point of view, and particularly to meet the demand of a fast growing population, this is a matter of vital importance. Field studies are in progress to evaluate the extent of the seepage losses, the reaches of higher percolations, and possible methods for the prevention of seepage losses.

Groundwater Resources

Irrigation requirements during the high flow season in excess of canal diversion capacities might be met by groundwater pumpage. This development program is being very carefully examined in the light of physical data, collected by various investigating agencies, related to the groundwater and soil characteristics throughout the Indus Basin Plain.

According to studies by the Water and Power Development Authority-cum-Pakistan engineers and United States experts, there exists 1900 maf of stored water in the upper Indus Plain to a depth of 450 feet, on the basis of twenty-five percent storage coefficient. With ultimate development the average annual groundwater pumping could be an estimated 49.5 maf. This will constitute twenty maf of seepage recharge and 29.5 maf to be mined from the reservoir; 24.4 maf from good quality groundwater zone and 5.1 maf from bad quality groundwater zone. In view of recent tests, these estimates of under-ground storage water are not considered very accurate, because the storage coefficient comes to only twelve to fourteen percent, compared to twenty-five percent assumed in the calculations.

The salinity concentrations of the usable water vary from a low acceptable value of 500 ppm in the northern zone to an intolerable high concentration of 30,000 ppm in some areas of Sind. It has been suggested to use the groundwater containing salts up to 3,000 ppm. Waters with a concentration of 2000 to 3000 ppm are to be used by mixing with canal water. Some twenty-seven million acres, or about eighty percent of the northern zone, have groundwater of salinity concentration of less than 3000 ppm. The presence of carbonate and bicarbonate contents in the groundwater was not taken into account in evaluating the usable quantities of water.

The use of groundwater will therefore require special consideration in the designs of the canal and tubewell systems for the distribution of surface water and the operation of canals and tubewells. If use of the groundwater, whether alone or mixed with the canal water, is not done scientifically under experts' control the salinity and alkalinity problems might be aggravated.

Tubewell Installation and Operation

At present the task of tubewell installation and operation is done both by the government and privately by cultivators, individually or collectively. In the public sectors, the tubewells are installed and operated by the Irrigation Department mostly in riverine areas of sweet water zone. In the salinity control projects the installation is done by WAPDA and the operation is taken care of by the Land and Water Management Board, a new organization created on the recommendation of the U.S. panel. So far, 3500 tubewells have been installed in the public sector and about 30,000 in the private sector. The large number of installations of tubewells by the cultivators indicates tremendous progress, in contrast to the program of suggested installation of 34,000 government tubewells in a period of ten to twenty-five years. With such a high rate of installation of tubewells in the private sector, it is expected that the number of private tubewells will reach 60,000 in the next three or four years. Now it is very seriously questioned whether there is any more need of installation of tubewells by the government and of spending huge sums on operation and management. Under the changed situation, it may now be quite appropriate for the government to undertake the completion of only those works which are not within the means or scope of the private sector. For instance:

(1) Marking boundaries of sweet water and brackish water zones.

(2) Power installation for the supply of electricity for running tubewells.

(3) Technical guidance and provision of other facilities in the installation of tubewells for cultivators, although the cost of the material and labor, etc., is to be borne by the cultivators.

(4) In the brackish water zone, the government may make arrangements for the subsidiary drains, while the construction of field and collector drains, to empty in subsidiary drains, will be the responsibility of the cultivators.

Soil Survey

There are various organizations engaged in soil survey work for specific purposes. The survey work for soil classification in irrigation projects is carried out by the Irrigation Department staff in the Directorate of Land Reclamation, from the point of view of irrigation, drainage and reclamation. The first regional reconnaissance of the Indus Basin under the Colombo Plan Administration, financed by the Canadian Government, was started in 1954. Simultaneously a semi-detailed soil survey was initiated for the irrigated areas of Upper Indus Plains, under a cooperative program with the United States ICA (now AID). The United Nations Soil Survey Organization is engaged in a reconnaissance survey of the whole of Pakistan. The Agricultural Department carries out surveys in the rain-fed areas from the point of view of soil and moisture conservation and watershed control. The progress of survey work during recent years is as follows:

Name of Agency	Name of Project/Scheme	Area Surveyed
Directorate of Land Reclamation Irrigation and Power Department	(1) Annual salinity survey (Thur Girdawari) for 1964-65	37.7 million acres
	(2) Reconnaissance soil survey of Right Bank Canal Area (Kuram Garhi New Irrigation Project)	150,000 acres
	(3) Soil Survey of Setharki minor Project (District Nawabshah) for Land Classification	50,000 acres
	(4) Soil survey of Taunsa Project Area for extension of irrigation in the new areas	1,331,615 acres
	(5) Soil surveys in small estates, viz. Kalri Open Jail Farm (Thatta District), Syadanwala (Lahore District), Tariq Estate (Lahore District), Manga (Lahore District). Baisat Khel (Bannu District) for assessing productivity and recommending remedial measures	5,106 acres
	(6) Soil survey of Bara River Canals area near Peshawar (New Irrigation Project)	60,000 acres
	(7) Quality-of-water survey of Kalri Lake, to assess its suitability for irrigation	50 square miles
U.N. Soil Survey Organization	(8) UN soil survey	24,467 square miles
Soil Survey Organizations of WAPDA	(9) Soil surveys in the northern area	27.76 million acres
	(10) Salinity soil survey in the southern part of Indus	7.55 million acres
	(11) Water quality surveys for the evaluation of useable groundwater resources in the northern zone.	33.0 million acres
Agriculture Department (Forest)	(12) Land use survey of the Indus watershed	34,625.66 square miles
Soil Conservation Organization	(13) Area surveyed to protect the land from erosion	318,073 acres
	(14) Area covered for engineering works for protection against soil erosion	59,242 acres

Program and Progress of Land Development

In new projects and also in quite a large number of holdings in already developed projects, there is undeveloped land which could be developed. The main problem of such lands is proper leveling. This cannot be done in a reasonable time with the present under-fed bullocks and old implements. This aspect has been given thorough consideration and facilities are now afforded by the government through advancing loans for the purchase of tractors and also undertaking this task through government agencies. At present the Agricultural Department maintains 114 tractors and 290 bulldozers. The number of private tractors is about 8000.

In addition the Agricultural Development Corporation has undertaken this task in various development projects and the details of bulldozers engaged in land leveling are given below:

Name of Project	Number of Bulldozers	Area Developed (Thousand Acres)	Area to be Developed (Thousand Acres)
Ghulam Muhammad Barrage	198	208	292
Guddu Barrage	140	18.3	357.7
Soan Valley	125	53.5	2446.5
TDA	250	240.3	609.7
TOTAL	713		

Progress of Land Reclamation

About 2000 to 3000 cusecs of river flood supply are utilized in summer for the reclamation of saline lands in an area of 125,000 to 135,000 acres, annually. The water allowance in this case is one cusec for forty-five acres. This supply is sufficient to meet the consumptive use of crops and also for leaching the salts from the soil profile. In the process of reclamation, rice or Sesbania Aculeata is cultivated during the summer and during the winter leguminous crops such as gram or lentil are grown utilizing reserve soil moisture. Where the winter water supply is available, such crops as berseem and shaftal (clovers) are also raised. This process is repeated for three or four years to completely reclaim the land. The total area reclaimed so far comes to 584,270 acres. Government support for the arrangements of additional supplies is a big relief to the cultivators.

For the prevention of salinity a permanent increase in the existing water allowance is necessary. To meet the consumptive use requirements of increasing crop intensities and for leaching requirements, the higher water allowance at one cusec for 150 acres would be needed compared to one cusec for 350 acres at present. This increased water supply is to be provided from surface and groundwater resources. Special reclamation projects are planned to deal with irrigation and drainage problems.

The first one is Rechna Reclamation Project, now called SCARP I (Salinity Control and Reclamation Project) which covers about 1.2 million acres. The number of tubewells installed in this scheme is 2043, with a capital cost of Rs. 102.6 millions, excluding the cost of transmission lines. Operational cost of the entire project during the last four years is given below:

September 1961 to September 1962.
Rs. 7.5 millions

October 1962 to September 1963.
Rs. 14.97 millions

October 1963 to September 1964.
Rs. 24.83 millions

October 1964 to September 1965.
Rs. 28.00 millions

Yearly pumpage figures in million acre feet with percentage utilization are given below:

Year	Pumpage in maf	Percentage Utilization
1961-62	1.78	62.60
1962-63	2.80	89.15
1963-64	2.48	60.32
1964-65	2.48	60.15

Decline of water table as compared to initial tested static water level is as follows:

1961-62	5'9"	Note: Initial water table varies from 6'11" to 13'4"
1962-63	6'9"	
1963-64	7'8"	
1964-65	8'3"	

Of a total area of 424,717 acres wholly or partially out of cultivation in SCARP I, an area of 248,900 acres is reported to have been reclaimed by the end of September, 1965. The overall average increase in the yield is 29.42 percent for rice, 37.6 percent for cotton, 42.7 percent for sugarcane, 15.72 percent for maize, 61.05 percent for wheat, 23.8 percent for barley and 6.55 percent for gram.

Similarly, two other projects, viz. SCARP II in an area of 2.2 million acres in Chaj Doab and SCARP III in 1.28 million acres in lower Thal Doab, have been formulated on lines identical to those of SCARP I. These projects have not yet been implemented.

Allocation of Funds in the Third Five-Year Plan

In the Third Five-Year Plan, the total outlay for various water and power schemes, operated by several agencies, is 4403.2 million rupees. Of this, 518.6 million rupees are for the Irrigation Department, 3670.9 million rupees for the Water and Power Development Authority, and 213.7 million rupees for the Agricultural Development Corporation.

Extension Service

In view of the great need to motivate the farmer to adopt modern scientific irrigation and agricultural practices and to have him follow the proper land and water use techniques, an efficient and regular Extension Service is required. Such needs for the present are being fulfilled through the Extension Service of the Agricultural Department and such other organizations as the revenue and land reclamation field staff of the Irrigation Department. In the Agricultural Department a team of agricultural graduates, consisting of 522 agricultural assistants, forty extra assistant directors of agriculture and eleven deputy directors of agriculture, is engaged in this work. About 3010 field assistants with minimum educational qualifications of matriculation and a two-year special course in agriculture are also on the staff of the Agricultural Department Extension Service.

The field staff in the Irrigation Department works on the distribution of water supplies and the assessment of the cropped area. This service includes nine land reclamation officers, twenty-six assistant land reclamation officers, forty-eight deputy collectors, sixty-two reclamation supervisors, 437 Canal *zilledars* and 4424 *patwaris* and *abdars*. Similarly, the field staff of the Cooperative Department and Revenue Department can be used for extension work. All these field workers are not well acquainted with the knowledge of soil-water-plant relationship and irrigation principles and practices. Yet, these organizations can be used to disseminate the knowledge to the farmers after proper training through special courses. Irrigation courses have already been introduced in the graduate schools in both the engineering and agricultural universities.

In view of the importance of the problems of irrigation agriculture, it is necessary to establish a special wing in the Directorate of Land Reclamation of the Irrigation Department of West Pakistan to conduct the training courses for all organizations. These courses should be of short duration and run the year round. Special, well trained, qualified staff should be employed for this task. The services of foreigners who are specialists in different subjects relating to irrigation agriculture may also be utilized.

Land Reclamation Research

Research has continued on the subjects enumerated in the Report of the 1962 NESA Seminar. To these subjects new problems have been added, and the program of research now in progress entails basic and applied research on soil and water problems for proper maintenance of salt balance in the use of irrigation water of different qualities on soil having varying physico-chemical characteristics, with special reference to the depth of water table and soil drainability.

These studies cover a wide range of soil and water problems connected with basic research on soil chemistry; on principles underlying irrigation, soil and plant relationship; movement of water and salts under saturated and unsaturated conditions; physical behavior of soil-water systems; soil moisture and infiltration studies; soil moisture energy concepts; relation of soil moisture to growth; influence of salinity and drainage on irrigation and soil management; physico-chemical reaction involved in aggregation and structure formation; physico-chemical properties of soil in relation to plant growth; occurrence and availability of plant nutrients; soil moisture characteristics; drainage investigating techniques; hydraulic conductivity, and layout of farm drainage systems.

Other projects include basic research on the quality of water and its improvement; different constituents in water and their effect on physico-chemical properties of soils and crop growth; investigations on analytical technique and interpretation of results, and groundwater testing work for various schemes and projects. Applied research has also been undertaken on soil chemistry, which includes chemical and biological properties of soil, soil moisture, effect of management practices on soil properties. Investigations are also being conducted on deterioration of irrigated lands, their causes, reclamation and improvement; management of saline and alkali soils and the use of amendments. Research is being done on methods of determining chemical properties of soil and plant material and techniques for appraising improvement in soil. Other work includes soil surveys, soil characteristics and land classification, determination of consumptive use of water by crops, and scheduling irrigation for maximum efficiency.

Some of the outstanding achievements in the field of research are:

(1) Fixation of standards of deteriorated and reclaimed soil on the basis of total salt contents and alkalinity (pH value of soil).

(2) Classification of soils into alkaline (bara, bari), saline (thur) and waterlogged (sem).

(3) Soil and land classification standards.

(4) Fixation of an index to determine the suitability of water for irrigation.

(5) Techniques in the reclamation of saline alkali soil, both by chemical and biological methods.

(6) Development of suitable farm drainage systems in high water table areas and for different types of soils.

As a result of long and continuous research work, the following basic and important conclusions have been drawn for future planning work:

(1) The existing water allowance for irrigated lands in the Indus Plain is not adequate to meet the consumptive use and moisture requirements of crops.

(2) The problem of soil salinity has resulted from low water delta use for irrigation and improper leveling, and the unscientific use of the available water supplies.

(3) To keep the soil free of excess salts and to maintain the permanency of irrigated agriculture, it is necessary that about ten to twenty percent of water over and above the consumptive use requirements be provided for soil leaching requirements.

(4) The existing water delta of two to three feet, which is used at present, should be increased about 100 percent for sustained agriculture and for keeping the soil free from harmful salts.

(5) For proper crop production, equal attention should be given to efficient drainage systems and the subsoil water must be maintained below the root zone depth of the crops.

Concluding Remarks

During the past few years the farmers of West Pakistan have demonstrated initiative and willingness to adopt modern irrigation and agricultural practices. This is indicated by the rapid spread of private tubewells — about 6500 a year — and the increased use of chemical fertilizers. If ample irrigation supplies are available at the time of need, the intensity of cropping can be raised by 200 to 250 percent. In some villages the farmers — owners of small holdings — have individually installed their own tubewells to enable irrigation of their crops at the time they need irrigating. As many as fifty-four tubewells are known to have been installed in one village of about 1300 canal-irrigated acres. Cultivation in that village is mostly confined to potatoes and tobacco under scientific irrigation practices. The availability of water to the cultivator at the time of need is well served by privately owned tubewells. Private tubewells can easily be adapted to day-by-day changes in the local requirements for irrigation water. This is the main reason for the rapid spread of private tubewells. The total number at present is about 30,000.

The supply of government water from canal or canal-cum-government operated tubewells is less reliable than that of water provided by a locally owned tubewell. The water delivery is also after a fixed interval, and the farmers have to adapt to the cultivation of those crops which can stand that long an interval between irrigations. Farmers should be given guidance in the choice of crops for cultivation. Suitable cropping patterns and irrigation practices should be suggested on the basis of water deliveries, consumptive use of crops and leaching requirements of soil. For this there is an immediate and great need for expansion of research and extension activities. This is all the more necessary when the use of inferior quality groundwater is increasing.

SAUDI ARABIA

Agricultural areas in Saudi Arabia are divided as they depend on ground or rain water.

The Western and Southern Areas

Agricultural work in these areas consists of single small holdings from a few donums to hundreds, scattered over the region. Except for some valleys the agricultural area is small. The depth to irrigation water is from 800 to 1,500 feet. Percentage of salts in the soil is 800 p.p.m.

Generally, this land has a poor water supply. Therefore the Ministry of Agriculture has built irrigation facilities.

Wadi Jizan Dam is the first one which the government constructed. Its capacity is forty-five million cubic meters, irrigating 150 donums besides the present planted area, which is about twenty donums. Other projects are the Abha Dam, costing six and a half million riyals, with a capacity of ten million cubic meters, the Akrama Dam in Taif, and the Anania, Ouyeyna, Bathan, Mashjer and Sibya dams.

Middle and Northern Areas

These areas depend on rain, as the groundwater supply is too deep, about 1500 to 3000 feet. The percentage of salt in the water is 1200 p.p.m. Therefore crop production is affected by drought.

The government is making a special effort to study the groundwater in these two areas, and has signed contracts with two companies for making these studies.

The Eastern Province

This area has available groundwater which can be supplied from a depth of 250 to 450 feet.

The Eastern Province is divided into two agricultural units, one being an important area of rice production which has disappeared slowly due to importing of rice from abroad. Rice production here is being replaced with date production, plus some vegetables and alfalfa.

At present the Ministry of Agriculture, having concern for these two areas, is stressing the importance of animal and plant production.

In Alhasa there are two companies entitled to drill sixty wells in remote areas. Moreover, construction of a net of drainage and irrigation canals and ditches is being studied.

In Qatif, the government constructed four main drainage units forty km long in the Qatif oasis. Results are being studied. Studies have also been made for construction of a net of irrigation canals and ditches to distribute the water. Work will be started in 1967.

A pilot experimental farm and agricultural center project was established to be undertaken by the Food and Agriculture Organization of the United Nations. A summary of the purpose of this pilot project follows:

Description of the Qatif Area

Qatif is one of the great oases in the Eastern Province of Saudi Arabia. Situated on the Arabian Gulf, the date gardens are about six miles long from north to south. The southern tip of the oasis is some ten miles north of Dhahran. At its widest point, it is approximately three miles from sand to sea.

It is estimated that there are about 4000 farms in the 10,000-acre area. The population of the oasis, which totals about 75,000 people, is centered around the town of Qatif.

The topography is quite flat, with elevations ranging from twenty-eight to forty feet on the western side to just a few feet above sea level on the east.

Although the irrigation water contains a relatively high salt content (2300 p.p.m.), where the water is available and drainage is possible, salt accumulation has been kept sufficiently low so as not to greatly retard crop production.

In years past, much of the water in the Qatif oasis was supplied by an irrigation system, parts of which were constructed perhaps 1000 years ago. Hand-dug wells tapped a relatively shallow aquifer, some fifty to 100 feet below the ground surface. In many instances, the pressure was sufficient to create a flow at the surface. Where the artesian pressure was not great enough, tunnels were built at a slight downhill grade which lead water to areas that could be irrigated by free flowing water from the wells. Parts of this type of system are still in evidence.

In summary, then, the Qatif oasis is simultaneously suffering from the diametrically opposite maladies of too much and not enough water. In addition, water keeps pouring out of the ground in a steady, apparently endless stream at a rate that is more than sufficient for the entire oasis. Only a complete revision of the irrigation system and the adoption of efficient irrigation practices can reverse the trend of declining agriculture in the area. While parts of the area can maintain a successful type of agriculture, a large percentage is not receiving sufficient water to do so.

Water Supply

There are approximately 175 drilled irrigation wells in the Qatif area. Although some of the hand-dug wells ('ains) are still functioning, they produce only a small percentage of the total water supply.

A much more serious objection to these wells is the fact that most of them are improperly cased and cemented. A correctly drilled artesian well should not allow any leakage around the outside of the casing. This is exactly what does occur in most of these wells. What is more to the point is that they would leak even more if the valves were closed so that water could not flow out the discharge pipe. Since the wells are neither cased down to the aquifer nor properly cemented, artesian pressure would force water out from the drill hole into the upper strata and thus contribute to a high water table. Under certain conditions, this artesian water table could block internal drainage and eventually cause salinization of the land.

A leakage of only ten percent of the total flow of the drilled wells is sufficient to raise the water table more than two feet per year over the entire oasis. This, coupled with the fact that water is constantly flowing from the wells, has made deep drains an absolute necessity.

Irrigation Plan for Qatif Oasis

The basic irrigation plan proposed for the Qatif oasis is of the community type. The area is divided into four main units, with a total of twenty-eight sub-units. Topography, main drainage canals, roads and estimated discharge per well were the principal factors used to partition the area into sub-units, ranging in size from about 100 to 500 acres.

Each sub-unit has its own water supply, canals, laterals and drains and could operate indeenpdently from the other units. Depending on the size of the unit, one or more pumped wells, supplemented by water pumped from 'ains, would supply water under controlled conditions to the various farms by means of irrigation canals and laterals.

The work to implement the recommended plan of action includes four phases:

(1) Water supply development.
(2) Main irrigation canals and structures.
(3) Irrigation laterals and secondary drains.
(4) Sealing unused wells.

First Phase — Water Supply Development

The primary source of water for each irrigation unit should be at least one large capacity irrigation well which can be supplemented by water from the existing 'ains.

In all cases, these water sources will have to be pumped. If free-flowing wells were to be employed rather than pumped wells, the total number of wells would be increased some four to five times and perhaps more. Also, in the western sections of the oasis, the piezometric heads of the Alat and Khobar aquifers are both below the elevation of the area to be irrigated. Thus, wells in this area that tap these aquifers will not flow. In addition, since the piezometric head is dropping at the rate of about 0.7 foot per year, in time all wells tapping the above aquifers will have to be pumped.

Although it is strongly recommended that most of the privately owned drilled wells used for irrigation be "killed," a few of them could be used to supplement the water flowing in irrigation laterals. Also, on the extremities of the proposed project, these wells should remain intact as they will be the only source of water. At present, it does not appear feasible to construct additional facilities for these areas.

Estimates have been made concerning yield-drawdown relationships and minimum well spacing. These estimates appear reasonable but may not be sufficiently accurate to determine exactly the number and location of the wells and size of the pump and power units. In discussing this phase of the project with the Aramco Hydrologist, Mr. R. L. Painter, the following criteria were established as a basis for estimating the number and spacing of wells:

Maximum capacity per well — 2000 GPM (4.5 CFS).

Minimum spacing between wells — 1,000 feet.

Approximate specific yield — twenty-five GPM per foot of drawdown.

The wells, then, were located on the basis of surface conditions (topography) and the above criteria. Information from the first wells would determine whether these criteria are realistic.

Second Phase — Main Irrigation Canals and Structures

The main distribution system shall consist of lined irrigation canals and appurtenant water control structures.

As mentioned earlier, each irrigation unit will have its own water supply and distribution system. Since the irrigation units vary in size, the canal sizes will vary accordingly. Canal carrying capacities shall be governed by the grade and the depth.

A 1¼:1 (horizontal to vertical) side slope was chosen to eliminate the need for using forms when the canal lining is to be installed, and to offset the general problem of slope instability. A one-foot bottom width was all that was needed for the carrying capacities involved.

To avoid hydraulically unstable zones, canal grades were kept at or below 0.002. A minimum grade of 0.0003 was selected. Canal depths of two, two and a half, and three feet were chosen to meet the varying needs of the different canal sections.

The type of lining recommended for these relatively small irrigation canals is three-inch, nonreinforced screeded concrete.

Third Phase — Irrigation Laterals and Lateral Drains

This phase deals with the installation of irrigation laterals including water control structures and lateral drains. Hence, it is primarily earthwork. Irrigation laterals will get their water through lateral turnouts in the main canals and in turn will deliver water to the farms.

Practically all the irrigation laterals have been located on farm boundaries where ditches of one type or another now exist. Thus, in many instances all that will be needed is cleaning out and reshaping these ditches to conform to the specifications.

Under existing conditions and knowledge, lining the irrigation laterals does not appear to be justified. There is another reason for not doing so at the present time. It is not known for certain that these laterals are so located that they serve all of the farms in the area. Inasmuch as the farms are quite small, it is very likely that some of them were overlooked. Thus, as water is delivered to the farms through canals and laterals, adjustments in the location of a few of the laterals are very likely. Ideally, the irrigation laterals should be lined with clay material whenever they occur in sandy soils.

With the exception of the drops the types of structures required in the irrigation laterals are relatively simple. These include farm turnouts and division boxes. The need for drop structures will be relatively light as the slopes for the most part are flat enough to prevent scouring.

The required capacities were based on acreage served and length of lateral. Seepage and evaporation losses were estimated to be directly related to lateral length.

The secondary drains, like the irrigation laterals, have been located on farm boundaries and start at the point where the laterals terminate. Thus, if for any reason more water is diverted into the laterals than is taken out, the drains can safely carry away this extra water without causing any flooding.

Since the main purpose of these drains is to help control groundwater, they should be relatively deep, at least five feet. Therefore, water, picked up by these drains will contain a fairly high concentration of salts, which will preclude its re-use.

In the future, there will probably be areas that will require additional drainage. These secondary drains can then be extended either parallel to the existing irrigation laterals or along new routes.

The depth of these lateral drains will depend on water surface elevations at their outlet into the main drainage canals and upon topography.

The government has constructed four main drainage units in all the Qatif area. The length of the units is approximately forty km. and benefits are already apparent.

Qatif Experimental Farm

This is a Pilot Experimental Farm and Agricultural Center project undertaken by the Food and Agriculture Organization of the United Nations, acting as the Executive Agency for the United Nations Special Fund.

Purpose of the Project

The purpose of the project is to establish a pilot experimental farm on irrigated land in the Qatif area in the Eastern Province for the improvement of technical methods in crop production and animal production. It is to give due attention to irrigation and drainage problems and also to non-technical problems related to the development of agricultural production. The emphasis will be on the adaptation of knowledge and experience gained elsewhere to the local condition of the project area. Special attention will be given to high-value crops, vegetables and fruits which may be grown in association with the traditional date palm.

It is expected that the results obtained will greatly contribute to the practical improvement of the existing agriculture in the Qatif area and in similar areas in the Eastern Province. The farm

U.N.S.F. PROJECT QATIF EXPERIMENTAL FARM
NUMBERS OF THE FIELDS.
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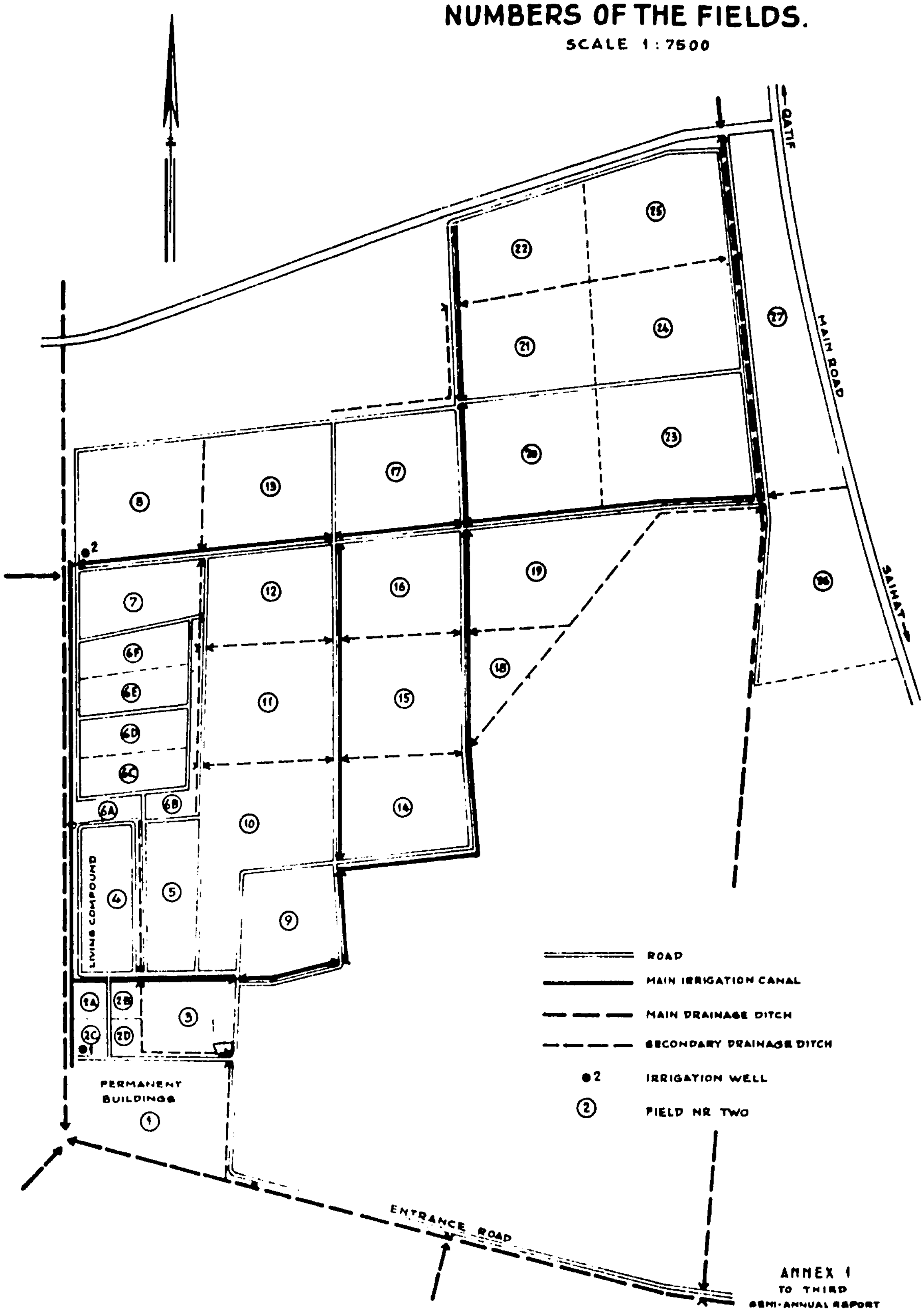

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also functions as a training center for Saudi agricultural technicians in the field matters covered by the Center activities.

Description of the Project

The pilot experimental farm was established on a tract of land of about eighty hectares in the Qatif oasis where a permanent supply of adequate water of good quality and good land were made available. A drainage program is being executed in the Oatif oasis by the government.

The present project was located in unit one under that program, with a direct outlet to a main drainage ditch. Donation of the land with an unquestionable title in the government's name, a sufficient and permanent water supply from wells, including drilling, oasis and pumping installations as required, construction work in respect to land development on the eighty hectares, including irrigation canals and secondary and lateral drains, land leveling, access roads, the planting of a permanent windbreak system where needed and construction of buildings including a barn for seed and farm products.

The project will have a duration of five years. With a view to the severe saline condition of the soils of the area, the first phase will be devoted principally to land development and reclamation, and the second phase will be devoted to experimental, demonstration and training work.

The Quality of the Irrigation Water

This factor, although not of a pedological nature is mentioned first deliberately, as the prevailing conditions necessitate the use of irrigation water of a rather poor quality and it is this factor which determines the type of soil suitable for irrigated agriculture.

The analytical data available on the water, that is expected to be used for irrigation in the area concerned, reveal the following information:

Most of the wells supply water with 1800 to 2500 p.p.m. total salts which, calculated in EC-values, would mean 2800 to 4000 micromhos. According to the classification standards as given in "Agriculture Handbook nr 60" of the U.S. Department of Agriculture, this water is of class C.4, which means: "Very high salinity, water is not suitable under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected."

Literature on the North African irrigation areas (Durand) points in the same direction. The conception of "well permeable soils" is, however, somewhat more specified here as it is stated that a well permeable soil should be sandy in order to restrict as much as possible the increase in salt concentration in the water between the time of application of irrigation water and the moment the excess water is leaving the root zone as drainage water.

In connection with the sodium hazard the cation composition of the irrigation water, as well as the total salt content, is of importance.

An analysis available on the nearest well (Aramco) shows the following figures in milliequivalents per liter.

Na	344 p.p.m. = approx.	15
Ca	195 p.p.m. = approx.	10
Mg	76 p.p.m. = approx.	6.5
SO4	451 p.p.m. = approx.	10
Cl	625 p.p.m. = approx.	18
HCO3	195 p.p.m. = approx.	3.2

Total 1886 p.p.m. = approx. EC 2900 micromhos
Sodium-Adsorption-Ratio (SAR) = approx. 6.

This would mean a sodium hazard of S2 (medium sodium water). Handbook 60 gives the following statement in this regard: "Medium sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil.

This water may be used on coarse-textured organic soils with good permeability."

Thus it may be concluded that to arrive at satisfactory agricultural results the soils selected should comply as much as possible with the following: sandy textured, permeability good; and drainage sufficiently deep and easily controlled.

It may be stated here that the "practical feeling" of the local farmers has more or less shown them the way to these requirements. Drainage is effected by raising the level of the soil in ridges. By bringing in non-saline desert sand from outside the oasis to form these ridges it is possible to obtain sandy soils with good permeability. This procedure, which is the only way to counteract salinization without investing a lot of money, has been developed over the generations by farmers.

Finally, attention may be drawn to the fact that an appreciable amount of the total salt content is gypsum. This fact considerably improves the otherwise rather dismal outlook and gives hope that reclamation is possible.

The Soil Profile

The parent materials of the soils show a great variety, resulting in rather large differences in the soil profile. Influencing phenomena are: limestone and marl formations and their erosion products, aeolian desert sand, tidal sediments of the Arabian Gulf and finally, desert sand hauled in by mule or truck. The prevailing hydrological conditions have led to a very strong salinization, with extremely puffed solonchaks in many places.

The most important aspect of the soil profile in the area investigated is the occurrence of a calcareous hardpan, a cemented, hardened and less permeable layer. Generally this layer is found at a depth of fifty to seventy cm below surface. In most cases the thickness of this layer is forty to fifty cm, although layers of eighty to 100 cm are no exception.

The consequences of the occurrence of this calcareous hardpan are:

(1) The root development of the crops is seriously hampered.

(2) Due to its impermeability, drainage of the profile is to a great extent limited.

The texture of the material overlying the calcareous hardpan is sand to silty clayloam, with all possible transitions in between.

In general, somewhat sandier soils are found in the middle of the area.

The parent material below the calcareous hardpan varies greatly. However, coarse textured soils prevail.

The more clayey layers are often of a weak, unripe nature, which indicates that a certain subsidence of the surface due to shrinkage will occur when they are drained in the future, resulting in additional drainage problems.

The Soil Salinity

From the observations made during the field survey it could be established that the soils are strongly saline. The Oil Operations Laboratory analyzed a number of soil samples according to methods described in Handbook No. 60 of the USDA. The relevant findings are indicated in the tables nrs 1 and 2. In each sampling "A" indicates that the sample was taken at a depth of zero to twenty cm below surface and "B," twenty to forty cm below surface.

Due to the high gypsum content of the soils various problems occur as to the method of analysis and the interpretation of the data found. This is clearly demonstrated when the composition of the 1:1 and that of the 1:15 extracts are compared mutually and with the gypsum figures as given in table 2.

Tables 1 and 2 reveal that the easily soluble chlorides in the 1:1 extract are already completely dissolved.

The sulfates, which are less soluble (as well as the hydrocarbonates which may, however, be disregarded in this case because of their low con-

Table 1

Ions-composition of the salts in the soil in milliequivalent per kg soil in a 1:1 extract

Sample nr	Na	Ca	Mg	SO_4	Cl	HCO_3	Total p.p.m.
4A	62	38	24	53	70	1	7576
4B	23	33	15	45	24	1	4465
8A	130	24	28	43	560	0.5	43250
8B	80	26	21	43	200	1	19600
35A	363	60	67	84	400	1	28871
35B	204	50	30	70	213	1	17005
40A	475	62	78	110	517	1	36247
40B	205	52	41	72	225	1	17713
59A	390	50	207	174	470	2	37538
59B	160	42	73	89	182	1	16172
61A	475	56	125	125	512	1	38143
61B	330	50	77	93	360	1	26771

Table 2

Some results of chemical analyses on Qatif soils

Sample nr	pH	$CaCO_3$%	Gypsum %
4A	7.2	13.7	28.3
4B	7.2	11.5	27.6
8A	7.3	4.1	41.3
8B	7.6	6.3	28.3
35A	7.6	1.2	30.0
35B	7.6	1.6	28.3
40A	8.0	2.4	35.0
40B	7.5	1.0	30.0
59A	8.2	1.5	29.2
59B	7.5	4.5	28.3
61A	7.5	11.8	33.8
61B	7.5	7.9	31.8

tent), are not yet completely dissolved in the 1:1 extract. Consequently the 1:15 extract shows a much higher content of SO4 and, naturally, also of Na, Ca and Mg.

In comparing these figures with the total gypsum content indicated in table 2, it appears that even in the 1:15 extract only a small part of the gypsum is dissolved, although all salts other than gypsum have indeed been completely dissolved.

In view of the fact that gypsum as a salt is more or less harmless, the total salt content of the 1:15 extract may be reduced with the gypsum content to get an idea of the real salinity hazard. The data thus obtained reveal that the soils involved have a salt content of up to four percent. As salt contents of 0.65 percent and higher allow for the cultivation of very salt-tolerant crops only, no satisfactory agricultural results may be expected on these soils under present conditions. Special measures, viz., drainage and leaching, should therefore be taken to arrive at a satisfactory agricultural production.

Besides an initial leaching to get rid of the excess salt, a permanent leaching will be essential in view of the quality of the irrigation water. A leaching requirement of thirty-five to fifty percent should be taken into account to cope with the expected quality of the irrigation water and the prevailing soil conditions.

The gypsum content of the soil may be expected to decrease gradually, which would mean that twenty-seven to forty-one percent of the components of the upper layers of the soil profile may disappear. The leaching of gypsum will therefore result in a considerable loss of volume and consequently cause a considerable subsidence of the soil surface, which in its turn may unfavorably influence the drainage of the area.

The Groundwater Level

It is known that the groundwater levels and their fluctuations are influencing the nature of the soil profile in arid climates if these fluctuations are prevailing at not too great a depth below the soil surface.

The groundwater levels as found during the field survey, carried out in the first part of May 1963, clearly indicate that the internal drainage of the soil is inadequate despite the existing main drainage system. American and Russian literature state that the critical depth of the groundwater level under these conditions is approximately 1.80 m below surface, which means that the groundwater levels found in the area are one meter or more above the desired level. These high groundwater levels are caused by too limited drainage possibilities of the main drainage system and by the large quantity of water flowing into the area from the constantly running wells. On the other hand, it may be observed that future irrigation, including leaching requirements, will call for an intensive, detailed drainage system.

The Drainage Possibilities of the Soil Profile

In the foregoing it is stated that the occurrence of a calcareous hardpan is seriously limiting the drainage possibilities of the soil profile. Consequently it will not be possible to arrive at the theoretically desired drain depth, and other possibilities to improve the existing situation should be investigated.

It makes no sense — taking the flowlines of the groundwater into account — to install the drains at a greater depth than the top of the calcareous hardpan. On the other hand, the groundwater level will be required not to exceed a level of approximately fifty cm below soil surface after irrigation. The drain spacing, therefore, will be approximately five meters on the basis of the existing drainage formulas. This spacing is so close that open ditches or trenches are impossible with a view to agricultural management, and tile drainage should therefore be taken into consideration. Since a local drain tile industry is absent, the use of plastic drains might be the best solution.

A favorable aspect of the described type of drainage system is that no particular demands are made on the main drainage system, so this system suffices as far as drainage depth and discharge capacity are concerned.

It might be possible to take measures which are more in agreement with the drainage depths theoretically desired. In this connection, breaking up of the calcareous hardpan by means of a subsoiler could be considered. The realization of such a measure in practice would mean that the restrictions as regards the drainage depth would disappear, and drainage at a depth of approximately two meters below soil surface and at distances of twenty-five to thirty meters would be possible. Should this procedure be followed, however, the depth of the main drainage system would be inadequate, which could be solved for the experimental farm by the installation of a simple pumping station.

SYRIAN ARAB REPUBLIC

Geographical Features

The Syrian Arab Republic lies on the east coast of the Mediterranean Sea, bounded by Turkey on the north, Iraq on the east, Jordan and Palestine on the south, and Lebanon and the Mediterranean Sea on the west, with a total boundary length of 2274 kilometers, and a total area of eighteen and a half million hectares.

Syria may be divided geographically into four areas:

(1) *The coast,* which lies between the mountains and the sea.
(2) *The mountains,* which lie on the west part of the country, from north to south.
(3) *The interior areas or the plains,* which include the plains of Damascus, Homs, Hama, Aleppo, Hasakeh, and D'ar'a. These plains are east of the mountains.
(4) *The desert area,* which consists of the desert plains in the southeastern part of the country, on the Jordan and Iraq borders.

Climate

The climate of the Mediterranean Sea generally prevails in Syria, which is characterized by a rainy winter and a dry, hot summer, separated by the two intermediate seasons. The coast is characterized by heavy rainfall in winter and a dry season of moderate temperature and high relative humidity in summer. The interior is characterized by a rainy winter and dry summer. The areas in the mountains with an altitude of 1000 meters or more are characterized by a rainy winter where rainfall may exceed 1000 mm., and with a moderate climate in the summer. The desert area is characterized by a small amount of rainfall in the winter and a hot, dry summer.

During winter snow falls over all regions having an altitude above 1500 meters. Regions with altitudes of 800 to 1500 meters are subject to rain and snow. Other regions with lower elevations above sea level are subject to rain, rarely to snow. In the desert regions sufficient rain seldom falls.

Frequently thunderstorms accompanied by heavy showers occur during winter, and in some regions the intensity of such showers reaches seventy-five mm. in twenty-four hours.

From time to time the country is subject to dry seasons with little precipitation, which leads to a great decrease in the agricultural output except in the coastal area. The atmosphere in Syria is characterized by a high relative humidity during winter and a low relative humidity in summer, except in the coastal area. It varies between twenty to eighty percent.

Soil Groups

Syria may be divided into the following main soil groups:

(1) *Red Mediterranean*: Includes the western hills of Syria with more than 600 mm. annual rainfall.

(2) *Grunnusol*: Includes the plains of western Syria with annual rainfall of 300 to 600 mm. This represents the wheat belt under irrigation. These soils are ideal for cotton.

(3) *Cinnamenic*: Includes the plains of inland Syria with annual rainfall of 150 to 300 mm. This represents the barley belt.

(4) *Desert*: Represents the grazing land in Syria with an annual rainfall of less than 150 mm.

(5) *Gypsiferous*: This is subject to wind erosion. Permanent agriculture is possible only under irrigation.

(6) *Alluvial*: Found in low valleys of the Euphrates and tributaries under irrigation. Used for cotton, but suitable for various forms of crops.

(7) *Groundwater soil*: Includes the plains of Ghab, Rouge, Radd and the inland lakes of Syria.

Agricultural Areas in Syria

The agricultural areas in Syria may be divided into the following:

(1) *Arid area*: The annual rainfall is under 250 mm. This area is mainly pasture land. Cultivation is possible only where water is available with irrigation. Cotton, sugar beets, and wheat can be produced. Dry farming is not successful.

(2) *Semi-arid area*: The annual rainfall is between 250 and 500 mm. Cereals and pulses are the principal crops. Some fruit trees and stone fruits are planted. Dry farming in this area is successful.

(3) *Semi-humid area*: The annual rainfall is from 500 to 800 mm. This is the main productive area in Syria with the highest yields. Barley, cotton, sugar beets, millet, potatoes, vegetables, fruit and olive trees, citrus, cherry, pistachio, vine, and fig trees all are planted in this area.

(4) *Humid area*: The annual rainfall is over 800 mm. Forestry is predominant in this area except in the valleys, where tobacco, potatoes, maize, vegetables, also cherries, apples, and other fruits are grown.

Syria has a total cultivated area of about seven million hectares. Five million hectares of it are planted. The present irrigated area amounts to 520,000 hectares, 370,000 hectares of which are irrigated by gravity. The remaining area of 150,000 hectares is irrigated by pumping. The non-irrigated or dry farm land amounts to 2,760,000 hectares. Fallow lands amount to 3,400,000 hectares.

The total uncultivated lands of Syria can be classified into: forests, with a total area of 450,000 hectares; pastures, with a total area of 6,100,000 hectares, and desert and rocky mountains and saline lands, having a total area of 3,140,000 hectares.

Syrian Water Resources

The annual rainfall in Syria in an ordinary year totals about fifty milliard cubic meters. Surface flow amounts to about ten milliard cubic meters. The remaining forty milliards are lost through evaporation and percolation. With the available rainfall an area of 750,000 hectares can be irrigated, assuming that about 15,000 cubic meters are required to irrigate one hectare a year. Only about 350,000 hectares are presently irrigated from this source.

Rainfall is not the only source of water for

Syria. A great amount of water flows into Syria through the Euphrates River and its tributaries. Water from this source amounts to about twenty-five milliard cubic meters in ordinary years. This amount is sufficient for 2,300,000 hectares, or five times the present irrigated area.

The main water basins in Syria are the Euphrates and the Oronte. The other subsidiary or secondary basins are distributed over most of the country. These are Jezirah, Aleppo, Horan, Damascus, coastal and the desert basins.

Rainfall and snowfall form the main sources of underground waters for these basins, except for the Jezirah and Oronte Basins, which are fed by external sources.

Detailed surveys have been made for the desert, the Horan and the Jezirah Basins. Detailed surveys of the other basins will be undertaken during the years 1966-1970.

The main rivers in Syria are Euphrates, Al-Khabour, Jaghjagh, Al-Balikh, Sajour, Oronte, A'frin, Querq, Al-Kabeer, Sinn, Barada, A'waj, and Al-Yarmouk. Their total length within Syrian territory is 2,154 kilometers, and their total average flow is 870 cubic meters per second.

There are more than seventy small rivers and springs with a flow of over fifty liters per second each, some of these reach a flow of as much as three cubic meters per second. There are six principal lakes in Syria, with a total area of 300 square kilometers, which can be used for water storage.

Irrigation Projects in Syria

The Syrian registered population in twelve districts amounts to five and a half million people. Seventy percent of the population relies directly on agriculture, which forms fifty percent of the total national revenue and eighty-five percent of the Syrian export.

Some years ago, the agricultural problems in Syria were acute as rainfall was the main source of water for crops. This caused stress on the national economy. Drought and dry seasons meant catastrophe. Besides that, the rainfall in Syria varies from one year to another from the quantity and distribution point of view.

In general, the area with an annual rainfall of 500 mm. which is suitable for dry farming without any need for irrigation, does not exceed ten percent of the area of the country.

In the last forty years, the Syrian Government and many Syrian farmers have recognized the advantages of proper use of water for irrigation. In 1930, the Syrian Government started the first irrigation project of Homs-Hama using the Oronte River water. Since then the number of government and private irrigation projects has rapidly increased, and as a result the irrigated land area using water from rivers and underground sources now amounts to 520,000 hectares. These lands are mostly irrigated by gravity. Deep and shallow underground water is used for lands irrigated by pumping. Thousands of boreholes and wells have been drilled all over the country, and good yields of water have been obtained from many of the boreholes, especially in the Jezirah districts.

Syria, in olden times, was famous for the construction of various irrigation projects. The Romans, the Sabaeans, who immigrated from Yemen after the failure of Ma'rab Dam, and the Arabs, all did magnificent irrigation works by constructing dams, digging canals, opening galleries, etc. Other water works were built for many purposes, especially for drinking water supply. Traces of old irrigation canals can be seen in several places in Syria. Many of these canals are still used.

Damascus Ghoutah, which has an area of about 255,000 hectares, and is well known for its apricot and other fruit trees, is still irrigated by the old canals, using the same old water distribution system, which is quite perfect. Many Roman underground galleries are still in good condition, and these too are used for irrigation and water supply with some yearly maintenance. These galleries exist in many parts of the country. Traces of dams on Khabour River, Heer Palace, and in the desert and along several valleys throughout Syria are still evident. The Dam of Quatinah Lake of Homs, which is the main element of Homs-Hama irrigation project, was built by the Romans. Some improvements have been made to keep it in good operating condition. Waters stored behind this dam amount to about two hundred and fifty million cubic meters.

In conclusion, I will mention the governmental irrigation projects of the past forty years. These are the Homs-Hama, the Yarmouk, Shaikh Miskeen, the Sinn, the Rouj, Madhakh, and the Khabour projects. The total area irrigated by these projects at present is 60,000 hectares.

In addition to the above-mentioned projects, new developments and extended projects are planned, some of which are nearly ready to be used. These new projects, included in a five-year plan, are Barada and A'waj, the Yarmouk, High Oronte Basin, the Houlah, the Nasiriah, the Sinn, the Ghabe-Asharneh, the Khabour, and the Euphrates projects. The total irrigated area will be greatly increased after the completion of these projects. It is hoped that the irrigated areas will amount to twenty-five percent of the total land area. This will be a great influence on Syria's economic growth, and will increase the national revenue to about one milliard Syrian pounds in a year.

In addition to the above projects, it is scheduled in the second five-year plan to construct many large, medium, and small local dams all over the country for flood protection, water storage, and recharge of the underground water basins.

TURKEY*

Turkey has an area of 776,980 square kilometers and is divided into two parts by the Marmara Sea. The Asian part is called Anadolu and comprises 96.8 percent of Turkey. The European part is called Trakya. Anadolu and Trakya are both surrounded by the sea on three sides. Turkey is a mountainous country. The mountain range running parallel to the shore line isolates central Anatolia from the effect of the sea. Its geographical location and topography give Turkey several climates. An arid and semi-arid continental climate prevails in the interior and central part of the country, while a sub-tropical Mediterranean climate prevails in the coastal plains. The distribution of precipitation during the year and from region to region is not uniform. Annual precipitation is as low as 300 millimeters in some parts of Anadolu while it is as much as 3000 millimeters in the eastern Black Sea Region. The amount and the distribution of precipitation are the most important factors controlling the crop pattern and farming practices in Turkey. Due to the lack of sufficient moisture, the early maturing crops such as cereals are grown in areas where citrus, cotton, vegetables, fruits and forage crops can be grown if they are irrigated.

Evaluation of the meterological data shows that ninety-six percent of the cultivated land does not have sufficient precipitation during the growing season and that irrigation is necessary for the most beneficial use of the land and for the greatest potential growing season. The weighted average of the growing season of the crops is only forty-eight percent of the potential growing season in Turkey.

The average annual precipitation in Turkey is 518×10^9 m^3. The total annual runoff carried by the rivers is about 167×10^9 m^3.

The amount of irrigable land is 12,600,000 hectares, as determined by the reconnaissance and semi-detailed land classification. Of this 1,310,000 hectares of land are under irrigation. Approximately 5.5×10^9 m^3 of water is used for irrigation, domestic, municipal and industrial purposes.

Accomplishments Since Last Seminar

At the beginning of the 1964 irrigation season, 330,106 hectares of land were under irrigation in government-built projects and 873,624 hectares of land were under irrigation in private projects.

In 1964, 85,421 hectares and in 1965, 140,-017 hectares of irrigation schemes were completed by government agencies. Thus the total area of land under irrigation in government-built projects at the beginning of the 1966 irrigation season is 555,544 hectares.

* This report was prepared by Aytcn Aydin, Chief, Planning and Investigation Department Directorate General of State Hydraulic Works (DSI), Ankara-Turkey, and Huseyin Yegin, Assistant Director, Directorate General of Soil Conservation and Farm Irrigation, Ankara-Turkey.

Plans for New Water Supply Development

According to the 1966 program, 97,635 hectares of land will be put under irrigation with the irrigation projects to be completed in 1966. Construction of irrigation systems for 154,920 hectares of land is proposed for 1967. Upon the implementation of these 1966 and 1967 programs, new irrigation schemes for 252,555 hectares will be put in service by government-built projects during the next two years.

The Second Five-Year Plan, covering the period of 1968-72, is being prepared. The target for the agricultural sector has not been established yet. Thus it is too early to give figures related to the proposed progress in irrigation for the period of 1968-72. But the area to be put under irrigation is approximately 550,000 hectares.

Development of Institutions and Procedures for Improving Irrigation and Drainage

(1) *Establishment of the Ministry of Village Affairs*

In Turkey seventy-one percent of the population earns its living through agriculture and lives in villages. As the population rate increase is high, 600,000 people are added each year to the existing population. There are 3,514,476 farm families, and each farming unit is approximately 4.9 hectares. There is an irregular migration from villages to cities as a result of the population increase and the lack of employment in villages. Primitive farming methods are used in villages. Most of the villages do not have electricity and some of the villages need good roads for all-year transportation and domestic water supply. The close economy which has been practiced in most of the villages for centuries has resulted in improper use of the land and water resources.

All the social, economic and cultural developments cannot be financed and carried out by the government alone. A solution of village problems is necessary through associations and cooperatives.

The Ministry of Village Affairs was established in July, 1964. This ministry is responsible at the village level for such public works as roads, electricity, domestic water supply, irrigation, soil conservation, education, and land settlement. It is to develop villages according to comprehensive plans prepared for each village or group of villages, and to coordinate the efforts of several other ministries serving the villages. Ministry of Village Affairs has four general directorates, namely:

(a) TOPRAKSU (Soil Conservation and Farm Irrigation)

(b) Yol-Su-Elektrik (Roads-Water-Electricity)

(c) Halk Egitimi (Public Education)

(d) TOPRAK ISKAN (Land Settlement)

(2) *Irrigation, Soil Conservation, and Land Reclamation Cooperatives*

The aim of irrigation is to increase agricultural production through the most effective use of soil and water resources. Construction of such structures as dams that make the water resources suitable to irrigation, and government distribution of water to farms is necessary but not sufficient for the realization of this aim. To realize the anticipated benefits from government investments in public works of irrigation, the farmers' own activities and investments are necessary in preparation of land, for irrigation with land leveling and grading, proper application of water to the field with proper irrigation methods and field irrigation structures, use of proper irrigation farming equipment, fertilizers, seeds and seedlings, and implementation of sound farm plans, including crop rotation, processing and marketing. To meet these requirements, the farmers should be encouraged to use their own manpower, material, money and credit.

Most of the farmers individually, do not have enough money or credit for new investments. Thus most of the irrigation, land reclamation, soil and water conservation problems require group action by the farmers who are affected by the problem. Processing and marketing facilities serve more than one farmer and can be organized and operated efficiently by a group of farmers. So, TO-

PRAKSU received from the Ministry of Commerce in March 30, 1964, permission for the establishment of "Irrigation, Soil Conservation and Land Reclamation Cooperatives." By January 1, 1966, 206 cooperatives were established. Now, ten cooperatives are established each month.

TOPRAKSU prepares a land and water development plan for each cooperative, helps the farmers to get loans, equipment, seeds and fertilizers, gives technical assistance for the implementation of a land development plan, and trains farmers in irrigated farming and soil conservation practices.

Additional benefits of organizing farm cooperatives are reflected in the following points:

(a) Cooperative movements facilitate the financing of soil and water activities, and effect a savings in both money and time.

(b) The service capacity of TOPRAKSU will be increased by efficiently reducing the required number of man hours per hectare of developed or reclaimed land.

(c) According to the Soil and Water Cooperatives agreement, cooperatives have to participate in thirty percent of the cost of a project in particular services, and in twenty percent of the cost in general services. Therefore, the participation of the farmer will be obtained in development costs of small water resources.

(d) A farmer has the opportunity to pay a portion of his share of the cost of a project through personal labor in the project.

(e) Cooperative movements have a great educational value in teaching farmers modern irrigation and soil conservation techniques.

(3) *Associations for Development of Soil and Water Resources*

Irrigation, Soil Conservation and Land Reclamation Cooperatives, on which brief information was given in the previous section, were established under the existing Commercial Cooperatives Law. Authority and activities of these cooperatives are limited. They have to finance their activities with their own money or with the loan they get from the Agricultural Bank. Some of the land development activities, such as land leveling, drainage, etc., are expensive. TOPRAKSU has provided a hidden subsidy by renting its equipment to the farmers at a price of fifty percent of the actual cost. TOPRAKSU has only five percent of the needed scrapers and trenchers. In private operations, contractors also have a number of scrapers and trenchers, but this equipment cannot be hired by farmers because it is used in mining, road building and other construction work, and private contractors cannot compete with the reduced lease prices of TOPRAKSU equipment. If TOPRAKSU had all the scrapers, trenchers, ditchers and ridgers necessary for the realization of the planned irrigation development in Turkey, and if all this equipment were operated by TOPRAKSU, the amount of hidden subsidy, the number of personnel employed in machinery services, and the value of inventoried stocks in workshops would be increased by twenty to thirty times, and this burden is too great to be carried by such an organization.

An open cost-sharing system is necessary, but impossible under the existing laws.

The credit of an Irrigation, Soil Conservation and Land Reclamation Cooperative is the sum of the credits of its members, and in most cases this is not enough to meet the cost of the planned development.

Water distribution systems can be operated more efficiently by the farmers themselves.

Until now, initiative for the development of some of the small water resources and for all the large water resources has come from the government. Farmers have taken for granted the government-built projects and have kept complaining, without feeling any obligation or responsibility.

A proposed law for the establishment of "Associations for the Development of Soil and Water Resources" has been prepared by TOPRAKSU and presented to the government for approval.

These associations will overcome the limited means and authority of cooperatives. They will be similar to Soil Conservation Districts and Irrigation Districts in the USA, and will have the benefit of cost-sharing.

(4) *A By-Law for Land Consolidation*

In Turkey there are 3,514,476 farm families, each with an average of 4.9 hectares of land in six parcels. The fact that lands are fragmented and scattered causes the area actually irrigated from irrigation systems to be low and the irrigation development cost to be high. Land consolidation works were started by TOPRAKSU on a small area in 1961. These works could not be conducted on a larger scale due to the lack of laws and regulations and necessary allocations, from the State Budget, for land consolidation. Results of the land consolidation projects carried out by TOPRAKSU since 1961 indicate that land consolidation decreases the irrigation cost at a rate of twenty-five to twenty-seven percent. However, there are expenses for additional surveys, plans, designs, application and investment for the realization of land consolidation.

A by-law for land consolidation was prepared by TOPRAKSU in 1965 and submitted to the Board of Ministers. It is hoped that this by-law will be approved by the board in the near future.

(5) *DSI's Joint Projects with Private Irrigation Associations*

Small irrigation schemes built by DSI (State Hydraulic Works) are preferably turned over to the farmer associations or municipalities and village councils for operation and repayment.

Statutes of the associations and the contract on the schemes have been revised.

According to these revised statutes small irrigation works deemed feasible may be put into operation after the contract has been signed between the government and a private agency, to let the scheme to the beneficiaries.

When this procedure is effected the small irrigation scheme is operated and owned by the private organizations.

The government is also making an effort to turn over to private agencies the small irrigation schemes which it now owns and operates. Yet, the private agencies do not want to pay all the costs of the project, but wish to accept and operate the constructed works without repayment. This poses a major problem in turning completed works over to private enterprise.

In addition to these efforts, the government is assisting farmers in establishing irrigation groups under tertiary or secondary canals in the larger project areas.

Two irrigation projects where feasibility studies are being carried out by DSI are the Germectepe and Karacomak projects in Kastamonu province in the northern part of Turkey. These projects will be let to the farmer association to operate and repay the project cost after construction is complete. The contract has been signed between DSI and the association. The construction has not yet started.

In irrigation schemes under construction in Antalya-Elmali, Kozan-Hacilar, Tosya-Derinoz and Kaleyakasi, the associations paid all the land acquisition expenses. In the Kaleyakasi project the association also shared the cost of feasibility and design studies.

Antalya-Kirkgoz-Yenikoy small irrigation scheme was put in the 1966 action program after signing of the contract. The association will meet land acquisition costs during execution of the project.

The existing two small irrigation projects, Akhisar-Akpinar and Mersin-Erdemli, could have been let to the association for operation and maintenance.

Education and Job Training

(1) TOPRAKSU trains farmers and its own personnel in its training center and training camps.

In 1964-65 engineers were trained on irrigation and soil conservation for six months; fifteen soil laboratory technicians were trained in soil analyzing methods for a month; twelve soil scientists were trained in advanced soil surveying for three months; a seminar was given to forty-seven engineers on hydrology for three days; another seminar was given to twenty-two engineers in soil conservation and irrigation.

In 1965, sixty-four engineers were trained in irrigation and soil conservation for six months; twenty-eight work unit chief engineers were trained in administration, control of construction and contracting procedures; twenty soil scientists were trained in advanced soil surveying for two months; fifty-five topographers and nineteen surveyers were trained for three months to meet the sub-professional personnel requirements of TOPRAKSU; 6000 farmers were trained in eighty training camps on the subject of soil conservation and irrigation. These engineers accomplished the implementation of eighty projects which had a total cost of twenty-five million TL. Forty-seven irrigation foremen were trained for a month. These foremen are teaching the farmers irrigation methods.

(2) DSI established yearly seminars for administrators and other high level personnel of the operation and maintenance organizations.

Personnel in the irrigation and distribution works are being trained at the regional organization level in the program prepared by the central office.

Training an operational staff is of great importance in the operation of DSI irrigation systems. It involves selecting the staff from among the graduates of related training institutes, preparing the general instructions and instructions for operational units and providing on-the-job training.

It has been decided to employ as ditchriders, the graduates of agricultural and horticultural schools. Forty-two of these were trained on the job in 1965.

The graduates of agricultural high schools are employed as watermasters. Each year, irrigation engineer workshops are held in the headquarters for these operation engineers. The first workshop was attended by twenty-eight engineers at the end of 1964. The second one was held in January, 1966.

Development of Standards for Irrigation

(1) *Elevated Precast Canals*

Where the canals must be lined the cost of the irrigation system is rather high. New methods of lining have been experimented with all over the world to reduce the cost by decreasing the thickness of lining, by mechanization of lining, or by using inexpensive material. Elevated precast concrete canals (canalets) are used in a few projects in Turkey. The result of the economic evaluation shows that under some conditions this method may be more economical than the conventional concrete lined canals.

(a) *Advantages of the canalet system.* The system consists of elevated precast canals. This system may compete with the conventional systems in many respects up to some limits. The principle advantages are these:

The construction time and erection in the place is shorter; the quality is better, even perfect; the transportation of the construction material costs less; operation, replacement and maintenance works are easier; acquisition cost is less; land lost is less; sedimentation and weed control problems are less; the size and cost of the auxiliary structures are less. This system does not create difficulties of surface drainage, and there is no need for tertiary drainage canals.

Inasmuch as the conventional system needs heavy construction equipment, which has to be brought from outside the country, and the canalet system needs only the equipment which can be obtained in the country, no foreign currency is required in the canalet system in Turkey.

These advantages are for Turkey's condition. They may vary from one country to another in some respects.

(b) *The major parts and the characteristics of the system.* The major parts of the system are foundation blocks, supports maximum two meters high, saddles and canals in five meters length. The shape of the canals are semi-elliptic and semicircular for small and larger canals respectively.

Since this system needs a certain factory there are economic limits in the practice.

Under Turkey's conditions, the minimum economic size of an irrigation scheme is 15,000 to 20,000 hectares, and the maximum economic transportation distance is about 300 kilometers.

(c) *Practices in Turkey and the cost comparisons.* In view of the above mentioned advantages of this system, it has been chosen for many large and important irrigation projects. One factory in Antalya and two factories in the Izmir region have been built by DSI; two factories in Adana and one factory in Kayseri have been built by contractors. The canalets for 43,000 hectares of irrigation distribution systems will be prepared by these factories.

The cost of the factory in Antalya is 2,500,000 TL. (approximately $288,000) and its daily capacity is 600 meters of canalet.

The cost comparison which was made for the Kesiksuyu irrigation project is summarized below:

	Conventional system	Canalet system
Area to be irrigated	14,000 ha.	14,000 ha.
Main canal	23 Kms.	20 Kms.
Secondary canals	54 Kms.	} 196 Kms.
Tertiary canals	213 Kms.	
Surface main drainage	16 Kms.	79 Kms.
Tertiary drainage canals	213 Kms.	
Area subject to acquisition	364 ha.	39 ha.
Cost (including acquisition expenses)	33,000,000 TL.	23,800,000 TL.
	($3,000,000)	($2,150,000)

In addition to the saving in construction cost, the operation and maintenance expenses will be less, and the loss to national income less, because the land occupied by canals is negligible in a canalet system.

Since this system has only recently been started in Turkey, a later evaluation will be more valuable.

(2) *Small Earth Dams*

In Turkey only 5.5×10^{9} m^3 of water is used for irrigation, culinary, municipal and industrial purposes. This is only 3.3 percent of the annual runoff. Programs have been prepared for large dams and reservoirs to irrigate the large plains located generally at the lower end of the watersheds. Because of the topographical and economic conditions of Turkey, the land in the upper watershed is also cultivated and needs irrigation. The irrigation water for the land in the upper watershed can be obtained by diverting and pumping from small creeks or by ponding the spring runoff in small reservoirs.

Small earth dams can be constructed in one year at a reasonable cost. TOPRAKSU's earthmoving equipment for land leveling and terracing can be used to build earth dams when there is a crop in the field and the land leveling or terracing cannot be done.

TOPRAKSU is developing programs for construction of a large number of small earth dams. Eleven soil mechanics labs are being established by TOPRAKSU throughout Turkey. Standards for investigation, planning, design, operation, and maintenance of small earth dams are prepared by TOPRAKSU for the efficient implementation of programs for small earth dams.

Research

(1) *DSI's Research*

Research on chemical methods of weed control in irrigation systems has been conducted since the last seminar and applied to the problem. Satisfactory results have been obtained from its application. In two years, weed control by chemical methods has been made in 7500 kilometers of canal in several of ninety-five locations. In addition, double frequency 2,4-D selective herbicide application has been made in 400,000 meters of levee. The total amount of herbicide used in two years is 97,000 kilograms, and approximately $700,000 has been spent for this purpose.

(2) *TOPRAKSU's Research*

Some of the research conducted by TOPRAKSU's research institutes and stations is listed in the following:

(a) Water requirements of sugar beets, wheat, pasture, citrus, cotton, rice and vegetables.

(b) Reclamation of saline and alkali soils.

(c) The effect of water table elevation on water requirements and the yield of crops.

(d) Resistance of crops to inundation.

(e) Resistance of olives to salt.

(f) The effect of different depths of cut in land leveling on the yield of crops.

(g) Drainage of organic soils.

Publications

Some 213 books or bulletins have been published on irrigation, drainage and related fields by DSI, TOPRAKSU, research stations and universities. This includes DSI's thirty-two, TOPRAKSU's eighty-three, Ministry of Agriculture's thirty-four, Ege University's eight, Ataturk University's three, and Ankara University's fifty-three publications.

UNITED ARAB REPUBLIC*

In the Fifth Seminar, held in India in March, 1964, a brief review of the country development plans was presented. Since then, much of the work has been executed. So it seems advisable to give a brief account of the present situation of the more important projects.

In view of the fact that the UAR economy depends mainly on agricultural production, great efforts have been devoted to this problem. The goal is not only to cope with the people's requirements, but also to attain a range of extra gross production, enabling the exportation of certain products.

With this aim in view, the government has devoted its efforts to utilizing all arable lands, through development of water resources as well as utilizing every drop of water. Meanwhile, efforts have been made to achieve maximum productivity on the present cultivated land, by maintaining fertility and planting suitable crops. However, this cannot be realized unless irrigation and drainage methods are improved throughout the whole Republic.

The river supply varies widely during the year. Although it is insufficient to meet the agricultural requirements during summer (February to the end of July), yet it increases during flood period and its level rises, in some years, to the extent that the safety of the whole country is threatened.

The first project for the Nile River control was construction of the Delta Barrage to raise the level of the river in the low stage so that the main Delta canals could provide water for cotton and other summer crops.

To increase the river supply during the low stage, the Aswan Dam was built in 1902 in conjunction with several barrages on the river to give command level to lands dependent on river water.

The extension of perennial irrigation and the development of new cultivated areas called for an increase in water supplies during the season of shortage. This was achieved by twice increasing the height of the Aswan Dam, thus increasing its contents from one to five milliards, and by the construction of a new dam at Gebel Aulia with a capacity of two and a half milliards on the White Nile.

The main problem that faced the revolutionary government was the very critical situation due to the rapid increase in population. Egypt is one of the most densely populated countries in the world. With a cultivated area of about 6.3 million feddans it must support almost thirty million people, of whom about nine million are actually employed in agriculture and live on the land. This means that the lowering of the already low standard of living can only be checked by increasing employment in industry, and by greatly extending the area cultivated, which is impossible without a great increase in water storage. This can be achieved

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* Prepared by Eng. Ahmed Ali Kamal, Undersecretary of State, Ministry of Irrigation, U.A.R., and presented to the Seminar by Eng. M. El-Madany, Tech. Advisor.

only by saving the large volume of flood water which is annually wasted to the sea.

The High Aswan Dam or the Sadd El Aali, besides storing the silt-laden waters of the flood, will complement the schemes of the Upper Nile projects for the complete utilization of the waters of the Nile.

The High Dam Lake

Upstream of the Sadd El Aali, a great lake will be formed. It will be the second largest lake formed by man. It will have a length of about 500 kilometers, and a mean width of about ten kilometers. The maximum width will be twenty kilometers, and maximum depth will be ninety meters.

The capacity of the lake will be 164 milliard cubic meters — more than four times the capacity of Lake Mead, which is one of the largest American reservoirs, and only slightly less than the capacity of Bratsik Reservoir Lake, in the USSR, which is the largest artificial lake in the world.

Description of the High Dam

The High Dam is one of the largest and highest dams in the world. It is of the rockfill type. Its height, from the river bed to the road level, is 111 meters.

In designing the dam many difficulties were confronted, due to the fact that the dam will be built on deposited material and in an area of the present Aswan Dam Lake, with a depth of more than thirty meters, and where in the years of construction the river discharge during flood period amounts to 10,000 cubic meters per second.

It was due to the natural circumstances of the site of the High Dam, the natural formation of its underground silt-deposit bed, and the type of construction materials available at the site, that the rockfill type was selected for the dam, in preference to other types of earth or concrete.

The width of the river at the dam site is 550 meters, and the length of the top road is 3600 meters. Its bed width extends to 980 meters, and the top road width is forty meters.

The foundation of the main dam is covered with a dense strata of sand dunes, rising to a height of about twenty-five meters. The rockfill which covers this strata is provided with a cofferdam, of seventy meters height, ten meters width at the crest, and sixty meters width at the base. Two water-tight cut-off lines protect the dam against collapse. The former is the upstream impermeable blanket connected with the cofferdam, and the latter is the vertical curtain which is being built by grouting. This grout curtain will extend to a depth of nearly 210 meters inside the silt-deposit stratum of the river bed underneath the dam, until is reaches the surface of the sound bedrock. Its top width will be forty meters, which will gradually decrease with depth until it reaches five meters in width. The depth of this grout curtain exceeds, by nearly forty meters, that of the one injected underneath Michan Dam in British Columbia, which has the deepest grout curtain.

The High Dam consists of three parts. The first is the upstream dam, which is fifty meters in height. By this part it was possible to close the course of the Nile and divert its waters to the new channel completed in May, 1964, on the eastern bank. In this way, it will be possible to construct the main dam.

The second part is the downstream dam, which was constructed to a height of about thirty meters. This dam prevents the downstream inflow from reaching the site on which the main dam of 111 meters height is actually being built between the up and downstream parts.

Cost and Benefits of the Project

The total construction cost of the High Dam, including compensations for areas which will be submerged by the storage waters in Nubia and the Sudan, as well as the erection cost of the electric-power station and transmission lines to Cairo and Upper Egypt, is estimated at about 245 million pounds.*

* One Egyptian pound equals $2.32.

It is anticipated that the direct annual increase in UAR's national income resulting from construction of the High Dam will be 235 million pounds. This increase will be produced by agricultural expansion, by guarantee of water requirements for irrigation of present lands and of newly reclaimed lands, by improvement of drainage conditions, by protection against high floods, by improvement of navigation conditions along the Nile, and by industrial development through use of the generated electric power.

Manpower

To meet the project's manpower requirements, 34,000 men were recruited, of which 17,000 are engineers, technicians, skilled laborers, mechanics, electricians, fitters, welders, car and crane drivers, excavators and engine operators, carpenters and many others. All work hand-in-hand with the Soviet mission experts, including 1800 engineers, technicians and skilled laborers.

Vocational training centers were prepared near the site of work, to promote craftsmanship among the Arab technicians and give them full practice in operating plants and other technical instruments to train car drivers and guide all workers in the principles of industrial security.

Progress of the Project's Works

From the beginning of work on January 9, 1960, to the end of October, 1965, the quantities of the main works of the High Dam project, which have been completed, amount to:

		Total of the cubes cubic meters	Maximum daily ratio cubic meters
(1)	Rock excavation in the diversion canal	10,948,000	23,000
(2)	Rock excavation in the tunnels	736,000	3,800
(3)	Concrete at the entrances of the tunnels	185,000	800
(4)	Concrete for lining tunnels	357,000	2,160
(5)	Concrete for the power-generating station	313,000	1,600
(6)	Rock fill in the body of the dam	10,026,000	30,600
(7)	Soft and coarse sand fill	11,879,000	44,000
(8)	Earth fill	1,341,000	
(9)	Supply of required materials and iron works from the USSR	250,000 (tons)	

Technical Data on the Project

General Data

The Nile maximum discharge at Aswan
13,500 cubic meters per second

The Nile minimum discharge at Aswan
275 cubic meters per second

Annual mean discharge at Aswan
84,000 million cubic meters per second

Reservoir

Maximum level of storage water — 185 meters

Capacity of the reservoir
164,000 million cubic meters

Dead storage capacity assigned for
silt accumulation, 30,000 million cubic meters

Live storage capacity, 97,000 million cubic meters

Capacity of storage assigned for protection
against floods, 37,000 million cubic meters

Length of storage lake	500 kilometers
Average width of the lake	10 kilometers
Surface area of the lake	5000 square kilometers
Possible constant annual draft of water from reservoir	84,000 million cubic meters
Average annual evaporation and seepage losses	10,000 million cubic meters
Present annual amounts of water used for irrigation in both UAR and the Sudan	52,000 million cubic meters
Net annual benefit in both UAR and Sudan	22,000 million cubic meters

Dam

Kind of Dam: Rockfill

Length at crest	36,000 meters
Length of part in river	520 meters
Length of right wing	2325 meters
Length of left wing	755 meters
Maximum height above bed level	111 meters
Width at crest	40 meters
Width at base	980 meters
Volume of materials of construction	42,855,000 million cubic meters
River bed level	85 meters
Crest level	196 meters

Power Station

Type	Francis
Number of turbines	12
Capacity of each turbine at design head	180,000 KW
Discharge at design head	346 million cubic meters per second
Diameter of turbine runner	6.3 meters
Rated speed	100 r.p.m.
Head	77 to 35 meters
Weight of turbine	765 tons
Capacity of each generator	175,000 KW
Voltage	15,750 KV
Weight of materials	1,600 tons
Total installed capacity	2,100,000 KW
Maximum available annual energy	10,000,000 kwh
Total weight of hydro-electric power equipment	30,000 tons

Transmission Networks

Voltage of main transmission lines to Cairo	500 KV
Number of main transmission lines	2
Length of main transmission lines	2 x 787 kilometers
Number of 500 KV substations	3
Voltage of branch transmission lines	132/220 KV
Length of branch transmission lines	937 kilometers
Number of 220 kw and 132 kv substations	10
Weight of towers and galvanized steel structures	44,300 tons
Weight of line cables	31,900 tons
Weight of reinforced steel, other iron works and underground cables	144,000 tons
Cubes of the concrete employed	118,000 cubic meters

The most important irrigation projects, resulting from the execution of the High Dam, are:

(1) Conversion of Upper Egypt basins to perennial irrigation.

(2) Agricultural expansion in an area of one and a half million feddans.

Basin Conversion Projects

These projects are considered the chief benefit of the High Dam. Circumstances have made it imperative to convert basin areas into the perennial irrigation system, since the flood phenomenon will completely disappear, following the construction of the High Dam. Therefore, studies were conducted toward defining the areas, where basin irrigation will be difficult to apply following the completion of the High Dam and the falling of the downstream river discharges and levels. These studies will make it possible to pursue the conversion of such areas along with completion of the High Dam.

Upper Egypt basin areas amount to 973,000 feddan, all flooded every year. Details of this area are as follows:

(1) 602,000 feddan are flooded as a thorough basin system.

(2) 257,000 feddan are submerged during

the flood period as mentioned above and are supplied in addition with summer waters to intensify cereal cultivation.

(3) 114,000 feddan are under the double irrigation system, i.e., inundated during the flood and supplied with irrigation water the rest of the year.

To implement this policy comprehensive studies were conducted, based on accurate analysis of the whole question, from all points of view. The most feasible project was adopted, based on the following principles:

(1) To have field irrigation by the lift method.

(2) To have the main canals fed by free-flow from upstream of the grand barrages erected on the Nile, avoiding the adoption of their upstream high levels.

(3) To avoid the erection of pumping stations and to minimize their assigned areas (if any).

The execution program, however, is divided into two stages:

The first stage deals with irrigation projects in areas which will cease to receive basin irrigation following the commencement of storage in the High Dam Reservoir.

The second stage deals with irrigation projects in the remaining part of basin lands, as well as with drainage projects in all basin areas.

This project is sketched on the basis of irrigation by three major canals:

(1) Nasser's Eastern Canal, extending 225 kilometers, to irrigate an area of 203,000 feddans.

(2) Nasser's Western Canal, extending 250 kilometers, to irrigate an area of 260,000 feddans.

(3) Nasseria Western Canal, extending 210 kilometers, to irrigate an area of 350,000 feddans.

Moreover, the project includes construction of a wide network of branch and distributary canals. There will be 900 such canals, with a total length of 3000 kilometers, requiring excavation work of about 105 million cubic meters. Some 2200 irrigation structures will be constructed, such as grand barrages, check bridges, syphons and pumping stations on both the Nile and the main canals.

This requires the employment of a number of workers, amounting to 15,000 per day at the beginning, and now reaching 40,000 per day.

The final cost of this project will be 95 million pounds, of which some 38 million were spent during the First Five-Year Plan (1960-65). It is intended that 57 million pounds will be earmarked for this project in the Second Five-Year Plan.

The expenditures of the First Five-Year Plan have included the execution of irrigation projects in Kena, Sohag and Assiut Governorates, covering an area of 538,000 feddans, of which 38,000 feddans are in the First, 261,000 feddans are in the Second, and 239,000 feddans are in the Third Five-Year Plan.

An estimated increase of about forty percent of the production of the area included in this project will be realized. This will result in an expansion of civilization and an increased standard of living for the inhabitants of the area.

Agricultural Expansion

While a number of engineers are entirely devoted to construction of the High Dam, others are actively engaged in various technical fields essential to reap the projects' expected benefits through the utilization of storage water in agricultural expansion.

Agricultural expansion areas are planned according to the following bases:

(1) Better soil cultivability and increased yield.

(2) Economy in water use.

(3) Economical lift.

(4) Land centralization in reasonable areas admitting the coordination of reclamation works and the execution of irrigation and drainage projects.

(5) Improved communication facilities with the surrounding area.

(6) Priority to reclamation areas where execution of necessary irrigation, drainage and reconstruction projects involves less cost.

The first part of the land development program is being achieved through soil and land classification, the control of soil salinity and alkalinity, the development of soil fertility, the judicious use of irrigation water, the improvement of drainage facilities, and the development of underground water resources.

Soil Classification

Detailed soil surveys have been undertaken with a view to providing information of both physical and chemical properties of the cultivated area. Three and a half million feddans have been surveyed.

Reconnaissance soil surveys have been carried out with a view to providing preliminary soils information for the proposed expansion areas. So far an area of fourteen and a half million feddans of the expansion area has been surveyed, using aerial photographs.

Soil Salinity and Alkalinity

For the control of soil salinity and alkalinity, the Soil Research Division, Ministry of Agriculture, is conducting basic research to determine the various factors involved and to develop the most economical and effective means for treating saline and alkaline soils.

The problems of sandy and sandy calcareous soils are being considered in the studies of the above division. The main problem of these soils is the low water holding capacity and the unfavorable physical conditions due to the high $CaCO_3$ content which gives rise to the formation of impervious layers.

Soil Fertility

A central laboratory has been established in the Ministry of Agriculture to conduct investigations on the fertility status of soil, and to estimate the fertilizers needed for each soil and crop.

To implement the reclamation work with scientific data, experienced technicians, and trained personnel, several research institutes and training centers have been established. The work is devoted to the improvement in techniques and duties of land reclamation, irrigation and drainage. Some of the prominent institutes are the National Research Center, The Egyptian Desert Institute, the Salinity Laboratory and the recent Land Reclamation Institute, in addition to numerous training centers.

Using data from the technical and economic studies, it has been shown that the area of fallow land that could be developed by the use of Egypt's share of the High Dam storage water (amounting to seven and a half milliard cubic meters), plus Sudan's credit (which, according to the Nile Waters Agreement of 1959, is one and a half milliard cubic meters) amounts to about 1.2 million feddans in all the UAR Governorates. The major part of the area lies east and west of the Delta.

However, the government has exerted every effort to expand the cultivated area without waiting for the High Dam waters. Efforts were doubled to find new water resources, with a view to increasing the summer supply during critical periods, and proceeding with the agricultural expansion policy prior to the completion of the High Dam. The government succeeded in making available 1.2 milliard cubic meters of drain and groundwaters, as well as in adjusting their distribution. In this way it was possible to develop an area of 520,000 feddans, where all of the necessary irrigation and drainage projects were completely executed. Of this area, 225,000 feddans were developed by the waters made available and the remaining area supplied by the High Dam. Nearly nine million pounds were spent in this field of activity during the First Five-Year Plan.

Immediately after the completion of irrigation and drainage projects in this area, reclamation and cultivation processes took place, in order that such projects might not be affected by meteorological and climatical factors, such as sand precipitation, earth-filling and collapse.

Agricultural expansion also took place in desert areas. In May 1959, the Egyptian General Desert Development Organization was established for the reclamation and development of those desert areas depending on the exploitation of all water resources available, both surface and subsurface.

The organization drew up two Five-Year Plans: 1960-1965 and 1965-1971:

First Five-Year Plan (1960-1965)

No.	Project	Area in feddan
(1)	New Valley	45,000
(2)	Northwest Coastal Zone	14,000
(3)	Northeast Coastal Zone	9,000
(4)	Wadi El-Natroun	6,000
(5)	Mariut	16,000
(6)	East of Suez Canal	6,000
(7)	Menia	4,000
	TOTAL:	100,000
(8)	Pasture Improvement in Northwest Coastal Zone	60,000

Second Five-Year Plan (1965-1971)

No.	Project	Area in feddan
(1)	New Valley	140,000
(2)	Nasser Project in Mariut and Extension	115,000
(3)	Northwest Coastal Zone	8,000
(4)	East of Canal	5,000
	TOTAL:	268,000
(5)	Pasture Improvement in Northwest Coastal Zone	100,000

Works in these plans include land reclamation, development of economic centers, social development projects, raising local industries dependent upon local raw materials, and creating a socialist cooperative society.

The reclamation areas were divided into:

(1) Areas depending on groundwater, namely: New Valley, Wadi El-Natroun, and the Northeast coast.

(2) The Northwest coast, depending on rainfall, and shallow sub-soil water.

(3) Areas depending on the re-use of the Nile water, namely the Mariut area to the south of Alexandria, Nasser Lake shores.

(4) Remote areas utilizing Nile water, namely east of the Suez Canal area, and the south of New Valley.

It is noteworthy to mention here one of the most promising projects:

Tahrir Province

This is a pioneer project exemplifying the battle against the desert. The southern sector covers an area of 43,000 feddans, mostly of sandy soils, and depends for its irrigation water from the Nile and underground sources. By the end of 1965 the developed area of this sector was 77,000 feddans. This will be increased to 121,000 feddans during the Second Five-Year Plan. This sector includes the largest farm utilizing sprinkler irrigation in the Middle East.

The northern sector covers an area of 19,500 feddans of loamy calcareous soils and depends entirely on Nile water for irrigation. The area of this sector will be increased to 94,500 feddans by the end of the Second Five-Year Plan.

So far about 100,000 feddans have been reclaimed, of which nearly 1000 feddans are in fruit, mostly citrus and grapes.

Groundwater Utilization

The utilization of groundwater was fully contemplated, not only because it is considered as an additional source of water for agricultural development, but also as a means of promoting drainage facilities.

Geological studies. These studies were begun in the Nile Delta. Some thirty-five test-holes were drilled, the depth of which ranges between 200 meters and 500 meters. In Upper Egypt twenty-one test-holes were also drilled with depths ranging from 400 to 1000 meters.

By the help of data obtained from these test-borings, the thickness and the characteristics of the water-bearing materials were determined.

Hydrological studies. A comprehensive plan was outlined to investigate and study the general direction of groundwater flow, its levels, hydraulic gradients, quantities, qualities, and its general sources. Part of these studies were directed toward the existing wells, to obtain data concerning their depth, diameter, yield and water levels.

Besides these studies, a series of observation wells, in different parts of the Delta, Upper Egypt and the adjacent deserts, were drilled. A total of 280 observation wells were constructed in deserts neighboring the Delta, and 158 wells were drilled in Upper Egypt. Gauge readings of these wells are recorded monthly. Some of the wells are equipped with automatic recording systems.

To study the feasibility of drainage by wells three pumping stations, about fifty meters deep, were constructed. Each of these stations consists of a five-well battery placed on the spurs of a square, the side of which extends to forty meters, and at its center lies the medium well. Around each series a group of observation wells were drilled.

Production Pumping Wells

The safe groundwater yield was estimated in 1958 at 300 million m^3. This is considered to be the maximum possible amount that could be pumped without jeopardizing the safe use of the underground reservoir, during the six-month critical period from February to July, each year.

The construction of the following pumping-well stations has been completed:

(1) Twenty stations of high productivity were constructed near Bahr Shebeen. The wells of these stations are ninety to 100 meters deep. The discharge of a single station is 1200 m^3/h, and its cost amounts to about LE. 280,000. They were completed in 1965.

(2) Fifty-five productive stations were constructed at spacing sites in the Delta area. Of this number, twenty-five stations are of a single-well type, and thirty others are of the three-well battery type, forming an isoceles triangle. The discharge of a single station amounts to 1000 m^3/h. The construction cost of the whole item reached LE. 730,000, and work was completed in 1964.

(3) Thirty artesian well stations, having a discharge of 300 m^3/h, each were constructed in the Menoufia Governorate, at a cost of LE. 100,-000.

Twenty-five additional stations of the battery type, having a discharge of 1000 m^3/h each, are under construction in the Delta area. The cost of these stations is nearly LE. 420,000.

Total construction cost of all the above-mentioned stations of the Delta amounts to about LE. 1,530,000, and the discharge, at a basic operational rate of sixteen hours per day, reaches 327 million m^3, during the critical six-months period of February-July.

Proposed Studies and Research

To secure the safety of the underground reservoir, further studies are being carried out to determine its condition following the completion of the High Dam. The proposed studies include:

(1) The expected effect of the High Dam on groundwater levels.

(2) Feasibility of reducing salt sea water intrusion occurring in the Delta area.

(3) Feasibility of utilizing groundwater in Upper Egypt.

Public Drainage

Since the introduction of the perennial irrigation system in the UAR, a serious problem has developed: The short span between the planting rotation, following the fall of the surface water levels in the upper clay strata, caused the water to raise to the soil surface and penetrate into the root-growing area; thus, the soil salinity increased and production was minimized. Therefore, the government immediately proceeded with the execution of free-flow drainage projects in the areas badly affected. Artificial drainage projects then followed in low-leveled pumping areas of the Northern Delta. A policy was then adopted for the drainage of the cultivated area, in the light of experience gained by engineers who have worked in this field, and in accordance with the scientific development of drainage. This policy includes the following:

(1) Construction of main drains extending to a length not exceeding thirty kilometers, whether free-flow or mechanical drainage is applied.

(2) Widening and deepening all main and branch drains, with a view to providing a field drainage depth of 1.25 meters.

(3) Erection of new drainage stations where the present ones fail to stand water heads. The expected increase in heads, as a result of the provisions of the new policy, entails an increase of drainage depths.

(4) Development of the construction of drainage stations to provide the depths necessary for all lands in the UAR.

The final cost of execution of public drainage projects, on the previous bases, including the erection of pumping stations and deepening public drainage networks, amounts to about 130 million pounds.

The number of drainage pump stations executed in the UAR during the first half of the present century amounted to forty, discharging 650 m^3/sec. approximately, or fifty-five million m^3/day. These stations serve an assigned area of about 1.9 million feddans.

During the period 1952 to 1960, thirteen new drainage pump stations were erected to discharge 280 m^3/sec. and serve an assigned area of nearly 880 thousand feddans. During the First Five-Year Plan, a sum of eleven and a half million pounds was spent in remodeling and deepening public drainage networks to serve an area of 900 thousand feddans. This sum includes the construction cost of twenty-six new drainage stations serving two million feddans. In the Second Five-Year Plan, a sum of thirty-four and a half million pounds is earmarked to cover this field of activity. This sum includes the remaining cost of the stations already constructed during the First Five-Year Plan, as well as the erection and strengthening of twenty-eight pumping stations. The area which will benefit by the erection of these pumps, according to the First and Second Five-Year Plans, amounts to about three million feddans.

Field Tile Drainage

Public drains, which constitute the backbone of drainage, are unreliable in draining the land lying within their areas. The only part that could benefit by these drains is the narrow strip extending alongside their banks. Therefore, the government policy has been to generalize arteries of tile drains, spreading throughout the fields and convey drainage water to public drains. In this way, the drainage of lands could be completely effected and investment of capital spent on public drains could be realized. Hence, the government approved the policy of generalizing field drainage projects throughout the Republic at an estimated cost of about 150 million pounds, which may rise — depending on the fluctuation of prices — to about 200 million pounds.

In view of the great expense of this project, the government conducted comprehensive studies to be sure that the investments in this field are put to the best advantage. The agricultural production statistics gathered from areas where tile drainage networks had already been completed, showed that:

(1) The average yield of maize and wheat has increased in certain areas by fifty percent.

(2) The increase in the average crop yield has reached its maximum three years after the completion of tile drainage networks.

(3) Soil analysis shows that the salinity has decreased by approximately fifty-five percent.

(4) Groundwater tables have fallen forty centimeters.

During the First Five-Year Plan, tile drainage networks were completed in an area of 249 thousand feddans, at a cost of seven and a half million pounds. In view of this project's effectiveness in increasing production of the cultivated area and increasing the national income resulting therefrom, a sum of forty million pounds was appropriated by the government for the Second Five-Year Plan to provide one million feddan with a tile drainage network.

TECHNICAL

REPORTS

CHAPTER V

Drainage and Salinity

SOME DRAINAGE PROBLEMS AND DRAINAGE RECLAMATION PRACTICES IN INDIA

by
Y. P. Bali*

Summary

Every individual watershed has its own drainage problems, dependent on the climate, topography, soil and sub-soil characteristics and land use. Poorly drained areas have low productive capacity but could be improved through proper drainage.

In India, the drainage problems are more acute in northern Indo-Gangetic Plains. In the southern Deccan Plateau region the problems are comparatively less severe. About fifteen million acres† have drainage problems. Another fifteen million acres along the coast frequently get flooded due to ingress of sea water.

The main causes of drainage problems and accompanying hazards of waterlogging, salinity and alkalinity are frequent flooding, seepage from irrigation canals and insufficiency of drainage facilities. The monsoon type of rainfall further causes seasonal fluctuations in the groundwater table.

The basic approach being followed is to deal with surface and sub-surface drainage problems simultaneously through suitable flood control and anti-waterlogging measures and by providing necessary field drainage. Investigations and surveys for specific causes of drainage problems in individual areas and required reclamation measures have to be conducted.

Flood control and anti-waterlogging programs in Punjab consist of surface storm drains, lining of canals and installation of shallow tube wells. These have been briefly described.

The recently started pilot drainage reclamation projects for farm drainage at Ranbirpura (Punjab) and drainage reclamation of coastal saline lands at Umrath (Gujarat) have been outlined. These projects would investigate drainage and reclamation through open and tile drains with and

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† Fifteen million acres equal six million hectares.

without application of necessary amendments such as gypsum. Mention has also been made of a few drainage projects in Gujarat State where necessary drainage facilities are being provided, as soon as the area is brought under irrigation.

Thus, the comprehensive drainage programs in India involve flood control to reduce surface congestion, anti-waterlogging measures to check and lower rising groundwater tables, and farm drainage works to reclaim waterlogged, saline and alkali lands. The priorities are assigned to flood control and anti-waterlogging schemes. Due to limited funds, the works are being executed in pilot stages in priority areas also to serve as necessary investigations and provide useful information for larger programs in the future.

Problems and Practices

Drainage refers to disposal of water from a basin through surface and sub-surface means. Each individual basin has its own drainage characteristics. The drainage of an area is dependent on the climate, topography, soil and sub-soil characteristics, particularly their hydraulic conductivity, groundwater regime and land use. Some areas are naturally well drained, while others have poor drainage, which creates problems of excess water. Poorly drained lands have low productive capacity, particularly for agricultural production, due to excess water in the root zone and subsequent development of salinity and alkalinity. Some of these lands could be improved by providing preventive and remedial drainage measures.

Drainage Problems in India

In India, in general, the northern region has poor drainage, mainly due to flat topography, frequent floods and canal irrigation, particularly in the vast Indo-Gangetic alluvial plains. The lands have a sluggish slope with a gradient of one to two feet per mile (0.02 to 0.04 percent). Large areas get flooded during the monsoon season. Of a total of about twenty-seven million canal-irrigated acres in India, nearly fourteen million acres (fifty-two percent) are situated in these great plains.

Drainage in the southern Deccan Plateau region is comparatively good, as the landscape is broadly undulating and flood hazard is less. However, some drainage problems exist in more flat areas, local depressions and irrigated lands. The present estimates place the waterlogged areas of India at around fifteen million acres.

Along the coastline of 35,000 miles* (56,350 km) length, there is a drainage problem in many patchy areas, due to periodic ingress of sea water during high tides, thus making the affected lands saline also. Such problem areas extend over about another fifteen million acres.

Main Causes of Drainage Problems

One of the main causes of drainage problems, particularly the surface ones, and accompanying hazards of waterlogging, salinity and alkalinity, is the frequent floods in many parts of the country, especially in the Indo-Gangetic plains. The floods are caused by the erratic intensity, frequency, distribution and amount of monsoon rainfall, which is concentrated during the months of June to September. During this period about seventy to ninety percent of the total annual rainfall is received. The river valley areas have been extensively cleared for agriculture and other uses, resulting in heavy runoff in the absence of water storage structures. The floods are further accentuated by extensive construction of road, rail, canal and other embankments which sometimes have insufficient provision for drainage. It is estimated that more than 600 structures such as bridges and culverts need enlarging or remodeling to allow sufficient drainage capacity.

In the State of Punjab, rainfall records for the past twenty-five years indicate that the total rainfall for the four monsoon months of June to September at various places varies from a minimum of 4.3 inches (107 mm) to a maximum of 75.8 inches (1925 mm) with an average of about twenty to thirty inches (508 to 762 mm). Maximum intensities recorded for twenty-four hours have totaled eleven inches (279 mm) and for one hour about three to four inches (76 to 101 mm). Such erratic rainfall causes frequent floods. The

* 35,000 miles equal 56,350 kilometers.

area affected by floods in peak years in the Punjab is about three million acres and the average annual losses from the floods reach about Rs.240 million.

The concentration of rainfall within four months causes a seasonal rise in the groundwater table. In Punjab, during 1963, for example, the water table was within five feet of ground level in 82,000 acres in June (pre-monsoon) and 1.45 million acres in October (post-monsoon). Areas with a water table of five to ten feet totaled 1.75 million acres during June and 2.12 million acres during October.

Frequent floods and seasonal fluctuations in groundwater table cause periodic waterlogging and drainage problems in many areas and these are often accentuated by seepage from canal systems, extensive irrigation, and poor drainability of soils. For the success of an irrigation project, it is essential to have standard pre-irrigation soil surveys to define and demarcate irrigability classes, including an estimate of the soil drainability. Provisions for complementary drainage, where required, are necessary for sustained benefits from irrigation projects. These aspects have not received sufficient attention in the past, and more advanced technology is now available. Many of the earlier projects were started as anti-famine relief, and extensive irrigation was mainly for protection against drought periods. In salt bearing areas, this led to development of saline-alkali conditions due to insufficient leaching. Heavy water using crops like paddy and sugarcane tended to raise the sub-soil water table in the absence of proper sub-surface drainage.

The waterlogged area, i.e., with water table within ten feet of ground level, has increased from one and a half million acres to about three and a half million acres since 1951 in Punjab. Of this total nearly half is also affected by saline-alkali conditions. In Uttar Pradesh, the waterlogged area of 0.67 million acres in 1952 increased to 1.9 million acres during 1957. In Maharashtra, during the period 1924 to 1952, the damaged area in an irrigation project increased from 29,000 acres to 86,000 acres. Waterlogging has appeared in the Chambal Project in Rajasthan, which started irrigation during 1960, and about 100,000 acres are reported to have been affected. The project authorities are considering drainage.

It can be seen that both surface and sub-surface drainage problems are prevalent in varying degrees and extent in many parts of the country. They often supplement each other in cause and effect.

Present Approach Towards Meeting Drainage Problems

The hard and sad past experiences from the havocs of frequent floods causing surface drainage problems and increasing the waterlogging and salinity-alkalinity problems in the irrigated areas have led to serious considerations of the proper approach to meeting the drainage problems. The basic approach now is to deal with surface and sub-surface drainage problems simultaneously through both preventive and remedial measures, by taking suitable flood control and anti-waterlogging measures and providing necessary field drainage.

Investigations of the specific causes of drainage problems in individual areas and the required reclamation measures are essential. Investigations for the study of topography, rainfall pattern, soil characteristics, hydrological aspects, expected drainage water yields, etc., have been started. Pre-irrigation soil surveys in areas of new irrigation projects and post-irrigation surveys in affected areas are being given due consideration. However, to yield meaningful data, these surveys and investigations need further standardization of techniques and procedures. Some research and pilot projects have also been started to supplement investigations, program planning and execution of works.

Many flood control projects to provide storm drains of sufficient capacity, remodel existing channels and structures, initiate soil and water conservation measures, provide storage facilities in the drainage basins, and the training and canalization of streams, etc., are being planned and constructed. Anti-waterlogging measures include canal lining to reduce seepage, sinking of shallow tubewells to lower the water table, and installment of interceptor drains. Pilot projects for drainage investigations on the farm scale to develop suitable drainage and reclamation measures are also being executed.

Some Flood Control and Drainage Works in Punjab

A very ambitious flood control and drainage program consisting of 380 miles of embankments, 8400 miles of drains, lining of 1100 miles of distributaries, 1400 shallow tubewells and deepening of 4000 miles of drains, has been proposed in a master plan for the state. The area has been subdivided into four independent watersheds. The works in the priority areas have been started. The drains are being constructed in pilot and intermediate stages of the designed sections and will be enlarged ultimately to the designed capacity. The link field drains of less than five miles in length, to drain small localized depressions, are proposed to be constructed using the voluntary labor of the beneficiaries.

However, there is great need for drainage reclamation programs for cultivated lands that are waterlogged and are affected with salinity and alkalinity. These programs fall outside the orbit of the flood control and anti-waterlogging programs, but are essential to the overall drainage program. One pilot project at Ranbirpura has been recently started.

Ranbirpura Reclamation Project (Punjab)

The project area of about 2000 acres is bounded on three sides by canals: Bhakra main canal, a link canal and a minor canal. The fourth side is marked by a rail embankment. Within the last eight or nine years since the opening of main Bhakra canal the area has developed a high water table under somewhat artesian pressures and has also developed salinity and alkalinity.

Preliminary investigations were made for contour surveys, soil characteristics, permeability tests, etc. These investigations show that the soils are mainly loam to clay loam to clay and are impregnated with carbonate concretions two to eight feet deep. Below ten feet there is generally a permeable sandy layer. The pH values of eight to ten and exchangeable sodium of one to twelve m.eq. indicate that the soils are alkaline. Permeability of the top two feet depth was nil in most cases, and was 0.5 to 0.9 inches per hour in some good patches. Generally, soils with exchangeable sodium above 2 m.eq. were impermeable. The gypsum requirements for the top two feet for alkaline and impermeable soils varied from ten to fifteen tons per acre. Some laboratory tests on mixing gypsum with soil showed that it revived the permeability from nil to about one inch per hour.

The pilot project will provide about 400 acres with tile drains of six inches diameter, laid six feet deep, 220 feet apart in 1000 foot lengths with a grade of 1:1000. In the initial stages, however, the tile drains will be laid 440 feet apart and, if necessary, intermediate lines added later. Gypsum will be applied at the rate of ten tons per acre. The remaining area of the project will be provided with open shallow drains. In the main and carrier open drains, relief pipes will be provided to ease the hydrostatic pressure. The cost of the project is estimated to be about Rs.0.5 million over a period of three years.

Drainage Scheme in Mahi Canal Project — Gujarat State

The pre-irrigation soil surveys of the Mahi Canal Project showed that the Cambay-Matar Bhal Land area in the lower command has drainage and salinity problems and would need leaching and drainage provisions for successful irrigated agriculture. Accordingly, the extension of irrigation to this area was withheld pending detailed drainage investigations. This is an appropriate step towards efficient irrigation.

The project covers about 9,000 acres. Five hundred auger holes were studied to chart the soil and sub-soil strata for location of drains. Recovery tests of about 130 auger holes showed average values of from one half to one and a half inches per hour, which were considered satisfactory. In the absence of any experimental data, the drainage yields were calculated at the rate of one cusec per 750 acres of cultivated land and one cusec per 1,000 acres for other areas. The cultivated area is about two thirds of the total area and the drain is thus being designed for a capacity of thirteen cusecs. About 33,000 feet of open main drain of six feet depth and 18,000 feet of open lateral drains are being planned. The Irrigation Department of Gujarat State proposes to carry out the irrigation extension and drainage works concurrently.

In another area in the Saurashtra region of the Gujarat State under the Shetrunji canal project, drainage has already been provided along with irrigation in an area of about 17,000 acres which had a high water table within about three feet of the ground surface with patches of saline soils. A total length of 72,000 feet of open drains, four to five feet deep, has been provided. The cost was about Rs.50 per acre.

Drainage Reclamation of Khar Lands (Coastal Saline Lands)

As already discussed, there are vast patches along the sea coast that have become saline and poorly drained due to periodic ingress of tidal sea water. These lands generally contain toxic amounts of salts, mainly chlorides. Often the pH and exchangeable sodium are high.

The first requisite for reclamation of khar lands is the construction of suitable embankments with one-way sluice gates to stop ingress of sea water but allow the monsoon rain water to drain out. The embankments are usually constructed to a height of three to five feet above the high tide level, with seaside slopes of 1:3 and landside slopes of 1:2, with the top width varying from six to twelve feet. Thousands of acres have been thus protected at many places in the coastal states. But very little area has been brought under cultivation due to lack of proper drainage and leaching, which is the second essential for reclamation of khar lands.

Pilot Project for Drainage and Reclamation of Khar Lands at Umrath — Gujarat State

To collect necessary data on leaching and drainage requirements of khar lands, this project was initiated in 1965. Of an area of more than 1200 acres protected from sea water by embankments, 600 acres have been selected for this project. Sweet water for leaching will be available from an existing canal system.

The project area is fairly level, lying ten to twelve feet above mean sea level. Preliminary examination of soils, permeability and other factors show that soils are mainly silty loam, clay loam and sandy loam. The total salts vary from two to seven percent, pH seven to nine percent, carbonates four to ten percent, and the permeability is generally poor. Gypsum requirement is about three tons per acre.

An area of 36 acres has been selected for experimental purposes wherein drains of about three feet depth at 110, 220 and 275 feet spacing with open, pipe and rubble drains will be tried. Leaching with a total of two and a half feet of canal water per acre is proposed to be tried, and without application of gypsum. Deep ploughing and leveling will also be done. The project is estimated to cost Rs.0.52 million for a period of three years.

The projects described above have been started recently. It is expected that by the next NESA Seminar, useful data and interpretations will be available for extension of drainage works in various areas.

In the above discussions, problems of drainage in India, their main causes and the approacn to meet the various problems have been outlined. It will be seen that composite and comprehensive programs to deal with flood control to minimize surface water, anti-waterlogging measures to control and lower groundwater tables, and farm drainage works to reclaim waterlogged, saline and alkali lands have been considered. Priorities are assigned mainly to flood control and anti-waterlogging schemes as protective measures. Also, pilot projects have been undertaken in priority areas for investigational purposes and to provide useful information before launching bigger programs in the future.

IRAQ

IRRIGATION, SALINITY AND DRAINAGE IN THE IRAQI DELTA

by

Nuri Majid Hayali*

"I have gathered a posy of other men's flowers and nothing but the thread that binds them is my own."
— **Montaigne**

IRAQ — "The Country of the Sun"

"The country of the sun" is the oldest meaning of "Iraq," the latter derived from the Akkadian name "Iraqi."

The Twin Rivers

Iraq is by nature an agricultural country, with its two great rivers, the Euphrates and Tigris, flowing lengthwise through its fertile lowlands. It is one of the wealthiest countries of the world.

The Euphrates and Tigris rivers have their sources mainly in the high mountains of Turkey and Iran.

The Euphrates rises in the mountainous regions of Turkey between Lake Van and the Black Sea, and its effective catchment, which lies in Turkey and Syria, is estimated to be about 110,000 square kilometers. It has two sources, the Furat SU and Murad SU. They meet at Kharput, some 400 kilometers west of Lake Van. The combined stream, augmented by tributaries from the right bank, enters Syria at Jarablus. The river receives on its left bank two main tributaries, the Belikh and Khabur, and enters Iraq at Alqayam. About 350 kilometers after passing the frontier, the river reaches its delta near Ramadi. From this point southward, the river is confined between embankments to prevent the inundation of the adjacent agricultural lands in the high water season.

In this reach to the south of Ramadi lies Lake Habbaniyah, a large depression. The usage of this depression was proposed by Sir William Willcocks for flood control and storage of Euphrates waters. This proposal was inaugurated and executed in 1956.

From Ramadi southward, the river supply

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shrinks as irrigation by lift and flow begins on a large scale. Between Ramadi and the Hindiyah Barrage, a distance of about 210 kilometers along the river, lie all the main controlled canals and most of the pumping installations on the Euphrates.

Before the Hindiyah Barrage was built, the river split at about that point into two branches, the Hillah and the Hindiyah, and over the centuries these branches alternately assumed importance. The Hillah Branch is now controlled. Further downstream below Kifil, the river enters an unstable area where control over its water is very limited. It bifurcates again and the two branches, the Kufa and Shamiyah, are well above the level of the adjoining marshes, a very profitable rice growing area of some 17,000 hectares, and a great silttrap. The marshes drain into various channels, which combine to reform the river just above Shamiyah. Soon afterward the river bifurcates a third time and reappears once more as a single stream at about Samawa. From Samawa to Nasiryah the river flows sluggishly with a small range in levels, and in the vicinity of the latter town, numerous channels dispose of the waters and pass them into the Hammar Lake, from which the outflow finds its way to the Shattel Arab, where it joins the waters of the Tigris.

The total length of the Euphrates from Kharput to Hammar Lake is 2200 kilometers, of which 1170 kilometers are in Iraq.

The Tigris draws its supplies from two sources, the upper reaches of the main river and six tributaries which are on its eastern bank. The upper Tigris rises in the high mountain ranges of eastern Turkey in the neighborhood of Diarbekir. The first of the tributaries, the Batman SU, rises in the heart of the Hakkiari mountains, and runs in a westerly direction to its junction with the main source.

The Tigris receives almost all of its tributaries in Iraq territory. These are five in number: the Khabur, the Greater Zab, the Lesser Zab, the Adhaim and the Diyalah. Soon after entering Iraq the Tigris is joined by the first tributary, the Khabur, and about 200 kilometers below the confluence of this tributary, the river passes Mosul. The area of the river basin above this point is almost 54,000 square kilometers.

The greater part of the flood water of the Tigris is supplied by the two important tributaries, the Greater Zab and the Lesser Zab. The former has its sources in Turkey between Lakes Van and Urmia. The catchment area of the Greater Zab is about 26,000 square kilometers.

The Lesser Zab has its sources in Iran. Its catchment area is about 22,000 square kilometers. This tributary joins the Tigris at a point about thirty-six kilometers below Shergat. The river at Beled, 143 kilometers below Baiji, enters the alluvial plains of the delta. A comparatively unimportant tributary, the Adhaim River, which drains an area of some 11,000 square kilometers, joins the Tigris between Beled and Baghdad. A hundred and thirty kilometers below Beled, the river reaches the capital, Baghdad, and thirty-two kilometers farther south the Diyalah River flows into the Tigris.

The Basin of this tributary covers nearly 30,000 square kilometers of land. At Kut, 343 kilometers downstream from Baghdad, there is a barrage spanning the river, and just above it the Garraf Channel branches off. This was an ancient branch of the Tigris which is now controlled and serves a large area of winter crops.

Above and below Amara, 203 kilometers below Kut, the river splits into several well defined channels which disperse their waters over wide areas and eventually form vast marshes where rice is grown. At Qurna, about 140 kilometers below Amarah, the Tigris joins a channel which was once the Euphrates but is now fed mainly by the outflow of the Amara marshes. From this point the river assumes the name of Shattel-Arab, and on its banks stretch the famous groves of date palms past Basra.

From Qurna, the Shattel-Arab runs for a distance of 180 kilometers before it spills its water into the Basra Gulf. At Fao it is joined by the Karun River, the one tributary between the Diyalah and the Basra Gulf. This tributary originates in the high mountain ranges of Iran and drains an area covering some 50,000 square kilometers.

Development in Ancient Times

Irrigation and Civilization. The study of the ancient irrigation of Iraq requires an understanding of the archaeology of the country. The fact that irrigation and agriculture have always been a determining factor in the degree of progress of the various periods of Iraq's history was emphasized for many thousands of years, as far back as the time of the most ancient civilization of Iraq. Irrigation and civilization went side by side, contributing towards the common welfare of the human race. The most ancient Sumerian and Babylonian cities flourished on the banks of the rivers and canals which intersected the lower portion of the fertile delta land.

Iraq's greatest monarchs proudly credited themselves with the digging of a canal to carry water to a distant field or the strengthening of the river banks to protect the agricultural areas from flood.

"The lessons of order and method are taught so thoroughly by irrigation," said Sir William Willcocks, "that it is not surprising that all the ancient civilizations of the world had their birth in the irrigated valleys of the great Old-World rivers. Uncivilized men could live in woods, and partially civilized ones in desert oases, but to exist in a country needing irrigation men had to be disciplined and to be amenable to laws and regulations." The first written legislation in regard to irrigation dates back as far as the second millenium before Christ, when the famous "Code of Hammurabi" was promulgated in Babylonia. The canals were carefully designed and dug either by prisoners or by slaves of the local population. Those who failed to strengthen the banks of their canals or left the water running so that it inundated the adjacent fields were fined.

These ancient regulations show evidence of a highly organized system of irrigation, by which all cases relating to water and personal rights were governed.

Code of Hammurabi

"53 — if a man has neglected to strengthen his dike and has not kept his dike strong, and a breach has broken out in his dike, and the waters have flooded the meadow, the man in whose dike the breach has broken out shall restore the corn he has caused to be lost.

"54 — if he be not able to restore the corn, he and his goods shall be sold, and the owners of the meadow whose corn the water has carried away shall share the money."

Ancient Irrigation Systems

For many thousands of years, Iraq has been the home of perennial irrigation, just as Egypt has been the home of the ancient basin system of irrigation with its single cereal crop each year. The ancient Babylonians made every possible effort to exploit the land of the two rivers, developing a comprehensive systems of canals for that purpose. It is well illustrated by the lofty banks of ancient canal systems which may be seen today all over the southern plain of Iraq, while the high embankments which protected the agricultural areas from flood may still be seen in most parts of "lower Iraq." The whole of Babylonia, it was said, was a continuous forest from end to end. A mention should be made here of the Habbaniyah Lake on the Euphrates, which we have sufficient ground for believing the Ancient Babylonians used, together with Abu Dibbis depression, as escape for controlling floods and as reservoirs for feeding the Euphrates in its low supply. It should be borne in mind that the Tigris has always been a menace to the country. For a while the ancient settlers harnessed the Euphrates by the use of their powerful escapes, but they never managed to control the floods of the Tigris.

The most monumental irrigation work on the Tigris was the famous Numrood Dam, which was constructed at the head of the delta over 3000 years ago to feed the Nahrawan canal system on the left bank and the Dujail and Is-haki canals on the right. The dam was swept away by a tremendous flood in the year 629 A.D.

The Sassanian period, in the early century of the Christian era which followed the Greek period, is thought to have witnessed the greatest prosperity of the delta. The gigantic Nahrawan canal irrigated all of the country east of the Tigris, and the Dujail and the Is-haki irrigated the country to the west, while four other famous canals, namely the Issa, Sarsar, Melcha and Kutha, took water from the Euphrates and irrigated the fertile agricultural areas lying between the two rivers. The great flood was the first heavy blow in the history of Iraqi irrigation and its effects were still being felt at the time of the Mongol invasions, in the thirteenth and fourteenth centuries.

Development During the Arab Period

Under the Arabs, great efforts were made to restore to the country its former agricultural prosperity by encouraging the cultivators to tend their agricultural lands and gardens, by remodeling the canals, and by reclaiming a large area of the Batha' lands. Kufah, Wasit, Basrah, and finally the famous round city of Baghdad are among the large cities of the Arab period. The most valuable work of the Arabs for the advancement of irrigation was the maintenance and development of most of the irrigation systems of their predecessors, the Sassanians. The maintenance of the famous Nahrawan canal system and the remodeling of the canals of the Euphrates, namely, the Issa, Sarsar, Melcha and Kutha, were two of the prominent features of the irrigation development during the Arab period.

The Mongol Invasions and Their Effects on Irrigation Development

The Mongol invasions in the thirteenth and fourteenth centuries mark a turning point in the history of Iraq irrigation development, for with the fall of Baghdad Caliphate, which gave way to the flood of Mongol world-conquest, the final blow was struck against almost all the irrigation works in the country.

Modern Irrigation Development

The beginning of modern irrigation in Iraq may be said to date back to the year 1908 when Sir William Willcocks was called in by the Turkish Government to report on the possibilities of agriculture in Iraq, by means of irrigation. Willcocks was confronted by an almost entire lack of scientific information, but after making on the spot investigations he submitted a comprehensive report in 1911 in which he made proposals for an extensive series of large works. Two of the most urgent works, the Hindiyah Barrage and the Habbaniyah flood escape, were begun. The former was completed in 1913. The advance of the British armies in 1914-1918 resulted in improvements to and remodeling of the derelict irrigation systems throughout the country. New canals were dug and great expanses of arid lands were brought under cultivation, particularly through the rapid progress made possible by pump irrigation. The number of pumps was almost nil in 1918.

In 1921, following the constitution of the National Government, the activities of the Irrigation Department, established in 1918, gradually extended. The development areas on the Euphrates and the Tigris kept the department busy with routine work for the control of irrigation in these areas. Cultivated areas have increased considerably during the last two decades, and several new schemes have been executed, including: Kut Barrage, Ramadi Barrage, Dokan Dam, Thurthar Flood Relief, Darbandikhan Dam, etc.

In 1950 the Government of Iraq established a Development Board and then a Ministry to direct the economic development of the country. In 1958 the Ministry of Agrarian Reform took the place of the former ministry. The latter has started a huge scheme for the revival of soil productivity and for land distribution.

Recent Situation

The total area of the country within its political boundary amounts to 444,442 square kilometers (equal to 44,444,200 hectares), of which about 120,000 square kilometers are cultivable. This area is divided into two zones. The northern or "rainfall" zone is fed by rainfall, supplemented by perennial streams rising in the mountains. The area of the cultivable lands in this zone is approximately 40,000 square kilometers. The other zone is the southern zone and forms the great delta of the twin rivers, the Tigris and the Euphrates. The area of the cultivable lands in this zone is approximately 80,000 square kilometers.

In the Tigris and Euphrates valleys, the total area of good irrigable land amounts to twenty-two million mesharas,* i.e., 55,000 square kilometers. Of this, thirteen million mesharas are cultivated on a partial basis at present. The government realizes that for the thirteen million mesharas now irrigated an enormous task remains, considering that the productivity of these lands can be increased many times by providing drainage facilities.

Irrigation Practices

Irrigation practices adopted in Iraq are not conducive to maximum use of the land. The so-called fallow system is followed, whereby the land is allowed to rest in alternate years, the theory being that during the rest period the productivity of the land will be restored. But this practice has resulted in low crop yields, in comparison with those obtained in other countries where modern improved practices, including drainage and proper methods of applying the water to the lands, have been followed. About half the lands now irrigated are supplied with water by pumping from rivers and canals rather than by gravity.

Where gravity irrigation is practiced, actual control of the flow of the rivers and canals is partially provided, taking full advantage of topographic conditions and thus obtaining a maximum extent of gravity irrigation. By establishing a crop pattern for the new areas, it was possible to estimate the amounts of water required for the maximum yields of the various crops. The annual water requirements for the existing and proposed new areas are summarized as follows:

	Area in Mesharas	Water in Milliards	Requirement in Meter of Depth
Existing Area, Euphrates basin	4,900,000	6.1 m^3s	0.50
Existing Area, Tigris basin	8,100,000	11.3 m^3s	0.55
New Areas, Euphrates basin	5,300,000	12.3 m^3s	0.93
New Areas, Tigris basin	6,200,000	15.0 m^3s	0.97
TOTAL	24,500,000	44.7 m^3s	

Water needed for navigation plus dilution of drainage water recaptured from irrigated land reduces slightly the above water requirement as follows: Tigris basin total annual requirement is 26.1 milliard cubic meters; Euphrates basin total annual requirement is 18.1 milliard cubic meters; making a total of 44.2 milliard cubic meters.

In the Tigris basin, successive dry years occurred from 1930 through 1934. During this critical period the total flow of the upper Tigris and its tributaries was 162 milliard cubic meters — 32.4 milliard cubic meters a year. As the requirement is only 26.1 milliard cubic meters, it would appear that ample supply is assured.

On the Euphrates river, average flow at Hit since 1924 shows 26.4 milliard cubic meters a year. The year 1930 was the lowest, with only twelve milliard cubic meters. The lowest successive dry years were from 1930 through 1934, when the total flow was eighty-six milliard cubic meters or an average flow of 17.2 milliard cubic meters a year. As the requirement for the Euphrates projects is 18.1 milliard cubic meters a year, it is apparent that insufficient supply must be supplemented with supplies from reservoirs in the future.

* One meshara equals 2,500 square meters or 0.618 acre.

The Physiographic Regions of the Iraqi Plains

The River Plain. The Tigris and Euphrates rivers are meandering streams. The Euphrates has a somewhat higher topographical position than the Tigris. During floods, which mostly occur in April and May, large parts of the plain may be flooded. Under natural conditions the river sediments are deposited during floods, thus forming relatively high banks or river levees on each side of the stream. As the coarsest material is deposited first, these levees consist of higher textured material, such as sandy loam, loam and silty clay.

The Delta Plain. In the delta plain both rivers, Euphrates and Tigris, split into many branches, that are still meandering. The reason for this phenomenon is the decrease in the general slope of the whole alluvial plain from northwest to southeast. The groundwater table is near the surface in the basins and somewhat deeper in the levees. During floods large parts of the delta plain may be inundated. In this physiographic region, the rivers easily break through their natural levees: new branches are formed and older branches are silted up. Therefore, many old and silted up river branches occur in the delta plain.

The Marsh Region. In this part of the plain both rivers and their branches descending from the delta area split into many additional branches, which invariably end in marshes.

The natural conditions in the marsh region have not been changed markedly as a result of human activity, although man did attempt to reclaim the borders of the marshes by diverting the river branches and silting up the marsh. Thus rather large areas south of Amara have been silted up and transferred into cultivable land, used mainly for the cultivation of rice. It can thus be deduced that this activity represents the oldest land reclamation process in the world.

The Estuary Region. In this area the sedimentation is influenced by the tidal action of the sea, which makes the water in the Shatt el Arab and its branches rise and fall twice a day. The range in the fluctuation of the water level is about two meters. Saline sea water penetrates the Shattel-Arab up to Abadan. North of this city the river waters rise and fall, and there is a salt wedge at the bottom of the Shattel-Arab, extending as far as Qurna. On both sides of the Shattel-Arab small levees occur.

The Coastal Plain. This is the southern most section of the Iraqi plain. It covers the area along the coasts of the Basrah Gulf. This area is at times submerged by the sea. Lees and Falcon (1952) believed that there is tectonic movement influencing this plain: that some sections of the plain are moving upward, other sections downward. This explains the occurrence of the marshes and lakes, which would have been silted up with the river sediments some centuries back.

Soils and Salinization

Soils — Origin and Age. The soils of southern Iraq, alluvial in origin, consist generally of finely textured silt-loams, clay-loams, silty clay-loams, silty clays and clays. Coarser textured materials (sandy soils) are rare and occur almost exclusively as stream deposits in river beds and canal beds or, due to the fine texture of the soil. Permeability is generally low and good natural drainage an exception.

The soils are young, even recent, and partly man-made. Most of the area is either ancient or modern cultivation, and the soil has been laid down by irrigation waters spread over the fields year after year from rivers and canals in historical times. Tell Asmar in the Diyala Region, for instance, the plain on which the first settlers built their huts in the Ubaid Period (4000 B.C.) lies ten to eleven meters under the surface of the plain of today.

Salinization. This is the process of salt accumulation in soils. It occurs where neither the surface nor groundwaters drain away satisfactorily. Salt is concentrated by water evaporation. Sodium salts usually dominate in early stages of salinization.

Fertility of the soils in the delta plain decreased rather rapidly as soon as salinization started. According to Dr. Buringh, this happened after irrigation by canals was introduced and applied as a new technique. At present nearly the whole delta plain is saline. Saline soils can be reclaimed by drainage facilities, and the salts can be leached from the various soils.

The Salts. Most frequently accumulating in the Iraqi soils are sodium chloride, sulphate, calsium, magnesium chlorides, magnesium sulphate, and magnesium, Nitrates also occur. The ultimate source of these salts is not entirely clear. Small quantities may come from the atmosphere borne by the winds from the Basrah Gulf. The larger part presumably has come by way of the rivers from the sedimentary rocks of the northern mountains. Some salts may have been part of the pre-alluvial underground of Iraq.

The Influence of Soil Conditions on the Rise of Civilization in Mesopotamian Plain. The only serious salinity of which we have record appears to have been due to the rise of the water table caused by over-irrigation when new supplies were brought into the area. In the south, particularly vulnerable because of its high water table, salinization had decisive and lasting effects and seems to have been a major cause of the end of the brilliant Sumerian civilization.

The investigation of settlement and abandonment of land in the Diyala Region through its long history points up with great force the inherent vulnerability of irrigation agriculture to political disturbances and weakening of central irrigation control. A great irrigation system needs constant attention such as only a strong, stable government is able to provide.

Babylonians defined salt as "the curse of God." But they were unaware of the possibility of draining their lands. Thus in a boundary stone from northern Babylonia at the time of Mardukapal (1200 B.C.), one of the curses pronounced runs: "May the God Adad, Chief irrigation officer of Heaven and earth, cause wet salt to disturb his field, make the barley thirst and not allow green to come." Archaeologist Jacobsen believes that intensive drainage designed to lower the water table and to facilitate heavy leaching of the soils is not attested in ancient sources, and search for archaeological or written evidence interpretable in such terms has given consistently negative results.

Classification of Lands According to Alkali Content. Since the injury caused to cultivated plants by sulphate is very slight compared with that due to chlorides, the following scheme of classification is based mainly on the chloride content of the soil (average to a depth of six feet):

Class 1: Chloride content less than 0.030 percent. The toxic salt as well as the total soluble salt content of these soils is low. Occasionally, the presence of large amounts of non-toxic salts may increase the total soluble salt content. All cultivated plants do well on lands of this type, their yields being entirely unaffected by the presence of soluble salts.

Class 2: Chloride content 0.030 to 0.120 percent. On lands of this class all cultivated plants can be grown. The concentration of the toxic salts is not high enough to exert any injurious effect on the alkali-resistant crops. It is enough, however, to cause a marked depression in the yields of crops sensitive to alkali.

Class 3: Chloride content 0.120 to 0.180 percent. Only alkali-resistant crops can be grown on these lands.

Class 4: Chloride content over 0.180 percent. No plants will grow on these lands.

Drainage and Land Reclamation

In the low delta of Iraq a high water table rapidly develops by seepage from high level rivers and canals, from flooding, and from heavy irrigation. This may lead to local waterlogging, but this is not so important as the indirect effect of soil salinization. The delta is of marine origin, and the sub-soil is consequently saline. With a high water table, capillary action raises sub-soil water into the evaporation zone. Evaporation leaves the salt contents of the water behind. The process is a continuous one as long as the water table is high. The salt concentration in the crop root zone frequently rises to toxic proportions, which affects the productivity of the crop and, in extreme cases, puts the land out of cultivation altogether. Surveys which have been made of salt-affected lands are limited in extent, but it is estimated that on the average about sixty percent of the gravity irrigated area is affected in this way. Pumped areas largely escape this trouble as from their nature they have a relatively lower water table.

Leaching Experiments. Land reclamation has been under consideration in the Irrigation Directorate for a long time. The first leaching experiment was conducted in 1927, in the Saqulawiyah area, but owing to the inadequacy of planning and designing of the drains and to the lack of maintenance, the land soon reverted to its barren condition. In 1945 further experiments were conducted in the same area, on a firmer scientific basis. Successive leaching experiments were conducted first by the former Ministry of Development and then by the Ministry of Agriculture, in the years 1952-1960, in the Dujaila and Annanah areas.

Nature of the Salts and Their Removal. Fortunately most of the salts existing in Iraqi soils are chlorides and sulphates, readily soluble and relatively easy to remove. The carbonates and the accompanying alkaline soils, which are difficult to reclaim, are not present in Iraqi soils.

Estimated Weight of Excessive Salts in Iraqi Delta. Weight of excessive salts existed in the Iraqi Delta to a five-meter depth over an area of 150,000 square kilometers* estimated at about one milliard tons.

Technical Findings in a Nutshell

The following summary is derived from the results of the second SaQlawiyah Leaching Experiment (1945):

(1) Area leached was four hectares.

(2) Two collectors dug to a depth of one and a half meters each, spaced at a distance of 400 meters.

(3) Four drains dug, to a depth of one meter each, and spaced at a distance of fifty and 100 meters; length of each, 200 meters.

(4) Permeability of the soil defined, as fifty centimeters per twenty-four hours.

(5) Average percentage of chloride content of the soil to a depth of two meters before leaching was 1.18 percent.

(6) Quantity of water supplied for leaching in seventy days was a depth of two meters of water above the leached area.

(7) Percentage of water removed by the drains to water passing through the plots (drainage runoff) was 34.4 percent.

(8) Average percentage of chloride content of the soil to a depth of two meters after leaching was 0.10 percent.

(9) Weight of sodium chloride leached from this area to a depth of two meters estimated roughly at 1000 tons.

(10) Maximum yield of wheat was 2.450 tons per hectare (without application of fertilizer) and maximum yield of barley was 3.520 tons per hectare (without application of fertilizer).

(11) Maximum percentage of nitrogen and protein contents in wheat and barley was as follows:

	Protein	Nitrogen
Wheat	12.77 percent	2.06 percent
Barley	10.96 percent	1.82 percent

Annanh Leaching Experiment at Hillah

Situation of Plot. The experimental plot lies on the western bank of the Hillah canal and faces the Babylonian Ruins.

Characteristics of the Soils

(1) A heavy textured soil in the above one and a half meters.

(2) A high water table, less than one meter from the surface.

(3) A high salt and exchangeable sodium content in the upper thirty centimeters and a very sharp decrease below that.

Layout of the Plot. A square area of six mesharas (one and a half hectares) was chosen, divided to thirty-six square basins of 400 m² each. A drain 150 meters long was excavated first in the

* Approximate area of Iraqi Delta.

heavy profile, and ten months later it was deepened to touch the permeable layer. Drainage water was pumped into a high level channel discharging to the nearest main irrigation canal. Two sets of piezometers and several lines of underground water observation wells were installed. The location of the plot and its layout is shown on the drawing.

Soil Hydrology and Salts. The following profile is defined as the average texture of the soil as follows:

Depth Profile	Soil Texture
0-40 centimeters	Clay loam
40-130 centimeters	Silt-clay loam
130-140 centimeters	Silt clay
160-170 centimeters	Silt-clay loam
170-200 centimeters	Silt loam

An important characteristic of this profile is the presence of a stratified layer of sand and loamy sand varying in thickness from one to one and a half meters.

Drainage Water and Salt Leached. During one year, the pumped drainage water was computed to be about 15600 m^3 and the total salt content was estimated at 168 tons. The average percentage of total salt content of the drainage water was about 1.8 percent just after pumping. Then the percentage increased to 3.2 percent, and dropped to 0.6 percent at the end of the year. The following table shows the quantity of water pumped and its salt content at different dates for a period of one year:

Soil Permeability. The horizontal permeability, measured by the shallow well pump-out method, at a time when the water table was about sixty centimeters deep, was found to be as follows:

Soil Depth in meters	Average Permeability 24 hours	Soil Texture
0.60 - 1.70	0.30	Clay loam and clay
0.60 - 2.00	1.10	Clay loam and clay
0.60 - 3.60	3.30	Clay loam and clay
1.70 - 2.0	4.00	Silt loam
2.00 - 3.6	5.00	Silt loam and sand

From the above figures it could be noticed that the permeability of the upper 170 centimeters is low, but a higher permeability was found when the silt loam and sand layers were reached.

Influence of the Drain on Underground Water. At the beginning the drain was excavated to a depth varying between 1.5 and 1.7 meters, which was wholly in the upper heavy profile. It was kept at this depth for about ten months, then it was deepened to two and 2.40 meters, until the sand was reached. During the first stage, the average daily discharge of the drain was about 40 m^3 per twenty-four hours. After hitting the sand, the daily discharge of the drain rose to 430 m^3 per twenty-four hours.

Date 1957 From —	To	E.C.e. mmhos centimeters average	Average percent of Salts	Drainage Water m^3	Salt Leached in tons
2/ 1/57	13/ 1/57	22.5	1.8	155	2.8
14/ 1/57	24/ 1/57	27.9	2.2	101	2.2
25/ 1/57	16/ 4/57	23.15	1.85	3639	67.4
17/ 4/57	25/ 4/57	18.45	1.45	386	5.6
26/ 4/....	17/ 7/....	13.7	1.08	2978	32.1
18/ 7/....	11/ 8/....	11.85	0.88	1083	9.6
12/ 8/....	25/ 8/....	9.95	0.75	668	5.0
26/ 8/....	18/ 9/....	9.55	0.71	1282	9.1
19/ 9/57	24/10/57	9.10	0.68	1029	7.0
22/11/57	21/12/57	8.80	0.65	3244	21.0
22/12/57	29/12/57	8.50	0.65	998	6.3
			TOTAL	15573	168.1

Effect of Leaching on Salt Content of the Soil. The soil was leached with ninety centimeters from 17/4/57 to 25/5/57, then sown (in rice, sesame and other summer cultivations). The following table shows the E.C.e. values of the soil saturation extracts of the above twenty and sixty centimeters before and after leaching (just before sowing):

Basin No. (average)	E.C.e.(mmhos/cm.) 0-20 cm. before	after	E.C.e.(mmhos/cm.) 0-60 cm. before	after
(1 - 6)	42	10	22	12
(7 - 12)	33	10	13	9
(8 - 18)	29	6	17	5
(9 - 24)	25	7	14	5
(25 - 30)	10	6	8	4
(31 - 36)	7	5	6	2.5

It is apparent here that leaching with ninety centimeters of water in one month dropped the salt content of the upper sixty centimeters to a level low enough for germination of summer crops.

Effect of Subsoil-water Depth on Leaching. The following table shows the effects of rice cropping on leaching and the changes of salt content of the soil to a depth of two meters:

Salinity in different stages expressed in E.C.e. of mmhos/cm.

depth in cm.	before leaching	before rice cropping "after leaching" forty centimeters	ninety centimeters	after harvest
0 - 20	35.6	13.7	9	3
20 - 60	10.8	11.0	8.6	2.3
60 - 100	7.5	7.4	....	1.8
100 - 200	5.0	6.6	....	1.8

Rice Cropping, Summer of 1957. Two mesharas (half hectare) were put under rice cultivation at a sowing rate of twenty kilograms per meshara. Seeds were soaked in water for five days and then sown. When they started to germinate on the soil surface, which was covered with water, nitrogen fertilizer was applied to the soil to assess its effect on the yield. Two application rates of pure nitrogen were used: seven and a half and fifteen kilograms per meshara. The fertilizer was applied to the soil in two equal applications, on July 28 and the other on August 20. During the growing periods, which lasted three and a half months, the rice had thirty-nine waterings with an approximate total depth of two meters.

The water was kept on the basin by small bunds, to soak into the soil, and was not allowed to flow from one basin to another. The salt content before sowing and after harvest, the rice yields of different basins, and the consumptions of nitrogen applied, are summarized in the following table:

Basin No.	Yield Kgs Meshara	Nitrogen Kgs. Meshara	E.C.e. before	—0.20 m. after	average	E.C.e. before	0.60 ms. after	average
1	673	0	12.3	4.3	8.3	15.3	6.6	11.0
2	720	7.5	12.5	3.3	7.9	15.6	1.4	8.5
7	860	15.0	13.2	4.6	8.9	10.4	1.2	5.8
8	630	0	13.2	5.3	9.3	11.9	2.9	7.4
13	805	7.5	6.7	2.9	4.8	7.7	1.6	4.7
14	785	15.0	6.8	4.0	5.4	5.5	3.6	4.6
19	920	15.0	4.7	3.8	4.3	3.2	2.4	2.8
20	850	7.5	5.1	4.5	4.8	3.8	1.9	2.9
25	760	0	9.8	1.2	5.5	6.4	1.7	4.1
26	975	15	8.3	2.2	5.3	8.4	1.6	5.0
31	1004	7.5	4.0	1.3	2.7	2.6	1.1	1.9
32	950	0	3.5	1.7	2.6	2.4	1.3	1.9

Analyses and Comments. The following points can be deduced from figures enlisted above as follow:

(1) Rice can tolerate salinity up to E.C.e. of ten mmhos per centimeter with good yields.

(2) The lowest yield was 630 kilograms per meshara in basin eight, which had an E.C.e. of 13.2 mmhos per centimeter and not fertilized.

(3) The maximum yield was 1004 kilograms per meshara in basin thirty-one, which was fertilized with seven and a half kilograms of nitrogen per meshara and had E.C.e. of four mmhos per centimeter before growing.

(4) The next highest yield of 975 kilograms per meshara was in basin twenty-six, which was fertilized with fifteen kilograms of nitrogen per meshara. But the salt content of this basin was higher than the salt content of basin thirty-one. It can be deduced from these findings that the effect of nitrogen on the rice yield has been dominated by the excessive salt content of the soil.

The End of the Attainment

Supplementary short notes on irrigation and drainage practices, soil and water:

(A) Irrigation Practice

(1) Capacity of a canal is indicated by its discharge at full supply levels.

(2) Canals should be run for irrigation purposes either on full supply or closed. During the closure rotations of small supplies may be run for domestic and drinking water requirements, etc., which are of course greater in the summer than in the winter.

(3) Canals should generally be designed to supply irrigation requirements at the period of maximum demand, with the whole canal system on continuous full supply.

(4) Period of maximum demand is from about March 5 to April 15, when winter and summer crops overlap. During this period an allowance of one cubic meter per second (one cumec), measured at cultivators' offtakes, will irrigate about:

6000 mesharas of winter cereals, using about 0.80 cumec.

600 mesharas of garden and catch-crops using about 0.08 cumec.

600 mesharas of cotton, or any other summer crops (except rice) using about 0.12 cumec.

Thus, during this period, one cubic meter per second (one cumec), will irrigate 7200 mesharas.

(5) Above discharge, allow during this period the watering of about eight centimeters depth each thirteen days on cotton and twenty days on other crops, after providing for losses on cultivators' main channels.

(6) Normal intensities of cultivations at the period of maximum demand are:

Fifty percent winter cereals; five percent gardens and catch-crops; five percent cotton or any other summer crops (except rice); making a total of sixty percent.

Canals are then designed with a capacity of one cumec per 12,000 mesharas cultivable, plus losses in main canals, etc.

(7) Capacity Factors:

(a) During winter and spring seasons the demand is normally according to capacity factors listed below, in order to irrigate the crops indicated in point 4 above.

Nov.	Dec.	Jan.	Feb.	March	April	Average
80	70	55	50	90	75	70

(Figures in percentages)

(b) Average requirements of all summer crops (excluding rice) can be taken as being one cumec per 3000 mesharas cultivated, which allows one watering of about ten centimeters depth every twelve days, average, after providing for the greater losses during summer in the cultivators' main channels.

(c) If ten percent of a cultivable area of 12,000 mesharas is planted with summer crops, then the irrigation supply required will be

$$\frac{1200}{3000} = 0.40 \text{ cumecs}$$

and the canal in point 6 above will normally run on capacity factors listed below:

May	June	July	August	September	Average
35	45	45	45	30	40

(Figures in percentages)

(d) In October there is little demand for irrigation water and a normal capacity factor is twenty percent.

(B) Drainage Practice

Data applied in layout of drainage pattern are as follow:

Branch Drains. Average depth* of drains is between 1.8 and two meters, with drains spaced at a distance between 1500 and 2000 meters.

Collector Drains. Average depth of drains is between 1.5 and 1.80 meters, with drains spaced at a distance between 500 and 600 meters.

Field Drains. Average depth of drains is between one and 1.20 meters, with drains spaced at a distance between fifty and 100 meters (spacing depends on the permeability of the soil).

(C) Soil and Water

(1) The saline soils of Iraq fall under the class of "Solonchaks." They belong to the type of solonchak containing great reserves of calcium in both soluble and insoluble forms. On reclamation the solonchak is converted to a solonetz of the extreme type, containing great reserves of calcium, and in time it becomes the fertile chestnut of desert soil.

* Depths are defined here as the difference between the natural ground levels and the water levels in the drains.

(2) Black alkali has never been found in Iraq.

(3) The waters used for irrigation and washing are in the main from the Tigris and Euphrates rivers. Both rise in limestone mountains and when in flood carry much fine sand, silt and clay in suspension. Records show that at the peak of a flood this material may be as high as two and a half percent by weight of water. The water has a maximum content of about 30 parts per 100,000 of dissolved salts, of which only a very small proportion is chlorides. The waters of the Tigris and Euphrates are at all times perfectly safe for irrigation and leaching.

(4) The difference in solubility of sodium chloride and gypsum is of enormous importance in leaching. The chloride of a soil can be leached out long before the gypsum has been dissolved. The leached soil therefore retains calcium in a soluble form and sodium clays are never produced. It should be clearly stated that the object of leaching a soil is to remove the injurious chlorides, not to remove all salts. The gypsum must not be leached out.

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Irrigation duties and preliminary runoff coefficients used for Drainage Projects in Iraq:

Categories	Unit	mm/day Main branch field I	II	III	mesharas per m^3/S Main branch field I	II	III
	Irrigation Present Allowance:						
(1)	Shitwi — Cereals		4.6	4.6			
(2)	Shitwi — Gardens		4.6	4.0			
(3)	Saifi — Cotton		6.9	6.15			
(4)	Saifi — Garden		4.6	4.0			
(5)	with sixty percent intensity expressed in cultivable (Gross) area		2.875				12,000
	Drainage - Runoff						
(6)	Washing			6.5-7.5			
	Normal Irrigation						
(7)	60 percent intensity		0.892	1.273		38,700	27,000
(8)	100 percent intensity		1.449	1.777		23,800	19,400
	Including Seepage Runoff						
(9)	60 percent intensity		0.94	1.34		36,800	25,600
(10)	100 percent intensity		1.52	1.86		22,600	18,400
(11)	From irrigated area without any branch drains		0.22			155,000	
(12)	As above but with branch and without field drains		0.45	0.64		77,400	54,000

THE PROBLEM OF WATERLOGGING AND SALINITY

by

Ch. Mohammad Hussain*

Irrigated agriculture all over the world exhibits similar problems of waterlogging, of salinity, or of waterlogging and salinity together. West Pakistan is confronted with these twin problems. According to estimates of the annual salinity survey, of thirty-seven million acres within the command of irrigation systems of Indus Basin, the area damaged by severe salinity is 5.6 million acres, moderate salinity 1.4 million, and mild salinity 10.2 million acres. This is forty-six percent of the total area of 37.7 million acres and agrees quite well with the estimate of forty-four percent obtained from soil survey work in the drainage project areas.

The extent of normal good lands in the northern region is fifty-six percent compared to thirty-one percent in the southern region. Ultra saline lands, or those with a very high order of salinity, are found much more in Sind than in Punjab, the proportion of the two being fifty-four and twenty.

Most of the area in the northern region of the Indus Basin is either saline-alkali or non-saline-alkali, the percentage of such areas in Rechna, Chaj and Lower Thal Doabs being fifty-eight, thirty-four and forty-four percent respectively. The percentage of non-saline-alkali soils for Rechna, Chaj and Thal Doabs is fourteen, nine and seven, and that of saline soil is five, eight and six. As the majority of our lands are saline-alkali and non-saline-alkali, high alkalinity might create serious problems under tubewell irrigation, with a high concentration of carbonates and bicarbonates.

Division of the area in respect to chemical nature of the profile to a depth of six feet, is shown in the following table:

Name of Doab	Total No. of Bores	Percentage of soil profile representing			
		Normal	Saline	Saline-Alkali	Non-Saline-alkali
Rechna	1944	37	5	44	24
Chaj	4657	58	8	25	9
Lower Thal	2159	50	6	37	7
Average	48.3	6.3		45.3	

* Director, Land Reclamation, West Pakistan

Source of Salinity

The main source of salinity is the existence of salts in the soil profile. These salts may be the remnants of the period when alluvium was deposited in the sea water. Under pre-irrigated conditions these salts had a distinct distribution pattern under the then prevailing meteorological conditions. This pattern of distribution of salts was changed with the introduction of canal irrigation. Salines began appearing along with the rise of water table in the upper region of Rechna Doab a few years after the opening of the Lower Chenab Canal in 1892. At that time, the water table in other parts of the Doab was fairly deep and irrigation applications were quite adequate to take care of the consumptive use of crops and the leaching requirements of soil. There were no signs of the spread of salinity in deep water table zones in lower parts of the Doab. Salinity was attributed to the high water table conditions, the groundwater being the source of salts. The earliest salinity surveys (Thur girdawaris), started in 1927 by the Waterlogging Enquiry Committee, were confined therefore, to areas where the water table was within five feet of the ground surface.

The investigations conducted later in 1937 in deep water table areas revealed that salts were originally present in the soil crust, and their movement toward the surface was not caused by water table alone, but was due also to low surface irrigation applications and unscientific irrigation practices. The quantity of water intended for a designed intensity of seventy-five percent cropping is now applied on more acreage under the present increased intensity of cropping, which is about 120 percent. The total water supply per unit area is about forty percent short of the requirements and is inadequate to keep the trend of salt movement downward. This is one of the major causes of the spread of salinity over the areas where the water table is below twenty-five feet from the ground surface.

The concentration of salts in the soil profile was further aggravated with the rising groundwater. According to our estimates, under existing water table conditions, in a majority of the areas under varying concentrations of groundwater, the salts are being added at a rate of from 1450 pounds to 8000 pounds per acre per year in the northern region of Punjab. In Chaj, Rechna, Thal and Bari Doabs, constituting an area of 16.4 million acres, about 4.36 million acres have saline groundwater of the order of over 1000 parts per million, as shown in the following table:

Region	Total area	Saline water quality area above 100 ppm.	Good water quality area salts less than 1000 ppm.
Rechna Doab.	4.7	0.7	4.0
Chaj Doab.	2.0	0.42	1.58
Thal Doab.	5.3	1.48	3.82
Bari Doab.	4.4	1.76	2.64
TOTAL	16.4	4.36	12.04

In addition, some salts may have been added from the river irrigation water, the concentration of which varies from 100 to 250 parts per million. Theoretical calculations indicate the addition of salts at the rate of one ton per acre annually.

Our Experience and Research Findings

We have had long experience in the use of good quality river water, for the past sixty to seventy years. We have also been quite in line with the advanced countries in our understanding of soil-water-plant relationships. Based on our experimental work, both in the laboratories and at the field experimental stations of the Directorate of Land Reclamation, we emphasized the need for revision of the water allowance to meet the consumptive use of water by crops and leaching requirements of soil in view of the increased cropping intensities. The revised water allowance suggested was one cusec for 150 acres instead of 350 acres. This has now been adopted in the salinity control projects.

Similarly for the reclamation of saline and alkali soils, we recommended a water allowance at a rate of one cusec for forty-five acres during the process of reclamation for a period of three to eight years. This gives an annual depth of seventy to eighty inches during the summer flood season from April to the end of September.

From the Lysimeter studies and field experiments we were also able to determine the rate of upward movement of salts under varying water table conditions with respect to the irrigation and cropping intensities. Under the present irrigation and 120 percent cropping intensity, the depth amounts to 2.4 feet, compared to 4.5 feet originally prescribed at seventy-five percent cropping intensity. From these studies it can be inferred that the root zone of a soil profile having a salt concentration within the permissible limits is resalinized in seven to eight years in deep water table areas, and in two to four years in high water table areas. On the basis of these facts introduction of rice or any other crops requiring heavy applications was suggested in the cropping pattern once in seven years for areas with groundwater table beyond ten feet, and every two to four years where the water table is within five feet. This was necessary so long as the existing water allowance of one cusec for 350 acres is not revised adequately to take care of consumptive use of the crops and leaching requirements of soil under an efficient drainage system.

All that I have narrated above relates to the irrigated agriculture that we have been practicing with good quality river water. In the use of groundwater, which is certainly of an inferior quality, our experience is very recent.

Use of Underground Water for Irrigation

In the evaluation of the suitability of groundwater for irrigation, we adopted the standards of classification of irrigation water on more or less the same pattern as those followed in other countries.

Even with these standards, the most recent appraisal made by Bower and Maasland for the quality of groundwater, which appraisal is used in Hafizabad, Khanqah Dogran, Jaranwala and Beranwala schemes, has revealed some interesting results. It has shown that of seventy-four tubewell waters, more than two-thirds contain residual sodium carbonate and half have calculated ESP values in excess of fifteen. It further shows that waters with residual Na_2CO_3 exceeding 2.5 meq/L are hazardous for irrigation use and on this account thirty-nine percent of the 729 Rechna Doab tubewells studied were considered hazardous.

Prior to the appraisal by Bower and Maasland, an appraisal was also made of the groundwater of 2154 tubewells in the SCARP I area on the salt concentration basis alone. These observations are available in the Progress Report of SCARP I, which was issued for the information of the White House Interior Panel. The quality of groundwater of 100 tubewells, on the basis of salt concentration — having electrical conductance over 3000 micromohos per centimeter — was considered unfit for irrigation purposes. That of another 297 tubewells with electrical conductance, ranging from 1500 to 3000 micromohos per centimeter, was also considered unfit for irrigation if applied alone. This water could be used however, by mixing 1:1 with the canal water supply according to the standard mentioned above. To accomplish this, we were short by 414 cusecs of fresh canal water. This created another problem for the permanent arrangement of fresh canal water in the area. Maasland and his associates also suggested mixing of tubewell water and canal water in 1:3.8, 1:2.1 and 1:1.2, to lower the ESP of hazardous tubewell waters to ten, fifteen and twenty respectively. That would mean a still greater need of fresh canal water in SCARP I. They considered the use of gypsum unfeasible because of the large quantity required. About 1.4 short tons of pure gypsum is required per day per three cusecs tubewell to precipitate two meq/L of residual carbonate.

The quality of water in some other schemes of SCARP I is still worse. Shahkot scheme is an example: Of 319 tubewells examined, the water of 284 tubewells has a calculated ESP of more than twenty. This is eighty-nine percent of the total.

As already indicated in the country report, eighty percent of the water was considered usable in the northern zone, having a salinity concentration of less than 3.000 ppm. It has now been demonstrated that possibly more than one-third of the groundwater that appears to be safe for irrigation, when only total dissolved salts are considered, may be hazardous because of sodium or residual sodium carbonate concentration.

The use of groundwater will therefore require special consideration for the designs of these canal and tubewell systems, in the distribution of surface water, and in the operation of canals and tubewells.

In the end, I would express my personal reaction in regard to the indiscriminate use of these waters. We may be able to solve the problems of waterlogging for the time being, but on the other hand we might possibly aggravate the salinity and alkalinity problems. In certain quarters the provision of more supplies through tubewells has been viewed as a measure of increased crop production and eradication of waterlogging. This may be true for the time being, but sustained agricultural production may suffer in the long run, unless a detailed scientific and precise study is made of the effects of sub-soil saline water. This calls for further research work and implementation of these schemes under the strict supervision of scientific personnel.

We have laid out some experiments both in the laboratory and in the field which are yet in a preliminary stage. Some of the experiments completed in the laboratory are presented in a separate technical paper.

DRAINAGE AND SALINITY PROBLEMS IN TURKEY AND MALTEPE TILE DRAINAGE PROJECT

by

Bahattin Sayan*

Summary

An area of 3,333,300 hectares in Turkey requires reclamation due to high water table and salinity. A great percentage of these lands are not suitable for agriculture, and while the rest can be used for agriculture, the yields are very low.

These problem areas are usually the result of lack of natural outlets and improper irrigation systems and practices.

Training of farmers, government investments and experimental data are considered together in the development of these problem areas.

Demonstrations, field days, farmer training camps, lectures, seminars and publications are the tools of the farmer training program.

To keep the government investments at an economical level, many experimental projects were conducted to collect required data for large projects. These can be termed pilot projects. One of them, the Izmir-Menemen-Maltepe tile drain project, is presented in this paper.

The project area is in Izmir-Menemen plain, surrounded by the Aegean Sea, Gediz River and Kozluca Dike, with an area of 24,500 decares.

The problem area is outside of the state irrigation system. Problems in the area include a high groundwater table, which has its source in the Gediz River and two small lakes; saline and alkali soils, and non-existence of a natural outlet.

After project surveys, the following measures were considered to be applicable to the area:

(1) An effective deep drainage system.

(2) Chemical treatments together with drainage to leach out the (Na) ions.

(3) An effective irrigation system.

(4) A good surface drainage system.

(5) Salt-resistant crops to be grown during the reclamation period and proper crops to be grown after development.

Before applying these measures to the whole

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problem area, a pilot project was established, covering 250 decares of land in the area. The results were used in formulation of the overall project.

Deep drainage by pumping, chemical treatments, and the other measures gave satisfactory results. These results attracted the farmers' interest and they joined in a cooperative to contribute to the reclamation costs of other areas near the pilot project.

In light of the progress, this type of project is expected to expand to all problem areas in Turkey to fulfill the requirements in the development of saline, alkali and marshy lands.

Problem Areas

From the General Soil Map of Turkey it is observed that 3,639,765 hectares of land require reclamation with regard to high groundwater table, salinity and marshlands.

Table 1. Soil Types Requiring Reclamation, and Their Present Use

Soils:	Area (Hectares)	Arable Lands (Hectares)
Young alluvial soils	820,400	
Hydromorphic alluvial soils	1,703,200	1,021,920
Hydromorphic saline soils	650,200	130,040
Coastal sand soils and marshlands	396,265	122,600
Saline solonchak soils	69,700	
TOTAL	3,639,765	1,274,560

Some 1,274,560 hectares of these problem areas are arable lands, but normal yields cannot be obtained. The remaining 2,365,205 hectares are non-arable land due to the high groundwater table, alkalinity, and marshlands.

Factors Creating the Problems

(1) *Natural Factors*

The formation of marshlands in lower areas, due to insufficient drainage for the disposal of rainfall water, and the formation of saline and alkali marshlands and dunes on deltas of alluvial coastal plains, are the results of natural factors.

(2) *Physical Deficiency of Irrigation Systems and Inadequacy of Irrigation Practices*

The following deficiencies have caused the high groundwater table and salinity problems in irrigation systems opened to the use of farmers:

(a) Inadequacy or non-existence of outlet systems for the disposal of the excess irrigation water and the runoff from rainfall.

(b) Inadequacy or lack of main drainage systems which will provide sub-surface drainage.

(c) Non-existence of lined canals to prevent seepage from irrigation canals crossing pervious soils.

(d) Management of water not in conformity with the best irrigated farming principles, and the application of irrigation water in excess of the crop requirement.

According to the statistical data from recent years, 110,765 hectares of land, within 270,360 hectares covered by irrigation systems, have high groundwater and salinity problems.

(3) *Inadequacy of Farmer Training in Irrigation and Drainage*

Farmers do not have adequate knowledge of irrigated farming. Therefore, the anticipated benefits from irrigated farming cannot be fully realized.

Farmers irrigate their lands without preparing them for irrigation. Most of the farmers have neither land leveling nor field irrigation and drainage systems on their lands.

Since the irrigation intervals are not properly determined, irrigation water is frequently and excessively applied, and a crop rotation suitable to the local soil conditions cannot be properly conducted.

In addition to all these deficiencies, the lack of repayment ability of the farmers can be mentioned.

Measures for Solving the Problems

The efforts made during the past six or seven years to solve the problems presented above, have produced favorable results. These efforts can be classified into four groups:

(1) *Training and Teaching*

Drainage applications and research in various areas have been demonstrated to farmers on certain "field days."

Farmer training camps on drainage and land reclamation have been organized in various locations. In these camps, farmers are trained during the implementation of drainage and reclamation projects.

Courses and lectures held both for civil and military service groups and publications to increase the knowledge of farmers in related subjects have been of much value.

(2) *Technical Aids*

Technical aids are made to help farmers establish associations and to guide them in the improvement of lands of joint ownership; to make the necessary surveys for drainage and reclamation of private lands and lands of farmer groups and public institutions; to make plans, design projects, and control the implementation of projects; to design drainage and reclamation projects that will be a basis for bank loans, and to control their implementation.

(3) *State Investments*

Implementation of main drainage systems which provide outlets for field drains are realized by state investments. At present, field drains are financed by the farmers or by loans to the farmers. Field drains and treatments necessary for the reclamation of saline and alkali soils will be subsidized in the near future. Cost-sharing procedures are being prepared for this purpose.

(4) *Experimental Work in Research Stations*

Experiments related to the drainage of irrigated lands and the reclamation of saline and alkali soils are conducted in research stations.

(5) *Pilot Projects*

Design of drainage projects may be accomplished by using analytical formulas or by using the results of experiments. Generally analytical formulas are developed by assuming certain soil and flow characteristics which may not be valid for a certain project. The results of drainage experiments cannot be used in areas where soils are different from the ones on which the experiments were conducted. Thus, is would be safe to select pilot areas of such a character as to represent the total project area so that the drainage criteria suitable to the characteristics of large areas can be determined with the preliminary experiments in these pilot areas. The results of the pilot projects can then be used for the drainage projects of larger areas.

Izmir-Menemen-Maltepe Tile Drainage Project

The Maltepe Tile Drainage Project is presented in the following paragraphs to illustrate the procedure adopted to solve drainage problems in a certain area:

(1) *Description of the Project Area*

Location: The project area is located within the Izmir-Menemen-Maltepe Plain and is surrounded by the Aegean Sea, Gediz River and Kozluca Dike. (Figure 1)

The project area is 24,500 decares. Six hundred farmers have lands in the project area. Since 1945, when irrigation activities were begun, many of the farmers having a good income have had to leave their lands because of the increasing salinity.

In 1960, in response to an application by the farmers to TOPRAKSU organization, the project area was taken into the TOPRAKSU Survey Program and the preliminary surveys were conducted in that same year.

Topography: The project area has uniform slopes of 0.25 - 0.30 percent in northern and southern directions. Its maximum altitude is four meters and an average altitude is about two meters.

Climate: The project area has mild winters and hot summers. Precipitation is high in winter. Monthly precipitation and temperatures are shown in Table 2.

According to the thirty-year average, the annual rainfall is 716 millimeters. The maximum annual precipitation is 1117 millimeters (in 1944), and the minimum annual precipitation is 488 millimeters (in 1934).

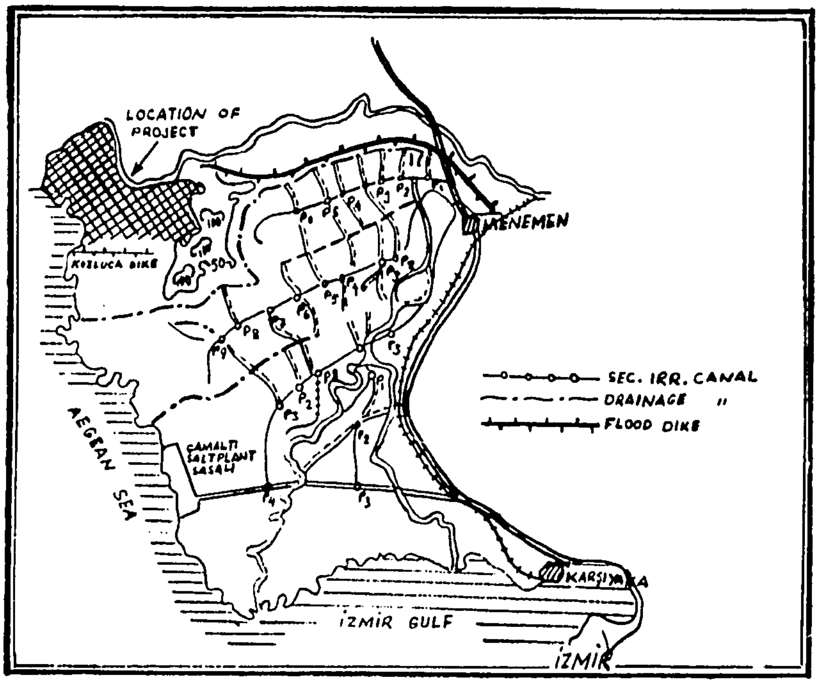


Figure 1. Project Area.

Table 2. Monthly Precipitation and Temperatures (Thirty-year average)

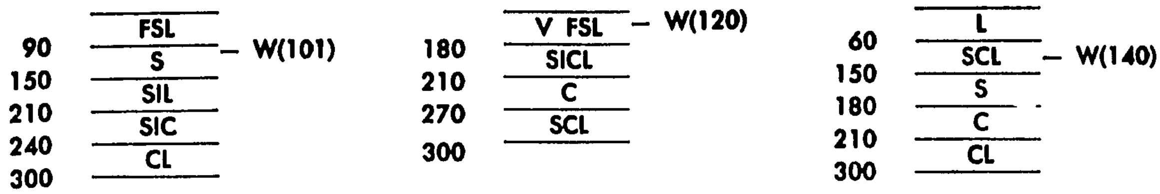
Months	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Precipitation (mm.)	130.2	104.1	69.5	53.1	44.3	13.0	6.7	2.6	15.9	46.2	93.6	137.5	716.7
Temperature C°	6.8	7.9	10.2	15.0	20.0	24.8	21.7	27.3	23.0	17.6	12.3	8.2	16.7

The maximum temperature is 44.5 degrees centigrade in August and the minimum temperature is −17.5 degrees centigrade in January. The annual relative humidity average is sixty-three percent; the minimum relative humidity is one percent in May.

Soils: Soils within the project area are of alluvial character. The soil profile is generally of medium light texture up to 1.80 - 2.00 meters depth, and of finer texture in lower depths.

The typical soil profiles within the project are shown in Figure 2.

Figure 2. Soil Profiles



The project area has saline, saline-alkali and alkali soils.

Permeability tests have been conducted according to the Auger Hole method in eighty wells dug in the area. The results of permeability tests for fifteen wells that represent the total area are given in Table 3.

Drillings made by deep drilling rigs for barrier determination show that a barrier consisting of a clay layer two meters thick is located twenty-eight meters below the ground surface.

Table 3. Results of Permeability Tests

Well Number	Well Depth in meters	Depth of water in meters	Permeability meters per day
10	2.10	1.20	5.5
10/A	2.00	1.20	3.6
10/B	2.10	1.05	4.8
24	2.10	1.48	2.8
35	2.10	1.30	2.85
48	2.26	1.64	2.1
64	2.10	1.20	3.0
65	2.00	0.97	3.3
69	2.10	1.20	4.2
70	2.00	1.00	4.0
71	2.10	0.90	2.9
72	2.00	0.97	3.7
73	2.10	1.52	3.0
78	2.10	1.20	4.3
79	2.00	1.00	4.00

Crops: Cotton, grain and rice are grown in seventy-two percent of the project area, but the yields are low. Twenty-eight percent of the area is not cultivated.

Water resources: The project area is outside the state irrigation systems. Farmers generally supply irrigation water by pumping from Gediz River. There are two lakes on the east of the project area; the bigger of these lakes is in private ownership and used for supplying irrigation water; the smaller one is not used for irrigation purposes: Table 4 shows the analysis of water samples taken from Gediz River and the lakes. There is a groundwater aquifer four meters thick, seventy-eight meters below the ground surface, but its water is excessively saline.

(2) *Problems*

(a) *High Groundwater Table*: Observation wells drilled by augers at 500 x 500 meters interval showed that a high groundwater table is the major problem of the area.

According to the observations, in seasons when the groundwater table is lowest, the average groundwater level is about 0.90 - 1.20 meter.

Piezometric studies show that the high water table is caused by Gediz River and the two lakes, one in Salih Eroglu Farm and the other on the boundary of the project area.

Table 4. Analysis of Surface Waters in the Project Area

Water Resources	PH	Electrical conductivity E.C $10^6 25^0$	Residual Sodium Carbonate	SAR	Salinity (That may be created on soil by the water)	Alkalinity
Gediz River	8.20	618	27.00	1.15	Medium	Very little
Salih Eroglu Farm lake	7.20	4818	45.44	5.50	Very high	Little
Lake on the boundary of project area	8.15	803	51.74	3.15	High	Little

Water table in the project area rises after irrigation and rainfall, as observed by measurements in the observation wells.

Since the irrigation canals are not lined, seepage also causes a high water table. Seepage rate is thirty-eight to forty percent, according to the research results obtained by Menemen Irrigated Farming Research Station. Piezometer batteries, installed at 3.5 - 5, 5 - 7.5 meter intervals in various locations of the project area, have not shown any artesian pressure, but all the batteries have shown only groundwater flow.

As shown in Table 5, the groundwater quality can cause excessive salinity and alkalinity in the soil.

Table 5. Groundwater Analysis

Water Resources	PH	Electrical Conductivity E.C. 10''25''	Residual sodium carbonate	SAR	The probable salinity and alkalinity created in the soil by groundwater	
					Salinity	Alkalinity
A4	7.00	12675	70.91	23.10	Very high	High
B1	7.12	25350	68.39	28.57	Very high	Very high
C2	7.14	36214	76.09	43.00	Very high	Very high
E1	6.90	46090	71.86	45.86	Very high	Very high

(b) *Saline-Alkali Soils*: The groundwater table has caused the salinity-alkalinity in the soil to increase. The soil surveys showed that eighty-five percent of the area is of a saline-alkali character.

(c) *Lack of Outlet*: In the project area there is no adequate outlet either for groundwater flow or for runoff from the rainfall and excess irrigation water. The surface drainage canal opened parallel to Kozluca Levee is functioning. However, its capacity is insufficient for the runoff water of the total area.

(3) *Reclamation Method*

The results of the surveys show the following requirements:

(a) Effective deep drainage system

(b) Chemical treatments for reclamation

(c) Rehabilitation of the irrigation system

(d) Need of a surface drainage system

(e) Works on the crop varieties to be grown in the area during and after the reclamation.

(4) *Pilot Project*

Some 250 decares of land (Figure 3) of such a character as to represent the total project area were chosen as a pilot project area on which drainage and reclamation criteria for the entire project would be determined.

The work conducted in this pilot project is as follows: Determination of drain spacing; application of chemical material for alkali improvement; determination of crop adaptation; demonstrative works.

(a) *Works on the determination of drain spacing*. As shown in Figure 3, a plan for the pilot project area has been designed to have experimental drains on spacings of 60 - 80 - 100 - 120 - 140 meters. Drain depths are 1.70 - 2.00 meters, drain lengths are 300 meters, and tile diameters are ten centimeters at sixty to eighty meter intervals, thirteen centimeters at 100 to 120 meter intervals, and sixteen centimeters at 140 meters intervals. Gravel filter around the tiles has a minimum thickness of ten centimeters. Due to the lack of an outlet of sufficient depth, tile lines (field drains) are drained into an open collector drain of 500 meter length and 2.70 meter depth.

A sump was constructed at the downstream end of the collector drain and the water is pumped with a four-inch centrifigual pump from the sump to a canal. The canal conveys the water to the main drain near Kozluca levee, a distance of one and a half kilometers.

The observations made during the two-year period show that a drain spacing of 100 meters would be suitable for a two-meter depth in the soils described in the above sections. In the same area, the drain spacing was computed to be sixty meters according to the Donnan formula, and ninety meters according to the Hooghoudt formula.

(b) *Application of chemical material for alkali improvement.* The amount of gypsum ($CaSO_4$-$2H_2O$) for alkali improvement was estimated to be 500 kilogram per decare. However, due to the high cost of transportation, 100 kilograms of sulphur (S), which is equivalent to 500 kilograms of gypsum, was applied at the rate of 100 kilograms per decare in the pilot project area.

(c) *Work on crop adaptation.* Cotton and clover were grown in the pilot area after reclamation. The yield of cotton in the third year of reclamation amounted to 350 kilograms per decare. This result is considered favorable when compared to the yield of the Menemen and Maltepe Plains and even to the average cotton yield in Turkey.

(d) *Demonstrative works.* One of the most important problems is to present to the farmers the structures related to the closed drainage project, which were used in the Aegean Region for the first time. The project was explained to farmers and as a result all the farmers in the Aegean Region who felt hopeless about the future of their lands because of salinity and high groundwater have been encouraged.

(5) *Formulation of the Projects Based on the Result of the Pilot Project*

In this project, the results of the work conducted on a pilot project area of 250 decares are used for solving the problems of the total project area of 24,500 decares. The favorable results of the pilot project have encouraged the farmers to endeavor to reclaim their saline and alkali lands which were deserted. To realize this objective, they have established a cooperative and have applied for government assistance for their project. Activities comprising the total project area have been started following the establishment of this cooperative. In the implementation of this project, private investments as well as public investments have an important role.

The drainage plan is given in Figure 4. The main drains (A,B) and collectors (A_1,A_2,A_3,B_1,-$B_2B_3B_4$) will be financed by the government. The purchase and operation of pumps, maintenance and operation of the entire installation and farm drains will be financed by the cooperative.

The government investments were planned for completion in 1965 and 1966. In 1966, private investments are being made as well, and farm drains are being laid down following the works on collectors connected to the main "A" drain, which was completed in 1965. Drains are of 0.15 meter diameter and of two meters depth. They are approximately 500 meters long, with a slope of 0.1-0.2 percent. Clay tile drains are being used.

Concrete pipe is being used for main drains and collectors. The average diameter of collectors will be 0.40 meter. However, in the main "A" drain, collectors will be of 0.50 meter diameter between 0.000 and 0.800 kilometer, 0.60 meter between 0.900 and 2.200 kilometers, 0.8 meter between 2.200 and 4.300 kilometers. The slope will be approximately 0.001. In the main "B" drain, collectors will be of 0.40 meter diameter between 0.000 and 1.400 kilometers, 0.50 meter between 1.400 and 3.400 kilometers, 0.60 meter between 3.400 and 4.800 kilometers, and 0.80 meter between 4.800 and 6.000 kilometers. Their slope will be approximately 0.001.

Drainage water will be discharged to the Aegean Sea through the surface drainage canal. Water to be drained has been estimated at 400 lt sec. For the present, two pumps of twelve inches will be used to pump the water from the sump to the surface drainage canal. After the area is supplied with electricity, an electro-pump will be used for this purpose.

FIGURE 3 : DRAINAGE PLAN OF RESEARCH AREA

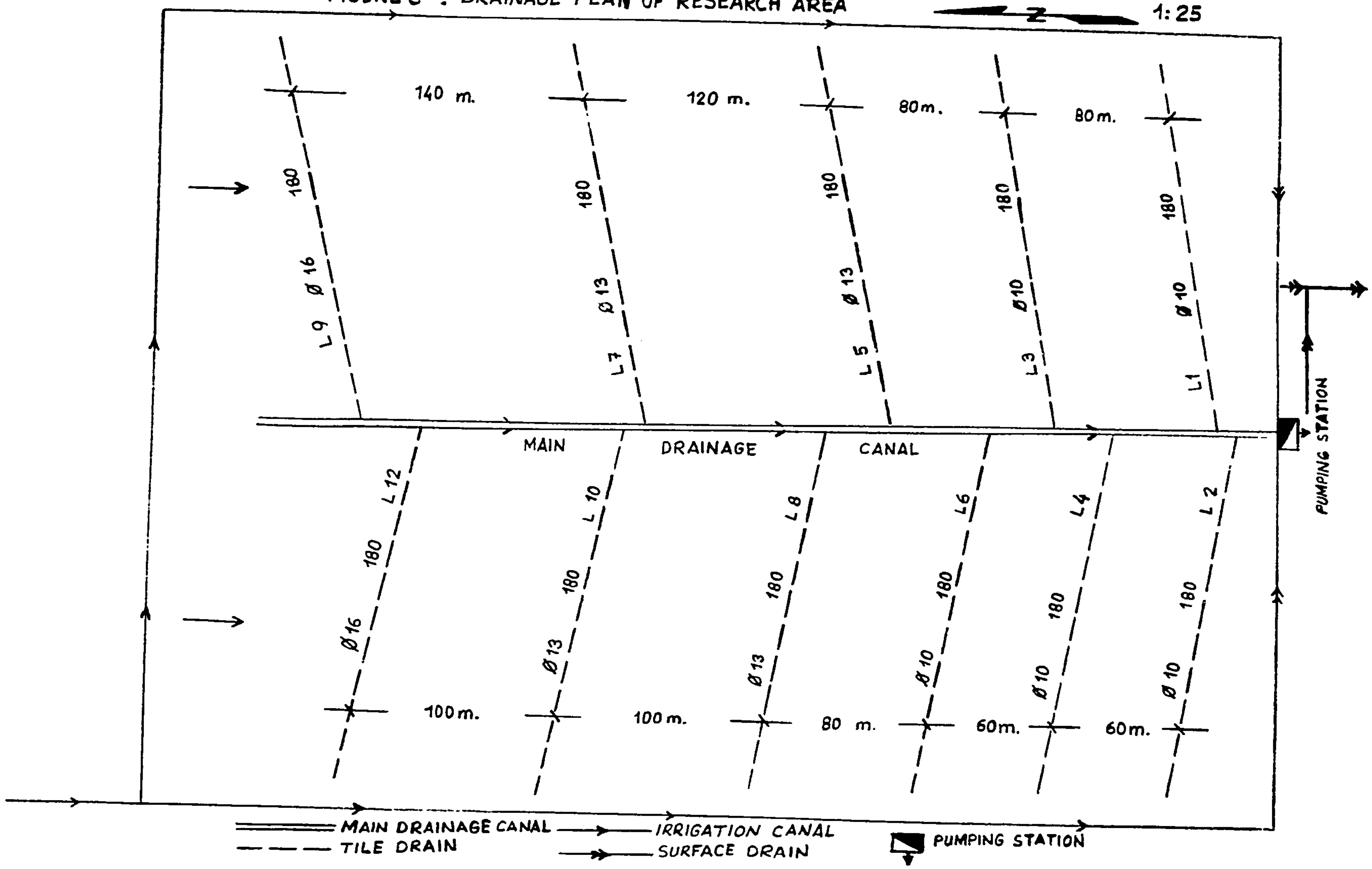
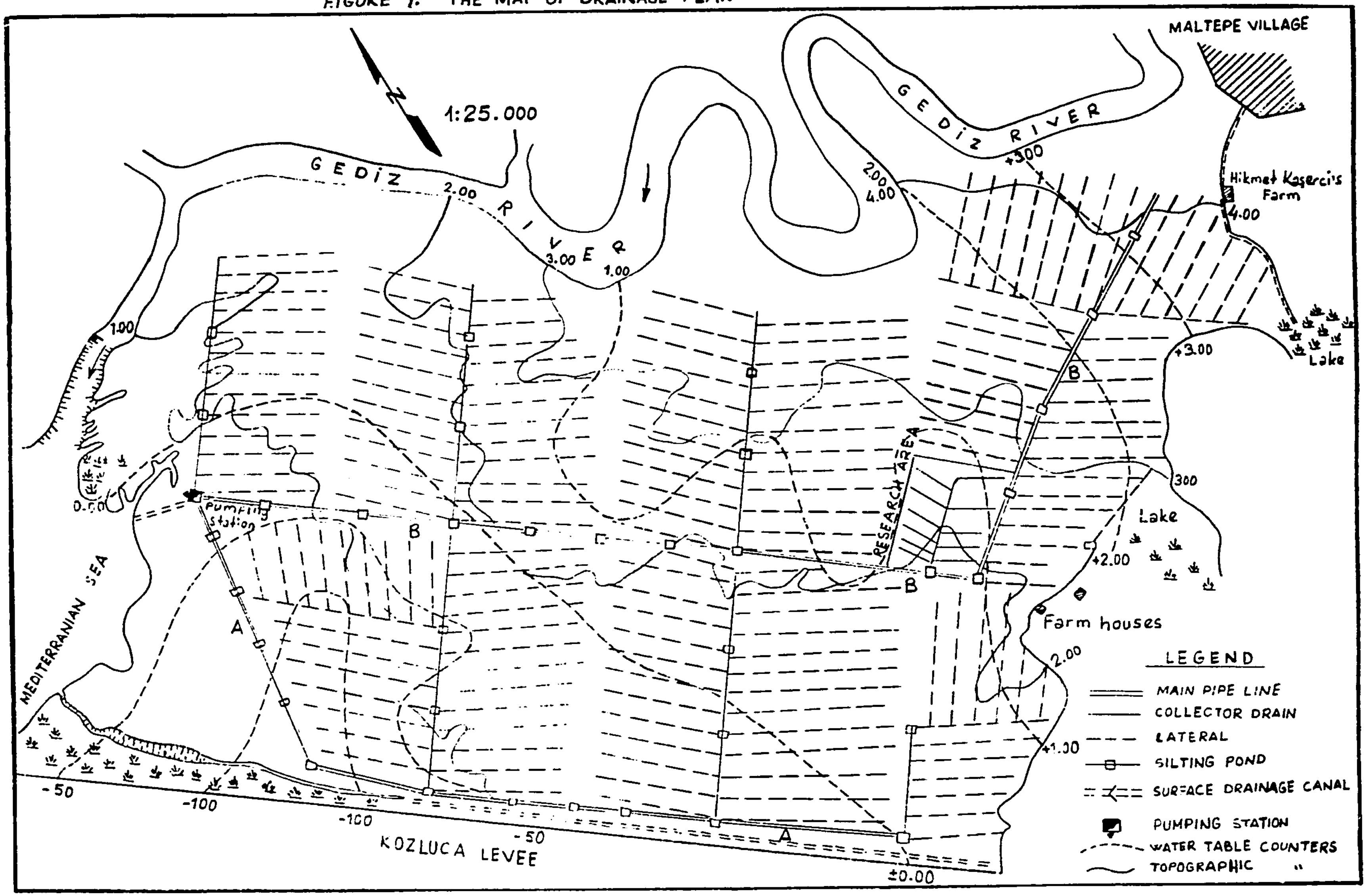


FIGURE 4. THE MAP OF DRAINAGE PLAN



EVOLUTION AND RECLAMATION OF ALKALI SOILS IN THE UNITED ARAB REPUBLIC

by

A. H. I. Mustafa and Dr. A. I. El Shabassy*

Summary

The development of deteriorated soil in Egypt made it imperative to study its evolution and reclamation. This paper explains the factors dealing with the nature of the alkali soils, their physical and chemical properties, and the different hypothesis of their evolution. The experimental work for reclamation of these soils required a great deal of laboratory and field tests. Gypsum plays an important role in the reclamation of these soils. The quantity needed and time of application is discussed.

Introduction

A basin system of irrigation in the past, connected with leaching of the accumulating salts, has protected the arable land of the valley and delta against salinization and alkalinization. By introducing free-flow irrigation in the twentieth century, liquidation of basin of salts activated very strongly the latent process of salinization and alkalinization in some soils in many parts of the country.

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Materials

The development of perennial irrigation was long ago observed to cause "salting" of land adjacent to high level canals in a way which seemed to be explicable on simple physical interpretations. Recent and more intimate study of such infiltrated areas has shown that this explanation is too simple and that infertility can be of a different type, which is characterized by impermeability to water and not necessarily even recognizable by an accumulation of salt.

It must be understood that impermeability is developed only at particular levels in the soil profile, where the equilibrium conditions necessary for its formation have existed. This may be at any level and its thickness also varies. But such impermeable layers affect crop-root development.

Such changes in the soil profile are definitely related to movement of underground water. The immediate cause of a raised water table or interference with normal underground water movements varies a great deal. All abnormalities in water table movements, however, will take place against the background of an extremely variable nature of the surface fluviatile deposits. Even in the simplest and very common case of infiltration from a high level canal, the actual course of the infiltration, and the area affected by it, have been found to be profoundly influenced by variation in the physical structure of the soil. In other cases, where land is not level, drainage to the low lying parts causes a high water table there. In still others the practice of over-watering, in relation to the physical structure of the soil, has resulted in the repeated formation over a number of years of an artificially high water table. The essential feature in every case is that a high water table from which evaporation can take place should persistently recur. The actual depth of the water table and the regularity of its recurrence determine respectively the nature of the infertile soil and the rapidity with which it is produced. Height above sea level has nothing whatever to do with it. Deterioration of land occurs in upper as well as in lower Egypt, so that its determining cause depends entirely on local conditions.

Properties of the Alkali Soils

Tables 1 and 2 give a clear idea of the laboratory test of these soils, and along with the field observation we may summarize the physical and chemical properties in the following:

(a) The dominant exchangeable base has become sodium instead of calcium and magnesium.

(b) There is a very marked increase in insoluble calcium and magnesium compounds; the calcium has been deposted mainly as carbonate and the magnesium as silicate.

(c) The amount of organic matter in the profile has been greatly reduced.

(d) The soluble salt content is low, but the "carbonate" and "bicarbonate" titration of the water extract is abnormally high.

(e) Analysis of the clays separated from the various horizons of such soils bring out a significantly higher silica and magnesium content as compared with normal soils.

(f) In the field they are extremely retentive of water and difficult to dry out.

(g) In the field a black skin of organic matter is sometimes present at the surface; hence, the name "black alkali" or "armout."

The adverse physical properties of such soils, their highly dispersed condition and impermeability to water are related not only with the fact that the dominant exchangeable base is sodium but also with the presence of the precipitated magnesium silicate.

Table 1. Water Soluble Salts in Milligram Equivalent Percent

Depth in layer in centimeters	Ca	Mg	CO_3	HCO_3	Cl	SO_4
0 - 15	0	0	1.4	6.7	0	1.8
15 - 30	0	0	3.7	4.8	0	1.1
30 - 55	0	0	2.5	6.0	0	0.8
55 - 80	0	0	0	10.4	0	0.5
80 - 105	0	0	0	8.3	0	0.5

Table 2. Exchangeable Bases in Milligram Equivalent Percent

Depth in layer in centimeters	Ca	Mg	Na	ESP	Saturation Capacity
0 - 15	5.7	4.3	27.2	73.1	37.2
15 - 30	2.7	2.1	37.6	88.7	42.4
30 - 55	2.0	2.5	37.1	89.2	41.6
55 - 80	2.9	3.6	....	....	....
80 - 105	5.1	6.7	....	....	....

Processes Involved in the Formation of Alkali Soils

Many hypotheses have been suggested to explain the evolution of soil alkalinity. In the UAR, the following suppositions may be regarded as the main factors of soil alkalinity:

(1) Gracie, et al.,* referred to the possible production of alkalinity in soils under anaerobic conditions:

In the permanent waterlogged systems, denitrification and desulphurization start as a result of the activity of the anaerobic bacteria and a variety of microspira desulphuricans, which utilize the oxygen so obtained for the oxidation of organic matter, and lead to the formation of H_2S and $NaHCO_3$.

In deep soil formations near the water table, it is customary to observe green or blue sediments and an accumulation of ferrous sulphate.

The increased alkalinity depresses the solubility of the calcium and magnesium salts. This explains the marked increase in insoluble calcium and magnesium compounds, and so permits a base exchange between the sodium salts remaining in solution and the exchangeable calcium and magnesium of the soil.

(2) Irrigation water and its relationship with the alkalinity of the soils:

The fluctuations in the chemistry of the Nile water through the months of the year show that the water is alakaline throughout due to the domination of the HCO_3-ion. The Nile water also contains Ca and Mg. The domination of the Mg ion — due to the fact that the Mg CO_3 is much more soluble than $CaCO_3$ — on the clay complex results in a state of alkalinity and bad structure similar to that resulting from the domination of $Na+$ on the colloidal clay complex.

Figure 1, shows that the bicarbonate ion is forming about forty percent of the total solids, silica comes next and is possibly present due to the laterization process in the Nile sources and through destruction of granite in the Nile basin.

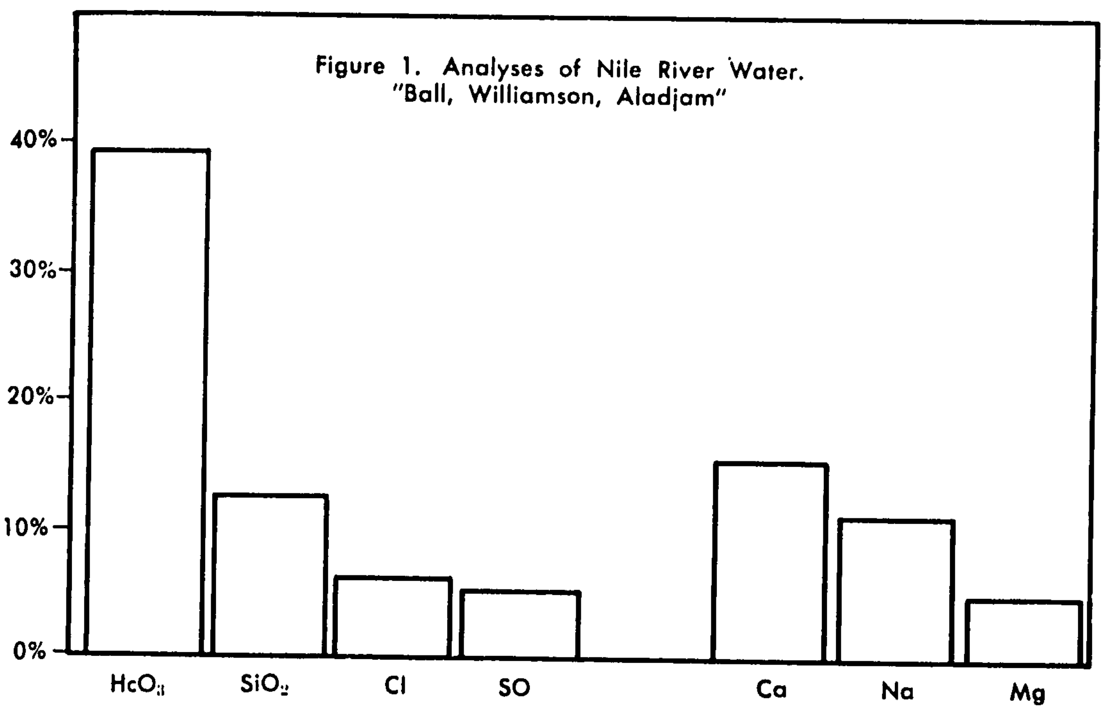

Figure 1. Analyses of Nile River Water.
"Ball, Williamson, Aladjam"

* Tech. Bul. 148, Ministry of Agriculture, 1934.

The Nile water has been used for irrigation for five to seven thousand years. Thus, the process of irrigating the Nile deposits and the evaporation of soil water resulted in the sedimentation of $CaCO_3$ and silica and the accumulation of soluble salts in the groundwater.

An analysis of the underground water in the delta region shows that the reaction of this water is alkaline. It could also be classified into the following four groups:

p.p.m.	The Dominant anion
200	HCO_3
500-4000	HCO_3 strongly expressed
5000	SO_4
11,000	Cl in the form of NaCl

As these waters evaporate, the role of alkalinization and salinization takes place.

(3) The improper leaching of the sodic and saline soils leads to the conversion of these soils to alkali soils.

To summarize, alkalinization is definitely related to movement of underground water, and is a by-product of a sequence of events which begins with the activity of sulphate-reducing bacteria, the alkalinity of Nile water, and the improper leaching of sodic saline soils during reclamation.

Reclamation of Alkali Soils

To understand the effect of reclamation measures, and to employ them successfully, we must understand the nature of the changes they produce in the dynamics of the soil.

I would like to emphasis that the term "Soil Dynamics" summarizes all the changes, chemical, physical and biological, that are continually occurring in soil, such as those caused by leaching, salt accumulation, drainage, evaporation, and by the whole soil population. The expression is convenient in illustrating the fact that there is no stability in soils. It is this dynamic character of soils that makes the elucidation of their reaction to reclamation measures so difficult. Unless the new treatment of the soil entirely changes the soil dynamics in a way that will lead to a normal agricultural soil, the reclamation, although possibly temporarily effective, will not be complete and the reclaimed soil will deteriorate again.

Accordingly, the remedy for the state of affairs described is the entire prevention of the deterioration of land by the installation of a system of intensive drainage, combined with defenses against infiltration. This means not only main drains but also field drains.

Along with the installation of drains, the reclamation of alkali soils is based on the application of substances which enter into ion exchange with the alkali soils. It is well known that the unfavorable physical, chemical and biological properties of alkali soils are mainly due to the fact that the amount of exchangeable sodium ions is rather high compared with other cations. The reclaiming agents contain calcium and effect the substitution of ions by Ca ions.

Methods of applying various substances, usually gypsum, sulphur, acids, acid metal salts or industrial wastes, have been adopted during the recent decades or even earlier. Most of these amendments have been tried in the UAR under field conditions. With respect to all of these substances, gypsum is the calcium salt which has widespread use owing to its cheap cost and highly beneficial effect in the UAR.

Besides the field trials, some lysimeter experiments have been conducted to study the effect of gypsum on the alkali soils. Two soils, one from El Tel El Kebir, with a base exchange capacity of 31.7 milligrams equivalent percent and ESP fifty-four, the other soil from Kafr El Zayat, with a base exchange capacity of 39.3 milligrams equivalent percent and ESP ninety. Tables 3 and 4 show the results of these experiments.

N.B. The quantities of gypsum were calculated on the sum of soluble CO_3+HCO_3 in treatment "C," and double and three times this amount in treatments "D" and "E" respectively. Treatment "F" is the amount of gypsum needed to neutralize CO_3+HCO_3 and replace the exchangeable Na.

The gypsum was mixed thoroughly with the soil before transferring the soil to the lysimeters.

With respect to the second experiment, the subsoil in treatments "C" and "D" only took gypsum, while in the other treatments only the top surface received the needed quantities.

Table 3

Treatments	pH	CO_3+HCO_3 mg. Eq. %	Exchange Ca mg. Eq. %	E Ca P	Exchange Na mg. Eq. %	ESP
The soil	9.6	5	6.1	19.2	17	54
A leaching alone	9.4	3.25	11.95	37.7	14.5	46
B 2 tons/feddan	9.4	3.85	15.7	50.00	9.9	31
C 5.4 tons/feddan	9.2	2.75	19.1	60.00	7.8	34
D 10.8 tons/feddan	8.6	1.75	20.8	65.6	5.1	16
E 16.2 tons/feddan	8.2	1.30	23.3	73.5	2.5	8
F 23 tons/feddan	8.1	0.8	27.00	85.1	0.7	2.2

Table 4

Treatments	pH	CO_3+HCO_3 mg. eq. %	Exchange Ca mg. eq. %	E Ca P	Exchange Na mg. eq. %	ESP	Permeability cm^3/day
A The Soil	9.8	7.3	1.6	4.1	35.4	90	0
A leaching	9.45	6.4	4.5	11.5	32.8	83.5	0
B 12.5 tons/feddan	8.8	2.5	20.8	52.9	16.4	41.7	10
C 12.5 tons/feddan	8.3	1.7	20.8	52.9	16.2	41.3	22.5
D 16.5 tons/feddan	8.1	1.4	24.5	62.3	12.8	32.6	27
E 33 tons/feddan	8.7	0.8	33.8	86.0	3.7	9.4	72

N.B. In treatment "B" gypsum was calculated so as to reduce the ESP to thirty percent in the top layer. In treatment "C" the top layer and the subsoil each got the same amount as in "B." In treatment "D" the gypsum needed to replace the exchangeable Na of the top soil (16.5 ton per feddan) was mixed thoroughly with the whole soil column. In treatment "E" the gypsum requirements thirty-three tons needed for both surface soils were added to the top soil.

It is clear that the application of gypsum has a significant effect on the chemical and physical properties of the soil. The effect is increased with the increment of gypsum. It is distinct that the ESP, the pH and the soluble CO_3+HCO_3 are decreased with the increasing quantity of gypsum.

Time of Application of Gypsum

It was thought that gypsum should be applied only after the bulk of the salt had been leached. However, experimental fields showed that decline of structure was prevented easier by application of gypsum on fully salinized soils than on partly leached soils.

CHAPTER VI

National Programs

ORGANIZATIONAL RESPONSIBILITIES FOR IRRIGATION IN INDIA

by
D. B. Anand*

Summary

Irrigation in India has achieved great importance in the country's Five-Year Plans. Irrigation projects are categorized as major, medium and minor schemes, according to their financial costs.

Irrigation is a state subject. Planning, however, for all sectors of development is done by the planning commission in consultation with the states, and allocations in each sector are similarly finalized. The major-medium schemes have to be approved by the planning commission before the start of construction, and fall within the purview of the Union Ministry of Irrigation and Power. Minor irrigation schemes fall within the purview of Union Ministry of Food and Agriculture.

The most important part of an irrigation scheme is the supply of water to the field from outlets constructed on government channels. The management of supply and distribution of the irrigation water is a very important function of the government. There are varying patterns of supply and charges for the irrigation water. This paper describes in broad detail the organizational responsibilities for the irrigation projects, especially the management, distribution and control of water in various parts of the country.

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Introductory

With a total cultivable area of 194 million hectares (480 million acres), 136 million hectares (337 million acres) net were already under cultivation in India in 1962-63. Thus, agriculture forms the base of the country's economy.

The primary requirement of agriculture is the adequate and timely supply of water to the crops. Wide variations in rainfall from year to year, and during the year, with regard to its quantity, incidence and duration, make artificial irrigation an absolute necessity for profitable agriculture. This and the wide variety in its climatic and soil conditions have led to extensive irrigation in India.

Prior to Independence (1947), the total area under irrigation by major and medium projects was 9.66 million hectares (twenty-four million acres). Since then, the irrigated area has increased by 4.59 million hectares (11.3 million acres) under the first two Five-Year Plans (1951-1961). It is expected that this figure will rise to 6.07 million hectares (fifteen million acres), thus bringing the total to 15.73 million hectares (thirty-nine million acres) gross by the end of the Third Five-Year Plan (March, 1966).

The area irrigated under minor schemes in the pre-Independence period was 12.95 million hectares (thirty-two million acres) gross. The additional potential during the three plans is estimated at 7.1 million hectares (eighteen million acres), thus making a total of about twenty million hectares (forty-nine million acres) gross, by the end of the Third Plan.

Classification of Projects

Prior to 1947, projects having an independent source of water supply and irrigating areas up to 1620 hectares (4,000 acres) were classified as minor irrigation schemes. These, as the name implies, consist of small projects utilizing surface water resources by small storage tanks, diversion or lift irrigation, and of sub-surface waters by dug-wells and tubewells.

The classification of the irrigation projects has since been revised and it is now based on capital cost. All works costing more than Rs. fifty million are classed as major projects. Those costing between Rs. one and a half million and Rs. fifty million are termed medium projects, and those costing less than Rs. one and a half million are categorized as minor irrigation works.

Irrigation is a state subject; the sector-wise allocations in the plans, however, are finalized by the Planning Commission in consultation with the concerned state and central ministries. The major and medium schemes fall within the purview of the Union Ministry of Irrigation & Power, and the minor irrigation in that of the Union Ministry of Agriculture.

It has been estimated that in the course of the next twenty or twenty-five years, the total cropped area in the country will rise to 141.7 million hectares (350 million acres) net, of which about 75.7 million hectares (187 million acres) gross, will be irrigated. It is estimated that of this, 45.3 million hectares (112 million acres) could be served by major-medium schemes, and the balance by minor irrigation. The total area under irrigation by the major-medium schemes by the end of March, 1966, as indicated earlier, is likely to be 15.7 million hectares (thirty-nine million acres), in addition to 9.66 million hectares (twenty-four million acres) of the pre-plan period. The irrigation potential still to be created will, therefore, be of the order of about twenty million hectares (forty-nine million acres) gross under major-medium projects and ten million hectares (twenty-five million acres) gross under minor irrigation works.

The total average yearly rainfall over the country is equivalent to about 3,700 milliard cubic meters (3000 million acre feet) of water. Of this, about one-third is lost by evaporation, and about 802 milliard cubic meters (650 million acre feet) is lost by percolation, leaving 1665 milliard cubic meters (1350 million acre feet) as surface flow. With limitations of topography, soil conditions, climate, etc., it is estimated that only about one-third of this, i.e., 555 milliard cubic meters (450 million acre feet) can be utilized for surface irrigation. At the end of the Third Plan, the total water utilization under major-medium irrigation projects is expected to be about 197 milliard cubic meters (160 million acre feet).

The utilizable water resources of the country fall short of total needs. It is, therefore, imperative to put it to optimum use by proper organizational and sound water management.

Central Government's Role in Irrigation Development

According to the Indian Constitution, irrigation is a state subject. Since the start of the Five-Year Plans in 1951, however, the state plans for all sectors have been discussed and approved by the Planning Commission, which also decides the central assistance to be allocated to each sector. Thus, no irrigation scheme is executed without the approval and technical clearance of the Planning Commission, for the central assistance is contingent on such sanction. In the matter of technical scrutiny of major-medium irrigation projects proposed by the state governments, the Planning Commission is assisted by the Central Water & Power Commission in the Ministry of Irrigation & Power. The minor projects are processed through the irrigation wing of the Ministry of Agriculture.

Although the responsibility for planning and development of the water resources for irrigation rests with the state governments, the Government of India, by constitution, is responsible for "regulation and development of inter-state rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by the Parliament by law to be expedient in the public interest."

The Indian Parliament has since passed the Rivers Boards Act (1956), authorizing the central government to control the regulation and development of inter-state rivers and river valleys by establishing river boards for advising the governments interested in such matters, after due consultation with them. However, no such river board has so far been set up. It has since been proposed to set up regional organizations in the Central Water & Power Commission for preparing master plans for irrigation development on inter-state rivers.

The Indian Parliament has also enacted the Inter-State Water Disputes Act (1956), which provides for the adjudication of disputes relating to waters of inter-state rivers and river valleys.

For construction of major irrigation and multipurpose projects, control boards are usually set up to assure speedy decisions and expeditious construction.

Irrigation Management in the States

By and large, the responsibility for the planning, investigation, design, construction, operation and maintenance of all major-medium projects rests with the irrigation departments of the states. The execution and operation of minor schemes may, however, rest with one or more such departments as the Irrigation Department, Agricultural Department, Revenue Department, etc. Some schemes are also handled by Zilla Parishads and Gram Panchayats, i.e., district and village community organizations. This practice varies from state to state.

The Central Water & Power Commission renders such assistance as may be required by the states with regard to investigations, designs, etc., of river valley projects. It is, however, the responsibility of the Irrigation Department, headed by one or more chief engineer, to carry out the planned development and utilization of water resources in the state.

Irrigation System

Broadly speaking, a major-medium irrigation project comprises storage reservoir(s) and/or diversion structure(s) across the river, with a head regulator for controlling the water in the distribution system for conveying water to the field. Depending upon the topography, area, etc., the distribution system will consist of the main canal, branches and distributaries, minors and subminors, water courses and field channels.

Normally, the state's responsibility ceases at the outlet through which water is let into a water course, reaching the fields through the field channels. This last link in the conveyor system is the most vital. If properly managed, the water would be used to the best advantage without wastage, misuse or overuse, and result in maximum benefits. The organizational management at this point is, therefore, important.

Water Course and Its Construction

A water course is the main channel carrying water from the government-owned conveyor system through an outlet, the usual limit of discharge being 0.03 to 0.09 cubic meter per second (one to three cusecs), depending upon the local conditions and practice. If the outlet is of a bigger capacity, the water course is constructed by government up to the point where the discharge needed is within limits locally accepted. Beyond this point, the water course is constructed by the users at their expense. Field channels convey water from the water courses to individual fields, or suitable-sized plots, and are constructed by the users. The maintenance of water courses and field channels is the responsibility of the users (irrigators).

During irrigation supplies, water is diverted to each such block from the field channel by making a small cut in the bank and closing the downstream end. After the block is filled to the requisite depth, the cut is closed and the process repeated in the next block.

The construction of carrier systems beyond the canal outlet is generally the responsibility of the water users. In some cases, however, this has lagged behind the availability of supplies at the outlet, and led to delayed utilization of the irrigation potential created.

With a view to making up this deficiency, the Planning Commission has made the following suggestions (1958) to the state governments:

(1) Project authorities should be responsible for the construction of water courses at government cost for blocks up to 100 acres (since revised to a discharge of one to three cusecs — 0.03 to 0.09 cubic meter per second). This limit may be varied in different states according to local conditions relating to topography, crop pattern, etc.

(2) The survey and alignment of field channels beyond the point to which water courses are constructed at government cost, should be the responsibility of project authorities. Responsibility for excavation of these channels should be entrusted to the beneficiaries and they should be helped and organized for this purpose, e.g., by the community project authorities, through Panchayats (i.e., village communities) and cooperatives. If the local people default in the discharge of this responsibility, the state government should have power through legislation to construct field channels, the cost being recovered from the beneficiaries.

(3) The maintenance of water courses constructed at government cost, as well as of field channels excavated by local people, should be the responsibility of the beneficiaries organized cooperatively, or through village Panchayats. The state government should have power, through legislation, to undertake maintenance at the cost of beneficiaries, or the village Panchayats, in the event of default.

Legislation requiring the beneficiaries to construct field channels themselves, or by such government agencies as Panchayats and Zilla Parishads, at the cost of the beneficiaries, is underway in many of the states. This is expected to result in speedy construction of these vital arteries for distribution of irrigation waters.

Supply of Water

The water resources of the country are not sufficient to fully serve all the cultivable commanded area, and therefore, water from irrigation systems is supplied only to a certain percentage of the cultivable command. Such a percentage is called the irrigation intensity, and varies from forty percent to over 100 percent. When it is over 100 percent, it means that the same acre is supplied water in more than one season. When it is less, it means either that different acres are irrigated in different seasons or the same acre may be irrigated in two seasons, but that the total annual acreage irrigated during the various seasons is less than the total cultivable command.

The design of water requirements is based on the probable cropping patterns, based on the pattern before irrigation with suitable modifications, and the intensity of irrigation, which is fixed on the basis of the probable command and the availability of water. The supply is made in various ways.

In some of the northern states, such as Punjab and Rajasthan, water is supplied as an allowance per thousand acres of the total cultivable command. The usual supply varies from 2.4 to about four cusecs (0.07 to 0.012 cubic meters per second) per thousand acres (405 hectares). The irrigators are free to use the water, as they desire, for any cropping pattern, and for whatever area they like to serve. Thus, the amount of water to each irrigator is fixed, but the areas irrigated could vary in location and extent.

In other states, such as Maharashtra and Gujarat, water applications are invited, indicating details of the crops proposed to be sown, and are sanctioned according to water availabilities. It is also the practice to arrive at agreements with irrigators on fixed cropping patterns for fixed periods — usually six years, and water supply to them is guaranteed on this basis. Thus, in this system, the acreage and cropping pattern are fixed, and the supply of water is given according to needs on the field. The irrigator is, however, free to rotate the actual piece of land on which he may grow the sanctioned crop.

In other states, especially in the South, the intensity of irrigation having been fixed, the irrigable area is localized for broad categories of crops, such as sugarcane, other perennials, paddy and dry-irrigated crops. This means that specific lands on which water will be supplied, and the crops, are nominated, and irrigators cannot change the areas or the crops. In case of shortage of supplies, the water is distributed proportionately to availability. Thus, specific crops are to be grown on specific areas.

Distribution and Control of Water

As mentioned earlier, water is supplied through outlets constructed on government channels, and is conveyed to the fields through water courses and field channels. The limiting capacity of the outlet varies from state to state according to local practice. Also, the type of outlets vary in the states, depending upon the historical evolution and the seasonal water requirements. While outlets, i.e., modules or semi-modules, which could automaticlly supply proportionate quantities of water at varying water levels in the main channel, are desirable, it is not possible to have such automatic devices when the seasonal requirements on the outlets are not the same. Usually, the outlets are controlled by sluice-gates, which are operated by sluice-keepers.

The mode and extent of control of water beyond the outlet is not the same in every state. In some states, the control rests with the Irrigation Departments, which also take action in case of misuse and wastage of water. In other states, the control rests with the Revenue Departments, and is functioned through village officers and lower ranks of the department.

In the northern states, such as Punjab, Rajasthan, etc., the divisional officer, called the executive engineer, is also the district canal officer. He controls both the regulation of supplies in the canal systems and the use of water on the field.

He has under him a technical staff, such as the sub-divisional officers and the sectional officers, who control the supply of water at the outlets. Below the sectional officer is a canal staff, headed by Ziledars, each having a number of Patwaris, who look to the use of water in the field. It is their duty to see that the water is properly used, and to prepare penal forms in case of misuse and wastage, etc. They also check the actual acreages irrigated, and prepare demand statements for charging water rates. In cases of severe shortages, they also assess the acreages on which remissions could be granted.

Parallel to the technical sub-divisional officers, the divisional canal officers staff also includes a revenue deputy collector, who guides and controls the lower canal staff, such as the Ziledars and the Patwaris, in the matter of preparing demand statements of water charges, which he compiles and submits to the divisional officer. He also takes action when there is complaint of distribution of water on an outlet, and prepares a roster, or share-list, of water supply to individual irrigators.

In other states, such as Maharashtra and Gujarat, the setup is similar, except for the exclusion of the revenue deputy collector. The lower canal staff is similar, and the work of the revenue deputy collector is done by the sectional officers and the sub-divisional officers, passing through the divisional officer, as in the earlier case.

The control and use of water, and penalization for wastage and misuse, are also the responsibility of the lower canal staff under check and supervision by the technical officers, from the sectional officer up to the divisional officer.

In the southern states, however, the responsibility of the Irrigation Department ends at the supply of water through the outlet, which is controlled by sluice-keepers. The internal distribution of water on the field is usually achieved by the users themselves. In case of disputes, the matters are settled by the Revenue Department, functioning through lower village officers of that department. The demand statements are prepared by the Revenue Department. There is no practice of imposing penalties for wastage and misuse of water.

It may be mentioned that the internal use of water beyond the outlet is, in almost all cases, left to the irrigators by mutual arrangement and consent. Where, however, there are disputes, a roster system in the form of share-lists, is adopted, in almost all the states, by various means and in various shapes.

In the North, for example, the rosters are run on a weekly basis, and every irrigator gets his proportionate share of water of the week for his land. It is for him to use it on whatever part of his irrigated area he would like to do; he would usually serve his area in more than one rotation, depending upon crop needs.

In such states as Maharashtra and Gujarat, the rosters are usually run on a ten to twelve-day basis, as this is the interval for watering sugarcane, which is popular in these states. Non-perennial crops usually get water once in twenty to twenty-four days. Therefore, in every rotational period of ten to twelve days, crops such as sugarcane get water for full acreage, while only half of the dry-irrigated areas are served in each ten to twelve-day period, which results in their rotation being twenty to twenty-four days.

The details of responsibilities, duties and powers of the various staffs are incorporated in the various irrigation acts and manuals of each state. These acts and manuals are revised as circumstances change and irrigation and agricultural practices evolve.

Water Charges

Charge for the supply of irrigation water is in the form of water rate, which varies with the type of crop and is levied on the basis of area irrigated. The rates vary from state to state. They are based on such factors as amount of water, benefits derived by the irrigator, etc. They are in various forms, e.g., specific water rate, consolidated land-cum-water assessment, rate on agreement, etc.

In many states, concessional water rates are charged in the initial period of development of an irrigation project as an incentive to the cultivators to change over to irrigated farming from dry or rainfed farming.

As mentioned earlier, the water supply in some of the states, is on the basis of a fixed quantum per thousand acres, leaving the choice and acreage of irrigation to the farmer. The water charges, however, are based on the actual area and the type of crop irrigated. The measurements of the area are made by the Irrigation Department, and demand statements for water charges are prepared and sent to the Revenue Department for collection. The land revenue is charged extra, and also collected by the Revenue Department.

In states such as Maharashtra and Gujarat, where agreements have been reached, water is supplied on demand for the agreed area, and the water rates charged on such agreed area, whether or not irrigation water is taken. In areas sanctioned annually, outside such agreements, water rate is charged again on the sanctioned area, whether the water is taken or not. The areas are measured by the Irrigation Department, which prepares the demand statements and forwards them to the Revenue Department for collection. The land revenue is extra.

In the southern states, areas are localized and water charges are levied according to the crops, whether water is taken or not. Usually the water rates and land assessment are amalgamated into a flat rate, and charged as consolidated assessment. There is no measurement of crops nor preparation of demand statements by the Irrigation Department.

The best method would be to sell water by volume. In the present day context of costs of agricultural production and commodity prices in India, the net return to the irrigator from the same quantity of water use is not the same for every crop; this, therefore, argues against volumetric sale of water. Also, the number of farmers on each water course is large, which makes it difficult to install a large number of measuring devices, besides involving loss of irrigation command on account of head loss at each measuring device. The expense also would be colossal, and control and maintenance almost unmanageable.

Attempts are therefore made to give supplies on a measured basis. This would connote that design requirements of actual crops grown on each outlet are calculated, and the outlets run for such periods as to supply the calculated amount of water.

After the water supply is made available, and a potential for irrigation created, there is usually a time lag in full utilization of the resource. This is due to various reasons, such as the general inertia to a changeover, land formation, availability of improved seeds and fertilizers, funds, etc. Attempts, however, are made to speed up the utilization as much as possible, so as to optimize utilization and financial returns. A suggestion in this connection has been made to split the water charges into a two-tariff rate, namely, (a) a persuasive assessment chargeable on the whole command to induce irrigators to take to irrigation, and (b) a crop rate according to the actual crops grown, the total of the two being equal to the water charge as fixed. This suggestion is under implementation only in one or two states at present. Some other states are also considering this suggestion.

Although the capital costs of schemes have been rising, the water charges have not always kept pace with the rising annual charges of irrigation projects. It is therefore necessary to optimize the returns, especially as most of the projects would not be able to earn enough revenues to qualify under the direct-return criterion. A committee, recently set up by the Union Ministry for Irrigation & Power, has recommended that the water rates for crops should be fixed as a percentage of the annual net, or gross, return to the farmer from the particular crop per acre. Also, that these rates should be reviewed periodically, so that the government gets a reasonable share of the financial benefits provided to the farmer by irrigation schemes.

Such a measure for optimization of revenues from irrigation projects is a necessary corollary of the acceptance of the benefit-cost ratio criterion for the sanction of such schemes, which means that the beneficiaries return to the community a reasonable share of the benefits derived by them from the projects constructed at the cost of the community.

Return on Irrigation Projects

As indicated earlier, an irrigation scheme is executed by the state government only after approval and technical clearance of the Planning Commission. Allocation of funds for each project is made by the Planning Commission in consultation with the states in annual plans. These allocations take into account financial resources of the state and an element of central assistance as loan and/or subsidy.

Irrigation schemes are financed from capital loans, and no attempt is made at their recovery. There is also a provision to charge a betterment levy on the command, as a fund for financing of further schemes. Recovery, however, is presenting problems.

Attempts are made to recover the annual interest on the capital outlay, plus maintenance and operational charges. In the pre-Independence days (1947), except for certain protective works, the productivity test criterion was normally applied. According to this, the total of simple interest on the capital cost of works at the beginning of a year, plus the working expenses for the year, was to be less than the direct and indirect receipts for the year.

Due to rising costs, the irrigation schemes are becoming more and more expensive, and cannot always qualify under the direct-return crite There are also schemes which need to be un.ertaken in scarcity and backward areas for general amelioration. This fact was realized even early in the century, and it was suggested that general benefit to the community should be an important criterion for acceptance of irrigation schemes. Owing, however, to the intervening period of two World Wars, and the depression years, this suggestion could not be implemented.

In the planned development that the country has now embarked upon, however, the criterion of development of natural resources for the general benefit of the community is being progressively accepted. In the case of irrigation projects, therefore, an assessment is made of the direct annual benefits and the direct maintenance and servicing charges in each case. The project is considered acceptable if the ratio of the two is 1.5:1 or more. This is mainly with the idea of first accepting schemes where the benefits are relatively higher. As the number of such schemes gets exhausted, and more difficult and expensive schemes come in the field, the ratio for acceptance is likely to be lowered.

LAND REFORM PROBLEMS

by

Eng. Asghar Azarnia*

Preface

The dynamic structural changes in landowner-peasant relationships, particularly displacement of the landlords' functions in supplying management, credit and marketing services, have necessitated intensive efforts by the government agencies to assure continuation of such services for the new class of owner-cultivators.

Changing from a feudalistic rural society to a modern democratic system without serious socio-economic implications was a difficult undertaking. Despite these difficulties, implementation and completion of the land reform program has been accomplished in much less time than expected.

This paper presents a brief account of land reform, its relevant laws and regulations, the problems encountered to date, and the nature of programs being implemented to solve these problems.

* * * * *

Land reform in Iran, in its real sense, started in 1950 with a royal decree of His Imperial Majesty Mohamad Reza Shah Pahlavi, for distribution of crown lands. Crown land was distributed plot by plot among peasants, based on a cadastral survey and mapping.

In 1955 the law for distribution of public domain, followed in 1957 by its enforcement manual, was passed through Parliament. In 1958 this law was actually implemented and distribution was begun, based on a cadastral survey and mapping. The maximum acreage of land given to each peasant was either ten hectares irrigated or fifteen hectares dry-farm for each fallow.

Since the landlords did not follow the examples of the crown lands and public domain distribution, the Land Reform Law was passed through Parliament. In accordance with this law, the maximum holding was limited to 400 hectares of irrigated or 800 hectares of dry-farm land. The government was bound to purchase the excess land and distribute it among peasants on a survey basis.

The bill presented to Parliament was entirely different from what was passed, and therefore it faced such difficulties as to practically prohibit its enforcement. A few examples of these difficulties follow:

(1) Landlords were authorized to transfer a

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part of their estate to their heirs within two years after the law was passed. Thus, identification of landlords subject to the law was practically impossible until the transfer period expired on May 16, 1962. Enforcement of the law had to be delayed until then.

(2) The landlord was authorized to retain under his possession, no matter how large the area, dry-farm and uncultivated land which he could make irrigable.

(3) The landlord was authorized to sell to the peasants, personally, as much land as he might wish, prior to initiation of distribution in his area.

(4) The landlord was authorized to transfer to others as much land as he might wish, and was required to pay only a small fee as development charges.

(5) An evaluation committee was required to evaluate each landlord's property. Should this evaluation be unacceptable to the landlord, he was given the right to protest. The protest could be investigated within six months by a provincial committee. If the landlord again disagreed, the case would be sent to court. The court's decision was binding.

(6) Finally, the landlord was required to pay an annual development charge for his excess holdings in case he was against enforcement of the Land Reform Law.

All of these difficulties prevented enforcement of the law passed by Parliament, and the government was determined to remove the difficulties of the law. After studies were made a legal decree was passed on January 9, 1962, by the Council of Ministers. The decree was enforced immediately. This decree established the Land Reform Law under which the present Land Reform Program of Iran is being conducted.

The balance of this report concerns key provisions of the revised law, and the measures taken in its enforcement.

Original Law

(1) *Maximum Limit of Ownership.* As provided in Article 2 of the Land Reform Law, approved on January 9, 1962, and henceforth called the "Original Law," any landowner may keep ownership of only one village, and the remaining estates of persons owning more than one village are covered by the regulations governing sale and distribution of land to farmers.

It should be explained that the Original Law defines a village as the residential center of a number of people whose main occupation is farming, and who earn their living by means of agriculture. In this way, as stipulated in Article 2 of the Original Law, the area of land is not taken into account in determining the maximum limit of ownership. In this phase of enforcement of the law, the area of the village chosen to be kept by a landlord may be large or small.

It should be explained further that the maximum limit is imposed on the land cultivated by tenant farmers. No limits are imposed on ownership of lands farmed by agricultural machinery, nor on the gardens where the landowner owns the trees.

(2) *Land Appraisal and Payment of Price.* As provided in Article 10 of the Original Law, in order to appraise the estates which are to be purchased from landlords, the Ministry of Agriculture first determines a standard conversion index for each region. To determine the index, agricultural experts in provinces and chiefs of agricultural administrations usually conduct some studies on the values of villages in each region. These studies are based on the distance of villages from cities, village revenue, and the manner in which the crop is divided between tenant farmer and landlord.

The product of the said index times the land tax of any estate determines the value of that estate. For example, if the index for a region were 120 and the land tax of that village, 20,000 rials, then the price of the village would be 120 times 20,000, or 2,400,000 rials. However, as the index for a region applies to all the estates within that region, the resulting price reflects an average value. Therefore, the price determined for some estates may be less or more than their actual value. In this case, both the landlord and the Land Reform Organization are authorized by the law to submit their protests of the determined price to a reviewing committee for investigation. This protest does not stop a transaction nor distribution of land to farmers; but a clause is added to the deed to the effect that should any change be made in the price of the land because of the review, it will be deducted from or added to the installments to be paid by farmers.

(3) *Period for Payment of the Price of Estates.* As provided in Article 11 of the Original Law, the price of the purchased villages is to be paid in ten equal installments. The first installment is paid to the landlord in cash at the time of purchase, and the remaining nine installments are paid over a period of nine years. However, by Article 4 of Amendment No. 46912, dated January 17, 1962, the original ten-year payment period was changed to fifteen years. For lands purchased after this amendment was passed, one-fifteenth of the price of land is paid in cash at the time of transaction, and the balance is paid in equal installments over a period of fourteen years. For payment of annual installments, the government uses printed drafts, called "payment orders," which are guaranteed by the Agricultural Bank. These payment orders have been given legal value and, under certain conditions, those who possess them can have them discounted and collect their money from authorized banks even before they are matured for payment.

(4) *Distribution of Land and Regulations Governing Cession of Land to Farmer.* Under the provisions of Articles 15, 16 and 17 of the Original Law, the government distributes and sells the lands of the purchased villages to the farmer-inhabitants of these villages. In this case a farmer is defined as a person who does not own land and who is personally and directly working on the land of a landlord and, finally, one who could at least produce his own plowing implements, i.e., ox, plow, and/or seed.

Still another condition for distribution and sale of land to a farmer is that he must first accept membership in the cooperative association of the village.

In distribution of land to farmers, each farmer shall own the same land on which he was working on the date of distribution. Therefore, the areas of lands sold to farmers often are not equal. Of course, this system of distribution has some disadvantages, of which the Ministry of Agriculture is aware. This inequality of land distribution involves some difficulties in management of cooperatives, with regard to keeping accounts. However, due to the urgency desired for the activation of the first phase of this law, and owing to lack of sufficient staff and funds for surveying the villages at this time, there was no alternative. The law authorized the Land Reform Organization to survey and make partition in any region it deemed advisable.

The sale price of lands to farmers is equal to the price of land when purchased from landlords, plus ten percent. This ten percent must be put into the development of the distributed villages, as provided in the law.

Articles Annexed to the Original Law

By application of the Original Law alone, some farmers would become landowners but, on the other hand, some others would remain tenant farmers. In villages belonging to landlords to whom the law did not apply, or villages kept as the maximum limit of landlord ownership, the status of tenant farmers was unchanged. In order that all Iranian farmers might enjoy similar opportunities, a supplementary law or amendment called "Annexed Article Law" was approved on January 17, 1963, to be enforced after the completion of the first phase (distribution phase) of the enforcement of the Original Law. Following are some brief explanations on the provisions of the Annexed Articles.

Under the revised land reform law, landlords are required to act in one of the following three manners in the case of villages or farms which did not qualify for distribution and remained in private ownership:

(a) Landlords shall lease their village to the peasants of the village for a cash rental and on the basis of its median revenues, calculated from revenues obtained during the past three years, not counting the levies, and in accordance with local customary practices.

The Land Reform Organization shall determine a rental factor for each region on this basis. The lease will be for a period of thirty years, and the rental may be revised every five years.

(b) From this date, landlords may sell their arable lands to the peasants by mutual agreement. The winter crops which are in the soil, as well as the spring crops such as rice and beets, and also any summer crops which might be planted before the sale goes into effect, will be divided between the peasants and the landlords in accordance with the customary practice.

(c) Irrigated or dry lands may be divided between the local peasants and the owner(s) according to the customary ratios of landlord-peasant shares. Thus, the share of landlord(s) from the irrigated and dry acreage, including his or their water rights (but without peasants) shall be set aside from the peasants' share, which, together with peasants' water rights, will be distributed among them all on the basis of the local agrarian practice.

Villages endowed to the public shall be leased with consideration for the best interests of the endowment — on a long-term basis, i.e., ninety-nine years to the peasants of the same village for a cash rental, which can be revised every five years. If necessary, privately endowed villages shall be purchased by the government and distributed among the peasants according to the provisions of the Civil Code. The funds obtained from the sale of such a village shall be allocated to the purchase of other property by the guardian of the endowment in accordance with Article 90 of the Civil Code.

To implement the articles annexed to the law pertaining to the second phase of Land Reform, upon studying and review by the specialists, implementary regulation of the annexed articles was prepared. This regulation was ratified by the special joint committee of the Houses on July 27, 1964.

As stipulated in this regulation, on the basis of Articles 17 and 45, a part of which is given below, the landlord can act according to the following:

If a majority of the farmers and landlords of a village agree, the entire village may be operated as a joint stock unit managed by a board of managers composed of three persons: one farmer, one landlord, and a third member selected by mutual consent. If the two sides cannot agree on the selection of the third member, he shall be selected by the Ministry of Agriculture.

The profit share of each person in such a village, whether he be a farmer or landlord, shall be in proportion to the total assets of agricultural importance owned by him subject to local practices and traditions.

Landlords whose lands do not exceed the maximum permissible area they are allowed, may purchase the farmers' rights by mutual consent, subject to the provisions of Notes 1 and 2 of Article 22 of the Land Reform Law, and may personally farm their lands, or they may act according to other provisions of the law.

If the area of land owned by the landlord exceeds the maximum as specified below, the landlord must act only according to Section (a) or (b) of Article 1 of the Supplementary Articles to the Land Reform Law. In case of a dispute between the landlord and farmers, the decision of the Land Reform Organization shall be final.

SCHEDULE OF MAXIMUM HOLDING

(1)	Rice paddies in Gilan and Mazandaran	20 hectares
(2)	Suburbs of Tehran, Varamin, Damavand, Shahr Rey, Shemran and Karaj	30 hectares
(3)	Other lands and villages in the above-mentioned Shahrestans (item 2)	70 hectares
(4)	Suburbs of provincial capitals, excluding those of Kerman, Sanandaj and Zahedan	50 hectares

(5) The Shahrestans of Gorgan, Gonbad; the lands in Dashte Moghan, and non-rice paddy lands in Gilan and Mazandaran ..... 40 hectares

(6) Khuzestan, Baluchestan and Sistan .... 150 hectares

(7) Other parts of the country...... 100 hectares

Landlords can take advantage of the areas in this article, if the area of their mechanized operations does not exceed the areas given above.

If they so desire, landlords subject to this article may benefit from others of the present regulations.

To realize the utmost benefit from the staff and means available to the Land Reform Organization within the period provided for the enforcement of first phase and second phase, the Ministry of Agriculture published a notice for purchasing land from volunteer small landlords. This notice was confirmed by Article 14 of the Land Reform regulations as follows:

Landlords who act on the basis of Decree No. 36105, dated 10-12-1340, between 1st Azar, 1342 and 1st Azar, 1343, obtain the following advantages:

(a) In the case of properties the value of which does not exceed 500,000 rials, ninety-five percent of the value will be paid in cash at the time of transaction, and the balance will be spread over fourteen annual installments, carrying a rate of interest of six percent.

(b) For property costing in excess of 500,000 rials, the 500,000 rials will be paid in cash and the rest in equal installments in fourteen years, with interest of six percent. To those who act after the first of Azar, 1343, government-owned factories' shares will be given, according to Article 6 of the law of sale of shares of government-owned factories.

Activities of the Land Reform Organization in Iran

(A) Staff

In the beginning, the Land Reform Organization started its work with a staff not exceeding twenty. After short-term training classes, the organization started to set up an equipped staff. As the activities of the organization extended to the provinces, the number of technical and administrative employees was increased. At present the organization has 1498 technical and administrative employees, both in Tehran and in the provinces, all of whom help enforce the law throughout the country.

(B) Budget

The funds required for administrative expenses and purchase of landlords' estates were secured from the government and Plan Organization budgets. The credits allocated for purchases of properties for the first three years of operation totaled 2,300,000,000 rials.

(C) Training

For management of cooperatives and with a view to building up the technical staff of the organization, short-term classes (not exceeding two months) were formed in Tehran during the years 1962-63. In these classes employees of the Ministry of Agriculture and the Land Reform Organization were introduced to the principles of cooperative associations and the nature of problems encountered in the enforcement of the Land Reform Law. Also, a number of newly recruited personnel, all agricultural engineers or diploma holders, were sent abroad for six weeks' training in cooperative management. In each ostan* where the Land Reform Law was to be enforced, short-term classes were formed and, with the help of the technical employees assigned to those classes from headquarters, the employees of the Ostan Agricultural Administration were given courses in land reform principles and regulations. For this the staff, both in Tehran and in the provinces, and even in the villages, was trained during the enforcement of the law.

(D) Land Reform Organization in Field Areas

In every region, or ostan, where the Land

* An ostan is a political unit comparable to a state or province.

Reform Law is enforced, a separate office is formed and operated under the supervision of the Land Reform Organization. The directors of these offices are often appointed from among the chiefs of the Ostan Agricultural Administration, or, in some cases, they are assigned from the capital. As the Ministry of Agriculture had instructed, all Agricultural Department employees in a region were to be placed at the disposal of the local Land Reform Organization if they were needed. In most instances the land reform work was so intensive that it demanded almost the full time of these men for several months.

Thus at the present time nineteen field land reform offices are operating, all of which refer their work directly to the headquarters in Tehran. Each of the regional offices has a number of subordinate units which receive their instructions directly from the field office concerned.

(E) Regional Development Organization

In each region of the country where distribution is being conducted, an organization called "Regional Development Organization" is formed for a term of two years. The function of this organization is to provide the requirements of the farmers who become landowners. This means that while performing such development activities as construction of granaries, roads, canals, drilling wells, building houses and the like, these organizations must also endeavor to meet those requirements of the farmers which were previously met by the landlords. The organization encourages the farmers as well as the cooperative organizations to participate in the implementation of its programs. Therefore, these operate so that after the termination of two years, the organizations could turn over to the cooperative association all of their responsibilities.

Three of these organizations have been established in three different regions. It is intended that when enough funds are available such organizations will be gradually established in organizations where funds are presently being obtained by borrowing from the Agricultural Credit Bank, with the Ministry of Finance as the guarantor. When the price of the estate is received from farmers, the additional ten percent will be earmarked for repayment of these loans. Also, under regulations recently established, government agencies, including the plan organization and the Ministry of Agriculture, are responsible for establishing coordination of their programs in these regions, centralizing their funds in one place, and spending these funds according to the Development Organization programs.

(F) Formation of Cooperative Associations

As earlier explained, one of the conditions for sale of land to farmers is that the farmer must first accept membership in a village cooperative. To form these associations, Agricultural Bank officials, accompanied by Land Reform officials, traveled to the villages which were covered by the provisions of the law. These officials jointly explained to farmers the advantages of cooperatives, and how to form cooperative associations. They then formed these associations and collected the farmers' subscription capital for the same. The amount of capital subscribed by these associations depends on the number of members, economic conditions of the regions, and the financial status of members. The minimum permissible share for membership in a cooperative association is fifty rials.

The number of cooperatives so far established in the application of the Land Reform Law (the Original Law) is 4952, with a total capital amounting to 653,408,308 rials and a total of 711,157 members.

Land Distribution Program

(A) Maragheh Pilot Project

(1) *Manner of Selecting a Region.* After passing the Land Reform Law (on January 9, 1962), the government decided to first apply the law in one of the regions of the country with a considerable landlord concentration. With due consideration of this and after extensive studies, the Maragheh region, in the southern part of East Azerbaijan Province, was found suitable for this purpose in every respect. Therefore, in the beginning of Bahman, 1340 (near the end of January

1962), the government proceeded to apply the Land Reform Law at Maragheh.

(2) *Organization's Work.* As soon as the work started, equipped field study units, under the supervision of one of the high ranking and well informed employees of the Ministry of Agriculture, were assigned to Maragheh. Funds, vehicles and the like, were placed at the disposal of the supervisor. It must be pointed out that when application of the Land Reform Law started, the Land Reform Organization did not have budgets or funds of its own. At the time, any kind of assistance rendered for the application of the law at Maragheh was made possible by the savings, equipment, and personnel of the Ministry of Agriculture, and thus the importance of the measures taken at that time should be especially appreciated.

(3) *The Problems Encountered.* As had been expected, the first large problem was the opposition of major landlords towards the law. This opposition was not confined to Maragheh landlords, whose interests were most immediately threatened. The large landlords of other regions of the country, who saw that the government was actually about to enforce the Land Reform Law, vigorously began their opposition and hinderances to the Land Reform Program. Resorting to every kind of instigation, they tried to stop the progress of the land reform officials' work. But, as these private instigations became more intensified, the Land Reform officials, as well as those of other government agencies, worked together more closely. Land Reform officials at Maragheh especially showed more devotion and respect for their duties.

Parallel to beginning application of the law, the Land Reform Organization launched an extensive propaganda program concerning the effects of land reform on different aspects of society, from political, economic and social viewpoints. This program was very effective in helping the people to understand the real meaning of the law and in neutralizing the harmful propaganda of landlords. After a short period of time, on Esfand 11, 1340 (March 1, 1962), at Maragheh, the first landlord volunteered to place his estates at the disposal of the government even before the legal deadline expired. In this way the Land Reform was actually put into effect in Iran.

(4) *Experience Gained at Maragheh.* In the course of putting the Land Reform Law into effect at Maragheh it was concluded that it would be possible to gradually start its application in other regions of the country through proper introduction of the law, accompanied by useful propaganda. During this period defects found in the Original Law were studied and removed. It was believed that if these defects were not corrected they would give rise to some difficulties in the enforcement of the law which would delay its application. Therefore, when a problem was encountered at Maragheh, it was immediately examined either in Tehran or at the locality. A suitable solution was recommended, and a legal decree passed. Prompt action of the government in approving these amendatory decrees recommended by the Ministry of Agriculture should be considered as one of the major factors behind the success of Land Reform officials in enforcing the law so quickly.

(B) Extension of the Maragheh Experience to Other Regions

After it was proved that the Land Reform Law, in spite of its difficulties, could actually be enforced, gradually means were effected for its application in other regions of the country. In pursuance of this aim, landlords were encouraged to sell their estates to the government voluntarily. This approach to application of the law first began at Ghazvin and then at Rasht, where landlords volunteered. Then the law was enforced with regard to the remaining landlords in these two regions to whom the law applied. Thus, the law was gradually enforced throughout the country.

Completion of the first phase of the Land Reform Law in all regions of the country was announced in October, 1963. Because of registration and legal problems only some of the villages became subject to this law. The Land Reform Organization, however, is trying to solve these problems.

In February, 1965, the second phase of the

Land Reform Law as a pilot project was begun in Naghadeh, an area in Azarbayejan Province. The operation in this area was completed within a short period of time. This phase of land reform was immediately effected in other areas of the country.

At present the second phase of land reform is in process throughout the country. This has stabilized the peasants on their land with independence in economy and social affairs, and has provided the landowners, who wish to mechanize their farm operations, with facilities for financing improved activities.

Study on Economical Units

One of the problems challenging to the Land Reform Law is that of preventing renewed fragmentation of the lands already distributed among peasants to smaller, non-economical units.

As provided in Article 19, any transaction on the allocated lands which might result in dividing such lands to plots smaller than the minimum area determined by the Ministry of Agriculture, shall be considered as prohibited and null. In case a peasant died and his heirs were not in a position to reach agreement for managing the farm, they can, with due regard to the first clause of this Article, sell their share to another peasant. Any peasant can buy land in the same village up to twice as much as the minimum provided by the law.

The Ministry of Agriculture and Land Reform Organization have also made some research and studies with a view to fixing the minimum site of a land-holding which cannot be fragmented, considering a peasant family of five persons as an economic unit. This matter has remained one of the economic problems because of the numerous factors which affect the determination of an economic unit. In the Land Reform Program, small family holdings are created to increase the level of production in the unit of cultivation. The livelihood of any family must be provided from the land at its disposal. Consideration must be given to cultivation conditions and to the possibility of mechanizing such farms in the future by attracting the surplus rural population to industry. It appears that the simplest way to determine the economical unit is as follows: Determine the average annual living standard of a five-member peasant household in any region; specify the net income from one hectare of cultivated land growing basic crops under average conditions of cultivation; and consider the conditions of the region, the classification of the land, and the crop rotation.

Generally speaking, the economic results obtained from implementation of the land reform may be summarized as follows:

(1) The distribution of land to farmers has established the farmers in the villages and prevented them from migrating into the towns to seek jobs.

(2) Giving peasants an interest in land ownership and independence in utilizing their properties has caused an increase in the production of cultivated land and enabled the peasants to produce any crops they might desire with regard to market demands.

(3) The amount of installments being paid by farmers to the government, on account of distributed lands, is usually lower than what they formerly paid to the landlords. Consequently, the payment of the land price is not an imposition on them and the fruit of their labor accrues directly to them.

(4) Inasmuch as the valuation of the lands purchased from landlords was on the basis of taxation paid and the regional index, the landowners refrained from paying to the government the true tax. The price of estates, which had risen enormously, fell, and the investment of capital in agriculture became possible.

(5) The tenure of land by peasants, as owners, has caused an increase in production of summer cash crops, which are a profitable source of income to them. Formerly the landlord did not allow peasants to produce such crops as tomatoes, potatoes, peas and similar products, as collection and checking of the production were difficult for them.

(6) The creation of orchards, plantations and planting of forage crops, such as alfalfa, clover, etc., are increasing in the villages. The landlords formerly did not allow the peasants to have a garden nor to plant such crops, because this would have given them "root rights."

(7) Formation of rural cooperative societies has created a spirit of cooperation among the farmers of a village. The credits granted to the peasants by the cooperatives save them from selling their products to advance buyers and free them from the clutches of peddlers.

FINANCING INDIVIDUAL AND GROUP IRRIGATION PROJECTS IN JORDAN

by

Naim Ismail Shouka and Muqbel Salim Dahabreh*

Agriculture is the main occupation and source of national income in Jordan. It is estimated that farmers comprise eighty percent of the population. Jordan has limited natural resources and a high rate of population growth.

Development of the agricultural sector will naturally increase the national income. The country on the whole is semi-arid to arid, being mostly desert. The total area is about 96,563,000‡ donums (37,500 square miles). About 13.5 percent of the total area is under cultivation, of which only about 4.6 percent is irrigated land, and about 1.2 percent is land that could be irrigated. Dry farming land, including fallow, is about 73.1 percent of the cultivable land, and there is about 21.1 percent of the cultivable land uncultivated. The following figures in Table 1 show the exact situation.

* Head of the Credit Section, and Soil and Irrigation Engineer, respectively.

‡ A donum equals 0.001 square kilometers or 0.247 of an acre.

More than eighty-eight percent† of Jordan's total area receives an average annual rainfall of less than 200 millimeters (eight inches). The critical points are the yearly average rainfall and the deviations from that average. An insufficiency of rainfall, which the country faces occasionally, normally leads to the failure of crops, with the result that large numbers of livestock vanish, owing to lack of fodder and grazing grounds. Consequently, it was considered extremely essential to exert every possible effort to make better economic use of the surface and underground water, and to place land, which is usually dependent on rainfall, under irrigation, with a view to increasing agricultural production and making fodder available for livestock.

† Shouk, N. I., Developing a Marketing System for Fruits and Vegetables in Jordan, A thesis submitted to the Graduate School for the Degree of Master of Science, New Mexico State University, University Park, New Mexico, May 1962, p. 4.

Table 1. Area of Cultivated and Cultivable Land in Jordan During 1963*

Area in 1000 Donums		Percentage	
Cultivated and cultivable land	13,000	13.5	of the total area of Jordan.
Irrigated land	600	4.6	of the cultivated and cultivable lands.
Land that could be irrigated	159	1.2	of the cultivated and cultivable lands.
Dry farming land including fallow	9,496	73.1	of the cultivated and cultivable lands.
Cultivable land still uncultivated	2,745	21.1	of the cultivable lands.

Improving methods of irrigation and land utilization are two major elements in the development of the agricultural sector. But it should be realized that such economic development requires sufficient capital for issue as loans to individual farmers and groups of farmers. For this reason the Agricultural Credit Corporation was constituted. The corporation embodied the agricultural credit agencies which existed in the country, namely, the Agricultural Bank, the Village Loans Scheme of the Development Board, and the Agricultural Cooperative Societies.

The ACC was constituted by a special law entitled Agricultural Credit Corporation Act, 1959 and Act No. 12, 1963, with an authorized capital of seven million dinars. It has a jurisdic personality and financial independence. It is administered by a director-general, a deputy director-general assisted by a number of executives, and a board of directors.

The corporation issues loans to individuals and groups of farmers to enable them to conduct a larger number of agricultural projects and to make better use of natural water resources for irrigation purposes. It extends medium and long-term loans. The maximum term for medium loans is ten years and for long-term loans it is twenty years. Loans to farmers are strictly supervised and paid in installments according to the progress of the project. Cost of engines, pumps, and pipes are paid to selling firms. Such a procedure was intended to ensure the development of successful irrigation projects. This, consequently, will result in increasing the national income, culminate in self-sufficiency, and in raising the standard of living and improvement of social standards.

Medium-term loans have been issued for minor irrigation projects, including purchase of engines, pumps, pipes, and other equipment; construction of irrigation canals, including concrete and non-concrete channels; digging of cisterns and artesian wells, and construction of reservoirs. Long-term loans have been issued for major irrigation projects involving six farmers or more.

Table 2 shows activities of the corporation in the development of water resources during the period 1960/61 to 1964/65.

Table 2

Irrigation	1960/61		1961/62		1962/63		1963/64		1964/65	
Projects	No.	meters	No.	meters	No.	meters	No.	meters	No.	meters
Artesian wells	6		1		5		6		7	
Cisterns	88		92		234		726		214	
Reservoirs	16		18		29		59		0	
Engines	16		26		16		49		48	
Pumps	15		25		17		45		40	
Pipes		4666		5754		13439		23534		26665
Conrrete Channels		23984		20751		28176		45335		17425
Non-concrete Channels				3285		955		2520		1580
Spring Improvements					2					
Dams					1					
Power Houses			11		21		27		34	

* The Hashemite Kingdom of Jordan, Ministry of Agriculture, Amman, Agricultural Statistics Division, Annual Report, 1963, p. 4.

During the period 1960/61 to 1964/65 ACC issued loans amounting to 3,700,462 dinars for different agricultural projects, of which about 684,018 dinars were invested in irrigation projects. Figures are shown in Table 3.

Table 3. Value of loans invested in agricultural projects and the percentage of irrigation loans to the total loans issued during 1960/61 to 1964/65

Years	Total Agricultural Loans JD	Irrigation Loans JD	Percentage of Irrigation Loans to Total Loans Percent
1960/61	457,680.515	60,124.000	13.13
1961/62	470,196.786	83,622.000	17.78
1962/63	1,036,306.079	104,251.000	10.06
1963/64	902,807.002	275,024.987	28.47
1964/65	833,471.715	160,996.090	19.32
Total 1960/61 to 1964/65	3,700,462.097	684,018.077	

Several village irrigation projects and group irrigation schemes have also been accomplished during the past five years, through use of long-term loans. Loans issued for such purposes amounted to 29,605 dinars and have been allocated for construction of concrete channels in Jerash, Soaf, Karak, Salt, and Ma'an.

Farmers have responded readily to such economic activities. They are convinced that the expansion of irrigated lands, by digging artesian wells and utilizing underground water, is an important factor in the increase of agricultural production.

In the course of studying applications for such loans, ACC obtains technical advice of the Central Water Authority and other government agencies. Indeed, there is a close cooperation and coordination between the ACC and government agencies involved in agricultural activities, such as the Ministry of Agriculture, including the Extension Department, Research Department, Veterinary Department and Livestock Division; Central Water Authority; East Ghor Canal Authority; Land and Survey Department.

The ACC took special steps to ensure that the loans given for irrigation projects, from which the cost of engines, pumps, pipes, etc., are paid, are not used for any other purpose. This is being strictly enforced by an efficient and effective supervision procedure implemented by well trained agricultural specialists.

To assure sound loaning principles the following procedures are followed:

(1) Loan applications are available for every individual through ACC branch offices all over the country. An applicant, with the help of the branch supervisor, fills in the application form, showing his needs. A technical test report, issued by the Central Water Authority, showing the water capacity of the artesian well, depth of the well, etc., is submitted by the applicant. Another report, issued by the Research Department, showing a water chemical analysis, is usually attached to the application form together with other documents, such as title deeds, a plan of the project location, a copy of the agreement intended between partners (if necessary), and other necessary documents.

(2) The branch manager submits the application form, with the above mentioned documents, to the head office of the ACC in Amman. Here it is studied in the light of available details, by the credit section, which recommends to the director-general the formation of an investigating committee. This committee usually consists of the soil and water engineer, the branch supervisor (an agriculture graduate), and an official of the District Land Registry. The committee investigates thoroughly the project requirement on the spot, and makes a study of the project soundness from economic and technical points of view. It recommends the amount of loan required for the establishment of the project and reports to the branch manager.

(3) The branch manager forwards this report, with the application and other documents, to the Branch Lending Committee. This committee consists of the branch manager as chairman, the senior officer of the Extension Department in the area, and a leading farmer of the district as members. They study the project requirements and amount of loan required, and approve or recommend a sufficient loan for the project. The branch manager sends the minutes of the meeting to the head office for final revision and approval.

(4) The credit section in the head office again revises the project requirements and studies the economic and technical aspects of the project as a whole, and submits its final recommendation to the director-general, or the central loan committee, or the board of directors, according to the amount of capital required. Final approval is then made.

(5) After the approval of the loan, the credit section prepares conditions for the payment of the loan. Branch managers also prepare the necessary security. Costs of engines, pumps, pipes, etc., are paid to the selling firms. Cost of building concrete channels, power houses, digging of artesian wells, etc., are paid in installments to the borrower according to the progress made and under effective supervision.

NATIONAL PROGRAMS FOR IMPROVEMENT OF IRRIGATED AGRICULTURE IN TURKEY

by

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Synopsis

Climatic conditions and increasing population make irrigation mandatory in Turkey. There is not enough moisture during the growing season in ninety-six percent of the area of the country. The population increases three percent a year. There is practically no more land for increasing the area under cultivation.

Irrigation of 800,000 hectares is by private enterprises. This is more than sixty percent of the presently irrigated area in Turkey. This seems to be the maximum development which can be achieved by the people without any assistance from government agencies. There are many administrative, technical and financial problems to deal with for further development in irrigated agriculture. Since the solutions of these problems are beyond the capabilities of the individuals, they must be given due consideration in the national programs.

The First Five-Year Development Plan (1963-1967) of Turkey gives great emphasis to development of water resources. In addition to the 1,115,000 hectares in 1962, another 515,000 hectares would be put under irrigation by the end of 1967. The irrigated area of the total agricultural land (25,300,000 hectares) would rise from 4.4 percent to 6.4 percent. Preparation of the Second Five-Year Development Plan (1968-1972) has started also. Major duties and responsibilities for improvement of irrigated agriculture are given in the plans to the General Directorate of State Hydraulic Works (DSI), the General Directorate of Soil Conservation and Farm Irrigation (TOPRAKSU), and the Agricultural Bank of the Republic of Turkey. Policy and targets are set up in

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the State Planning Office, physical investments are conducted by DSI and TOPRAKSU, and credit is made available by the Agricultural Bank.

Still there are quite a number of unsolved problems, including: Small land holdings, illiteracy of the farmers, establishment of unified operations by the farmers on a nation-wide scale, lack of well established water rights, and reluctance of farmers to undertake costly programs. Steps have already been taken for their solutions.

I. Introduction

(A) The Place and Importance of Water in the Agriculture of Turkey

The need for irrigation in Turkey arises from climatic conditions and increasing population. The effect of the climate is to require the application of water to the land, even to produce conventional crops. While grain crops may be grown without irrigation by dry farming, the yields per decare are much less than grain crops grown under irrigation. Most row crops, orchards, alfalfa, and hay must be irrigated to survive.

The main characteristics of the precipitation in Turkey are its non-uniform distribution during the year and its variation in many regions with respect to quantity, incidence and duration. There is not enough moisture during the growing season in ninety-six percent of the country. Due to this fact and due to unequal distribution of precipitation, irrigation and flood control are vital problems in many regions.

The population of Turkey increases at the very high rate of three percent a year. The present thirty-two million population will double by the year 2000. Great masses live in very primitive conditions without any of the benefits of civilization. It is essential to meet the needs of the continuously expanding population and to raise the standard of living. Irrigation for agriculture can make an important and necessary contribution in meeting the growing food demands as well as improving the present diet of the people. In view of the fact that there is practically no more land for increasing the area under cultivation, great attention must be paid to the development of irrigated agriculture.

Water shortage will not be a problem for irrigation when it reaches its target: the irrigation of 5.1 million hectares. The storage systems presently under operation have a total active capacity of about five billion cubic meters for consumptive use. This capacity can furnish irrigation water for approximately 500,000 hectares. This much land has not yet been prepared for irrigation from these storage systems. This condition dictates continuous irrigation development in Turkey.

(B) The Necessity for National Programs to Improve Irrigated Agriculture

There have been irrigation activities in Turkey for centuries. Wherever a stream could be diverted easily, one can trace the remains of some irrigation ditches. However, the first irrigation project with sound technical standards was constructed in the period of 1908-1913 in the Konya-Cumra plain. In the Republican era (starting from 1923), the Nazilli Right Bank Irrigation System was the first project built with engineering standards, in the years following 1930. Since then, construction by government agencies has continued, as well as the construction of small systems by water users' corporations or individuals. At present (1965), aside from a total irrigated area of about 545,000 hectares, the construction of which was fully or partly financed by the government, irrigation is practiced on nearly 800,000 hectares by corporations or individuals. These systems of private enterprises are mainly small irrigation works and the benefits derived from them help to improve the living standard of the farmers to a limited extent. Their effect on the economy generally does not go beyond the villages where the irrigators live.

Irrigation of these 800,000 hectares by private enterprises represents more than sixty percent of the presently irrigated area in Turkey. This seems to be the maximum development which can be achieved by the people without any assistance from government agencies. With their own small systems, irrigators can utilize the natural flow of the rivers, which flow is ample to meet all irrigation requirements until the end of the flood season. Then the natural flow drops sharply below the irrigation requirements. With an inadequate supply, crop losses are inevitable or crops must be held to the early season type. If much of the flood flow can be captured and stored, not only will existing areas be assured of sufficient water to mature late season crops, but much new land can be added to the irrigated areas. The solution is storage systems. Their initial cost can be met by national budgets.

On the other hand, many of the irrigation systems are very old and lack proper technical standards. The distribution of water cannot be controlled with sufficient accuracy. Besides, high water table and salty lands may become a growing problem. So, without improved irrigation, available water may create new hazards. Improvement of such systems is beyond the capacity of individuals. A national program is necessary.

The farmers' lack of knowledge of irrigated agriculture is likely to prevent their realizing the full benefit of it. To remedy this, a national program and a uniform nation-wide attack on the problem are needed.

Inadequate water resources of a country are one of the limiting factors in its economic development. Wise utilization of them is indispensable. Therefore, the government should not permit individuals free use of their own methods to benefit themselves, but arrange the utilization in accordance with common good, and not permit the waste of a drop of it.

It is obvious that farmers have already become familiar with irrigation development to the extent that they could easily benefit from the existing resources and facilities. What is left now is the part of the task which requires government attention — capital or intervention. Without government, it is doubtful whether the farmers can go ahead to any considerable extent.

In Turkey, for example, millions have been invested to build big dams to store water. If subsequent measures are not adopted by the government, and water not brought to head ditches, all past efforts of the government are fruitless. Therefore the government must give due consideration to completing the job and make the water available to the farms.

On-the-farm development is a matter of demonstrating, of training, and of convincing the farmer how to best utilize the water. Next comes the credit requirements to be covered. What is most important is a coordinated effort by all government agencies concerned. All these phases of irrigation development require a well designed program for the whole country, to be jointly implemented by all parties concerned.

After all, investments made, programs designed, and jobs performed are to be in accordance with the targets set up in overall attempts for national economic development.

This, for sure, can be reached if such a national program is designed in advance.

II. Essential Points to be Given Due Consideration in the Development of National Programs

(A) From the Administration Standpoint

(1) *The need to organize the farmers.* One of the main steps in the development of national programs for irrigated agriculture is the formation of farmers' organizations. There are many reasons for such a need: first of all, the governments of neither developing countries nor developed ones can afford all the costs involved. They cannot grant the services required nor can they provide the manpower needed, if services are to be directed to individuals. This is a waste of time, capital, manpower and energy. Furthermore, a large percentage of irrigation projects designed can become economically feasible only if they are to cover a relatively large area concerning a *group* of farmers. Moreover, uniting the farmers into a group helps to generate more power than simply adding the powers of individuals together. In addition, it eliminates many problems confronted when working with individuals.

It is obvious that the creation of farmer groups for irrigation development is difficult at the beginning. To work with individual farmers is easier in the beginning than to work with groups. Therefore, in almost every country, individual contact is first realized. Converting the services to groups takes a long time. This has been our experience in Turkey. And such has been true in many other countries also. After many years of effort in Turkey we have started to form cooperative type organizations. Since the merits of group service are obvious, it is to recommend that every effort be made to shorten the transitory period, from working only with individuals to working with farmer organizations.

Irrigation associations and irrigation districts, like those in the USA, may be the type of formations needed.

(2) *The need for appropriate policy and adequate procedures.* Irrigation is accomplished in three stages: The first stage comprises planning, design and construction of main, secondary and tertiary canals. Next comes the stage of converting the water from the tertiaries to the head ditches. The third stage can be described as on-the-farm development.

First, a sound government policy to cover all three stages is a must. Sound principles and procedures to enable each stage to complement the others are also needed. These principles and procedures should be clearly established, should be in conformity, and should avoid conflict of authority and friction of any kind. Having policies and procedures not in accordance with each other may prove to be more harmful than not to have any policy or procedure at all.

Of course, these policies and procedures should cover the whole plan, from water rights to the loaning policies for on-farm development. Policies and procedures must be developed to cover water rights, ownership, land titles, authorized agencies, authority and responsibilities of individual farmers in the farmer groups, and functions of corporate bodies. The kind of investment, the way to invest it, the source of money, the method to get it repaid (through water charges, or loan collection) are the main policy questions to be decided, or appropriate alternatives selected. Unless sound and firm decisions are made on each of those subjects, no reasonable success can be expected in the program.

Some of the subjects mentioned above have been problems in Turkey. Most of the points are being worked on, and although considerable progress has been made, complete solutions have not yet been found.

(3) *The need for full cooperation between concerned agencies and the need for them to work at the same speed.* Full cooperation requires complete agreement in the areas of authority and responsibility as well as mutual willingness for cooperation between the agencies concerned. Once this atmosphere of understanding is secured, many problems arising from the execution can be eliminated. On the other hand, unless the concerned agencies work at the same speed in their activities no immediate success can be expected.

This rule is very important to our particular subject, because the speed of work tends to slow down as we go ahead, as we become more involved with the human factor. Therefore, the third stage works progressed slowly compared to the second, and the second stage works slowly compared to those of the first stage. Work in the first stage is not a problem because it is construction, which is dependent mainly on machinery and involves a negligible human factor.

The second and third stages require more effort, more time, and more patience. This is especially true in the third stage, which requires very detailed work. Persuading the farmer to carry out the portion of the work on his parcel is a process that always causes delays and slows down progress. On the basis of observations in Turkey, the following conclusion is reached: the method of accomplishing on-the-farm development must be carefully programmed at the beginning of the planning stage. Therefore, it may be a wise policy to program and assign more men and more equipment to the second and third stages compared to the first, to avoid the delays and to get the quickest possible return from the investments made in the first stage.

(B) From the Technical Standpoint

(1) *The need to train the farmers.* The need to train farmers for irrigated agriculture is one of the main factors of agricultural development. This is important not only from the standpoint of conservation of the limited natural resources, but also from that of feasibility of the investments made for the purpose, and to obtain the expected return. Technical know-how is a kind of insurance for a continuous and steady utilization and benefit. Steadiness of income in the rural economy is, of course, one of the important basis of social welfare. Furthermore the extra costs of irrigated agriculture can be economically justified if a wise and rational irrigation method is applied. All these points are directly related to the training of farmers.

(2) *Necessity for raising the technical standards of the irrigation projects.* Many of the irrigation systems are very old. The distribution and drainage systems are lacking the proper technical standards. The lands are generally unlevelled and the farmers irrigate by flooding their fields. In many cases much larger amounts of water are applied to the fields than the crop actually needs. Taking away the extra water requires a good drainage system, otherwise such water causes a high water table in the ground and loss of crop yield. Seepage losses may be high during the conveyance of the water from the water source to the fields if the canals are not lined. In 1964, on 25 major irrigation systems covering a total of 168,687 hectares of irrigable area, only 91,668 hectares could be actually irrigated; that is 55 percent utilization of the original design. Unlevelled lands, in many cases, lack of secondary and tertiary canals, and seepage losses were the causes of this.

Furthermore, compared with the present standard, the canals on old projects were designed with small capacities, and, in addition, their irrigated areas enlarged by water users since the time of original construction.

As part of the programs for improvement of irrigated agriculture in Turkey, the above-mentioned conditions of irrigation systems must be thoroughly surveyed and rehabilitation activities must be carried out on them. Financing of such improvement work is beyond the capabilities of water users. Therefore necessary funds must appear in the national budget.

(3) *The need to solve the problems related to the land itself.* From the view of irrigation development, there are many problems related to the land itself.

First: In many countries, the land is excessively fragmented. Since soil conservation and irrigation type work and investment on small holdings is not economically feasible and does not provide a fast chain type of work, land consolidation becomes an urgent need. (It is accepted that this is not an easy task to realize in the near future, in most countries.)

Secondly: In many regions land titles are not likely to reflect the present ownership status correctly. Many comprise measurements different than that of the actual sizes, many are not registered in the name of the present day owner, or ownership disputes on a particular parcel have come up in many cases. Work to straighten out all of these problems has either not been started or has been moving ahead very slowly.

If and when government investment, or the investment of farmers through credit facilities, require correct land titles, action to correct the titles is expected to be very slow. It is already a retarding factor in the extention of agricultural credit. Therefore, appropriate measures to improve titles to farms is needed prior to irrigation development programs.

(C) From the Financial Standpoint

(1) *The need to improve conditions for the more capital formation in farm enterprises.* It seems to us that capital formation in farm enterprises in many region countries is a very slow process. Because productive capacity of the land is not being utilized at maximum level, most

farmers are subsistance type or smaller than subsistance type. The goal of production is consumption rather than for the market. Farmers are generally poor, and what is worse, accumulated capital is utilized to buy more land, instead of being channelized to production factors. This may seem a practical method of land consolidation. Since no attention is paid to this approach, new pieces of land are usually separate and the problem gets bigger. There is no doubt that accumulated capital could serve the prosperity of the farmer if it was assigned to purposes to increase the yield instead of buying new land and not benefitting from it reasonably. Therefore, the farmers' inclination and hunger for new pieces of land should be converted to willingness for more investment on the parcels already owned, and for machinery to secure better results and for improved feed seed, water, fertilizer, and the like for bigger yields.

It is a fact that the portion of fixed capital (as land) in the assets owned is very high, while the production factors are almost completely lacking. This is one of the problems to be solved. Education can do much. Extension services might help. Investment in production factors (other than land) is a must.

(2) *The need for allocation of adequate funds.* Since on-farm development requires large amounts of money, the need should be carefully studied and allocation of adequate funds should be punctually secured. Since the return of investment can be expected after the on-farm development is completed and increased yield realized, it is important that allocations be made available for each stage. Furthermore, due to reluctance of the farmer's side for big investments and due to the lack of capital formation, credit facilities should also be made available.

(3) *The necessity to start a policy on repayment of government investments.* Repayment of construction costs of irrigation projects, in addition to the cost of operation and maintenance, must be an important responsibility of the beneficiaries of irrigation activities. Creation of new funds for further reclamation works is always a big problem before the governments. Without adequate financing there would not be, of course, a reclamation program, which is a part of the improvement of irrigated agriculture.

Individuals, corporations and government, all, must share the burden in varying degrees. However, the farmers of Turkey should not be expected to pay whatever the computations on retirement of construction costs and operation and maintenance expenses show nor should their payment be restricted to their "willingness to pay." Because of families crowded on small tracts, the living conditions of the farmers may not develop, even with the irrigation, to a certain level where they can save money for their repayment obligations.

However, it is believed that a certain percentage of the increase in net farm incomes realized through irrigation, could still be taken from the farmers for repayment purposes. Such a percentage may not cover the total cost of irrigation, but the start of a "repayment policy" must be considered as the major point in this procedure.

(4) *Need for development of a suitable credit system.* As has been touched upon in previous paragraphs almost all on-farm development work depends on credit. Taking into consideration the importance of on-farm development and recognizing the fact that until on-farm development is realized, all investments for the first and second stages are fruitless. Any government is bound to provide loanable funds to finance the third stage. Although for maximum benefit from the loans and not to waste this chance, formulation of measures to get farmers to use the proceeds of loans for the right purposes is equally important as making the credit available.

The danger of misusing the funds is a fact worth careful attention. In some regions many farmers are so needy and many farmers are so poorly educated, that many of them will not hesitate to use the specific funds for other needs. In that case, it is not an excuse even if the proceeds of loans have been spent for some other agricultural purpose.

Economically feasible projects, adequate loans, technical assistance, less formality, delegation of authority, prompt service, supervision and effective control, establishment of credit discipline and development of a favorable psychology for repayment in the minds of farmers are essentials for a successful credit system.

Here, it is worthwhile to touch shortly upon a credit system, which is a successful operation for irrigated agriculture. It is the supervised credit system. If the credit is provided as a supervised credit (of which a short description is: credit plus technical guidance plus effective supervision), then problems arising from misuse of loan funds and problems related to collection can easily be eliminated.

Supervised credit is not only a system best suited to meet the needs of farmers for irrigated farming, but it can also be considered as insurance for the whole investment, by both the government agencies and farmers. It depends on farm planning and farm management techniques, it provides the technical assistance of the technicians to train farmers in proper utilization of water, and aims to secure maximum yield from a unit of land. Converting separate pieces of subsistent type farmers' land into economic farming units is one of the main objectives of the system.

III. National Programs Related to the Improvement of Irrigated Agriculture in Turkey, Participating Agencies and Their Activities

(A) Programs

The new constitution of Turkey provides for the establishment of a State Planning Department. This department prepared the First Five-Year Development Plan (1963-1967) of Turkey.

Since agricultural and social development largely depend on the utilization of water resources in the country, great emphasis is given in the plan to the development of these resources. Irrigation is one of the most important factors in the development of intensive farming and in raising productivity. The following table shows the irrigated crops at the beginning of the plan period and also the goals for 1967.

Irrigation in the First Five-Year Development Plan

Crops	1963 Hectares	Percent	1967 Hectares	Percent
Wheat	200,000	17.9	300,000	18.4
Cotton	250,000	22.4	400,000	24.5
Vegetables	200,000	17.9	220,000	13.5
Citrus Fruit	25,000	2.2	37,000	2.3
Other Fruit	145,000	13.0	173,000	10.6
Maize	70,000	6.3	90,000	5.5
Sugar Beet	82,000	7.4	105,000	6.5
Rice	60,000	5.4	75,000	4.6
Feed and Forage Crop	30,000	2.7	130,000	8.0
Others	53,000	4.8	100,000	6.1
Total	1,115,000	100	1,630,000	100

In addition to the 1,115,000 hectares in 1962 another 515,000 hectares would be put under irrigation by the end of 1967. The irrigated area of the total agricultural land (25,300,000 hectares) would rise from 4.4 percent to 6.4 percent. The plan also recognizes the problems of the irrigated areas and contains some measures for the development of a high-standard of irrigation in Turkey. Among them are the reclamation of lands, the adaptation of crop patterns for highest yields, the formation of irrigation districts and legislation on water rights. While the First Five-Year Development Plan is in operation, the government has taken necessary steps for the preparation of the Second Five-Year Development Plan. Government agencies, universities and other national institutions have participated in the preparation. The steps taken in this activity were an inventory of past accomplishments, evaluation of results, survey of present undeveloped resources and needs, and establishment of basic principles to be taken into consideration in the Second Five-Year Plan.

As far as the improvement of irrigated agriculture is concerned, among the basic principles that the "inter-agency committee" on "development of water and resources" reached are: coordination of activities at all stages, collection of proper data for sound irrigation practices, conservation of water, giving priority to the completion of works already started, formation of irrigation districts, starting a repayment policy, establishment of water rights, etc.

In the First Five-Year Development Plan of Turkey, irrigated agriculture is given one of the first priorities. The plan anticipates that in five years 515,000 hectares of land will be put under irrigation.

(B) Government Agencies Involved

(Objectives, organizational set-up, functions and implementation)

(1) *State Planning Office.* A State Planning Office was set up in 1960, by a law, in accordance with the new Constitution. It has been established to develop long term and annual development plans for the country.

The office keeps record of all resources (natural, social and economic) of the country and helps the government to shape economic and social policy and development targets. It acts as a coordinating body among the ministries, prepares development plans, makes recommendations, watches the implementation of the plans and prepares national budget estimates. It is composed of three main sections: a section for economic planning, a section for social planning and a section for coordination.

(2) *DSI* (State Hydraulic Works). The General Directorate of State Hydraulic Works is the largest of the organizations dealing with irrigation at present. It was established in 1925 and presently is under the Ministry of Energy and Natural Resources. In accordance with law No. 6200 (Law concerning the organization and duties of the General Directorate of State Hydraulic Works) it has duties and authorities for the development of surface and ground waters for multipurpose use and preventing them from becoming harmful to land and property. With its central office in Ankara and sixteen regional offices over the country, DSI carries out investigation, planning, design, construction, operation and research works related to the development of water resources. Activities related to irrigation are part of these works.

(3) *TOPRAKSU* (General Directorate of Soil Conservation and Farm Irrigation). TOPRAKSU was established in 1960. Its main objective is to provide for soil conservation and farm irrigation. Eighteen regional offices are scattered over the country. (Detailed information about TOPRAKSU was given in the country report of Turkey at the Fifth NESA Seminar, and will not be repeated in this paper.)

Out of the plan targets for the first five years, small irrigation works were to amount to 18,550 hectares and overall irrigation development totaled 163,000 hectares for the first three years (up to 1965). On the other hand, farmer training for irrigated agriculture has been intensively conducted, field days and demonstrations arranged, and many farm-oriented youngsters trained for a profession of irrigation to help and work for the farmers of small communities.

(4) *Turkiye Cumhuriyeti Ziraat Bankasi* (The Agricultural Bank of The Republic of Turkey). This is the primary source of credit for the rural people of the country. It is an autonomous, state economic enterprise, possessing a legal personality, and is subject to private laws. Since the loan volume of other local banks and some cooperative type organizations serving a limited number of farmers in small communities is only about one percent of that of the T.C. Ziraat Bankasi, we can state that it is the main credit agency for the agricultural sector. The origin of agricultural credit in Turkey goes back to

1863, when local organizations, bearing certain characteristics of agricultural credit cooperatives, were created in the southeast part of the Balkan peninsula to help needy farmers.

After a few years of successful operation, these little cooperative bodies failed to realize their aims because political problems of the Ottoman Empire affected them badly.

The need to reorganize them gave rise to a new idea of forming a central organization. That is how "Ziraat Bankasi" was founded in 1888. The little cooperatives became the branches of the bank. After various modifications made in the original statute, the present T.C. Ziraat Bankasi gained its modern personality under the name of "Turkiye Cumhuriyeti Ziraat Bankasi," with a law promulgated in 1937. Hereinafter we will refer to it simply as "the bank."

The main function of the bank is to provide farm loans to farmers, although it also conducts commercial loan business. It is entitled to accept deposits and to perform all kinds of banking transactions.

There are 670 branch banks in Turkey. Ten thousands employees of the bank help the farmers to secure better living conditions.

It is one of the largest financial institutions of the country. Its volume of loans represents about one-fourth of the state budget. Twenty-six percent of all deposits in Turkey are with this bank.

The bank provides the farmers two kinds of loan services:

(a) Direct loans from the branch banks to farmers.

(b) Loans to agricultural credit cooperatives to be reloaned to member farmers.

The number of agricultural credit cooperatives is 1700, with a membership of about one million farm families. These cooperatives are created by farmers with the help of the bank, which also finances and supervises them. There are also 214 agricultural marketing cooperatives (and fifteen unions of them) financed and partly supervised by the bank.

The bank aims to help the farmers reach the production targets set up by the Five-Year Development Plan of Turkey. Most of the resources provided by the government or generated through accumulation of deposits are directed to the agricultural sector.

A High Council of Credit, composed of certain ministers and other principal officials, set the credit policy in the bank including the priority purposes for which loan funds are to be used.

The bank grants agricultural credit for the following general purposes:

(a) To meet the working capital needs of farmers.

(b) To increase and improve the agricultural output.

(c) To enable the farmers to purchase a farm or a smaller piece of land to enlarge it.

(d) To assist in marketing of produce.

Besides the loans made to farmers and cooperatives, the bank may grant credit to concerns engaged in the manufacturing of implements, materials, machinery and equipment required by the farmers, or may participate in such concerns. The bank may establish industries or participate in them or finance them when home-grown raw materials are used.

Direct loans by the bank may be of short term (up to one year), intermediate term (up to five years), or long term (up to twenty years). Usually short-term loans are production loans to meet farm operating expenses.

Intermediate term loans are granted generally for working capital like machinery, equipment, livestock, etc.

Long term loans are the ones concerning the subject of this paper. This type of loan is intended to meet the costs of soil improvement, irrigation, flood control, farm buildings, the purchase of heavy machinery, improvement of land or establishing nurseries, orchards, vineyards, etc.

The interest rates charged vary from five to nine percent annually, plus half of one percent appraisal or supervision cost when it is provided. Usually, short-term loans are secured only by a guarantor system (joint liability), while intermediate and long-term ones are secured by a mortgage on the land.

The law of the bank provides certain exemptions and immunities with relation to agricultural credits granted by the bank, directly or indirectly.

The volume of farm loans extended by the bank, as of the end of 1964, is as follows: (Nine TL. = $1).

Loans made directly to farmers	1519,980,469 TL.
Loans made to agricultural credit coops	621,045,988 TL.
Loans made to agricultural marketing coops and to the unions	944,341,614 TL.
Loans to Government Equipment Agency	....
Loans for seed distribution	159,186,191 TL.
Total farm loans	3244,554,262 TL.

The number of farm families benefiting from bank loans is 1,665,881. Since the majority of Turkish farmers are of subsistent type or even under that, the problem with short-term loans is to get them utilized for production purposes, rather than consumption. To get the farmers to produce for market rather than for family consumption is one of our goals.

A suitable credit system has been developed. The system of TOPRAKSU loans spread over the country. About 3000 farm families have been granted TOPRAKSU loans. The volume of loans has amounted to TL. fifty-five million. Since every loan depends upon a project developed by TOPRAKSU, and due to the fact that the application of the project is closely supervised by TOPRAKSU, loans are spent for the right purpose and the return is satisfactory.

(C) Functions of the Agencies Related to the National Programs

Of the total of 515,000 hectares in new irrigation projects planned in the First Five-Year Plan, about 450,000 hectares would be built by the General Directorate of State Hydraulic Works (DSI). Priority would be given to irrigation studies in under-developed regions which have a high economic potential in land and water resources and would benefit particularly from irrigation, as well as to studies and projects for small water works in dry under-developed regions. Improvement of existing irrigation networks forms another part of activities of DSI included in the plan. A total of 320 million Turkish lira was estimated as the cost of such works during the five-year period. To obtain full returns from irrigation works, as indicated in the plan, it is essential to undertake complementary investments in canal distribution systems and farm irrigation works. Thus the irrigation programs of DSI would be coordinated with those of the other agencies. DSI would also participate in the activities for setting up of farmers' irrigation associations and proper legislation concerning water resource development.

The functions of TOPRAKSU related to irrigation development projected in the First Five-Year Plan are mainly as follows: Small water development to provide irrigation water to 33,940 hectares, to follow the operations of DSI in big project areas for the irrigation development of 443,300 hectares through farm irrigation system, works on saline and alkaline soils, development of farm drainage systems, etc.

The Agricultural Bank has had conventional type irrigation loans for many years. These loans depended upon a kind of a certificate of need prepared by extension agents. In fact, very negligible supervision could be secured and very little has been accomplished. After TOPRAKSU was formed, the Agricultural Bank started to cooperate with them as well as extension people. Policies and procedures were developed and new type loans provided. This system of TOPRAKSU (soil and water) loan depends on a project, developed by TOPRAKSU, aiming at solving soil and water problems of a specific parcel. This includes a work plan, cost estimates and technical guidance. In some cases recommendations related to crop rotation are made. This is a good and workable system. TOPRAKSU and the Agricultural Bank are cooperating on projects developed for individual farmers. Recently we have also been working on and financing projects developed for groups of farmers. A new type of cooperative has been created and about two hundred of them already formed. We are planning to give priority to the demands from cooperatives.

Another type of credit: supervised agricultural development loans, was described in general previously in this paper. This system may include funds for a TOPRAKSU activity, but it is not confined to a loan for this purpose. Under this system the best utilization of all the resources under the control of the farmer are studied. All lands, including the parcels not having any soil and water problem, are visited and all needs covered. The repayment schedule is linked with the actual income of the farmer. In most cases credit is provided in kind. Education of the farmer and solving of his problems are objectives. All activities are supervised. This service is provided for the duration of a long term farm plan in accordance with an annual farm plan developed for the individual farmer.

IV. Evaluation

(A) Accomplishments

Organizations needed for the purpose have been set up. The State Planning Office, DSI, TOPRAKSU and the Agricultural Bank are the links of the chain for service. Policy and targets are set up in the State Planning Office, physical investments carried out by DSI and TOPRAKSU, and credit made available by the Agricultural Bank.

As to the other accomplishments, because of low standards of old irrigation systems, the General Directorate of State Hydraulic Works (DSI) started a "rehabilitation and betterment" program in 1961. The cost of the program is about 252 million Turkish lira, and it will be practiced on twenty-one major irrigation projects. As of the end of fiscal year 1964, some twenty-seven million lira had been spent on sixteen projects.

Rehabilitation activities include investigation, planning, design and construction stages. The difficulty in the application of programs is the coincidence of construction and irrigation seasons. Using precast units in construction, which is a new activity of DSI, will of course facilitate the rehabilitation program.

The present irrigation charges in the projects operated by DSI cover the operation and maintenance costs only and vary with the kind of crop. In determining the charges per decare of irrigation, the irrigation water requirement of the crop and the farmer's expected net income per decare are taken as Parameters. Rates are determined annually by an inter-ministries committee and approved and announced by the government before the irrigation season starts.

On the other hand, according to Law No. 6200, the investment in irrigation, drainage, water supply and power projects must be repaid by the beneficiaries. The investment in flood control works, including the flood control share of the investment for storage systems, is nonreimbursable. The present charges to water users on irrigation projects operated by DSI do not cover the amortization of capital investment. This is mainly because Turkey is in the development stage of modern irrigation. Some of the small irrigation projects were built by DSI and turned over to the water users' organizations for operation. Still there are some which were improved by DSI while they were already under water users' control. Starting in 1964 DSI has been trying to draw up contracts with the managements of such projects for repayment of the investments made from the national budget. As of the end of the calendar year 1965, on three projects covering a total of 2400 hectares, contracts have been drawn up for retirement of about 2.2 million Turkish lira. There are negotiations for sixteen other small systems.

A second group of repayment contracts is for small projects under construction. These are four in number and cover a total of 5200 hectares. The total of the investments involved is about 1.6 million Turkish lira.

Still there is a third group of contracts, which already have been drawn up, for the projects at planning or design stage. These are three in number and involve irrigation works on 3,000 hectares totally.

The repayment provisions of one of the above-mentioned contracts are indicated below:

—Amortization period: Forty years

—Repayment is interest-free

—Annual installments:

First year	0.0028xKxI.
Second year	0.0056 "
Third year	0.0084 "
Fourth year	0.0112 "
Fifth year	0.0140 "
Sixth year	0.0168 "
Seventh year	0.0196 "
Eighth year	0.0224 "
Ninth year	0.0252 "
Tenth year	0.0280 "
Eleventh-fortieth years	0.0282 "

"K" is the capital investment; "I" is the ratio between the price levels of the years that the repayment installment belongs to and the year when the construction contract was awarded.

The present tendency is that a fifty-year amortization period and interest-free annual installments are sufficient provisions to include in repayment contracts for irrigation projects which DSI fully or partially finances.

(B) Unsolved Problems and New Endeavors

Although the targets of irrigation development, anticipated in the national programs with certain time limits, have been hit, the services related to the implementation are not perfect.

There has not been an especially satisfactory farmer participation in the investments made by the government. Moreover, many problems still remain unsolved, as follows:

(1) The rural population of Turkey totals 3.5 million families and, since the total agricultural lands are 25.3 million hectares, the average land ownership is about 4.9 hectares per farm family. The active population engaged in agriculture is 72 percent of the total active population. Furthermore, 29.4 percent of the agricultural land is operated by 75.4 percent of the families engaged in agriculture. These have an average of 2.95 hectares of land. These figures clearly point out the problem of small holdings on irrigation projects, as well as on dry land areas.

(2) The present percentage of illiteracy among the people of school age and older is 61.5. The majority of them live on farm lands. From this standpoint not many farmers can master the technical concept of sound irrigation practices, nor can they develop such concepts themselves.

(3) Although irrigation has been practiced in Turkey for centuries, and though there have been some primitive local organizations, the unified operations of farmers on irrigation projects have not been realized yet on a nationwide scale. So, the government is in the position of dealing with each farmer on the projects under its operation.

The need for the formation of farmer groups has already been described. It has also been mentioned that if the services were directed to individuals this would mean waste of time, capital, manpower and energy. Economic feasibility is another factor itself.

The bank and TOPRAKSU have worked jointly on a sample statute of such a cooperative. It has been approved by the Ministry of Commerce. With a minimum of seven farmers, such a cooperative can be formed. Now the bank and TOPRAKSU are working on the procedures regarding the supply of credit for cooperatives. This type of organization can perform an important role for the following purposes:

- To provide credit to farmers easier
- To generate more funds
- To train farmers
- To work on larger areas
- To develop feasible projects
- To secure maximum utilization of loan proceeds and manpower
- To use the cooperative as a tool of subsidizing some of the costs involved

This last consideration has great value for the policy of subsidy to attract the attention of the farmers and lead them to bear the heavy costs of on-farm development.

The problem side of this effort is to train the farmer to form voluntary groups serving an actual need and not aimed at obtaining a loan only.

(4) Lack of a well established water rights system within the project areas and along the rivers is another problem. Present practice cannot make the farmers carry responsibilities for the beneficial use of certain amounts of water. Water charges are not on the basis of the volume of water applied to the field. A draft law has been prepared to cover the control of the distribution and use of water resources of Turkey. This is presently under discussion.

The formation of irrigation districts will of course facilitate the inventory of the present usage of water and establishment of water rights.

(5) The most important problems of present and future irrigation operations in Turkey are "personnel" and "communication." The basis of irrigation service for fifty years or longer is not only the design and construction of a system of canals. The present policy of the General Directorate of State Hydraulic Works (DSI) in determining the personnel requirements of each project is to take into consideration the skills of available personnel and the communication facilities on the project. The supervisory personnel of present and future irrigation projects must learn the necessity of water measurement, records and water handling. The subordinates must be taught how to deliver water and keep the records. Such objectives require sc[illegible]ng activities for the personnel, but, in the midst of present conditions of irrigation in Turkey, it is a "must."

In the last two years (1964, 1965) DSI has held "ditchrider training courses" at regional offices and "irrigation operators workshops" at the central office in Ankara. The first one is an on-the-job training for newly employed ditchriders and the second is somewhat of an annual meeting where the latest techniques and procedures adapted for application are explained to the operation engineers.

(6) Although a rehabilitation program is started on many projects, still the distribution and drainage systems are lacking the proper technical standards. On many, the distribution of the water cannot be controlled with sufficient accuracy.

(7) In many cases the irrigation operators are lacking proper training. It is believed that the formation of irrigation districts may solve many of the above problems automatically. The farmers must share with the government the duties and responsibilities of successful irrigation projects. Existing laws do not seem to provide sufficient control over the irrigators. A survey by the General Directorate of State Hydraulic Works in 1959 and 1960 showed that there were more than eight hundred local irrigation enterprises in Turkey. In most cases these enterprises lack written documents on their organization and activities. The survey does indicate, however, that Turkish farmers can accomplish the unified operations on their irrigation projects. The present problem is to achieve the detailed legislation for formation of irrigation districts.

Presently, water users can organize districts in accordance with existing laws concerning the creation of municipalities and similar public organizations. To facilitate this activity DSI has prepared standard regulations and has been announcing them to the villagers through its regional offices and the offices of governors or mayors. Some districts have been organized on this basis and DSI has entered into contracts with them which are mentioned above. On the other hand, a draft law, special for formation of irrigation districts, is being discussed by concerned government agencies.

(8) Farmers are reluctant to undertake costly programs. This is another factor slowing down activity, especially irrigation works for on-farm development. Most farmers do not believe that any extra expenditure can produce as much as the money invested. Therefore the rule of self-repayment is still to be impressed on the minds of farmers. They are inclined to keep feeling satisfaction with what "God gave them," and not anticipate more than they usually produce. The result of fertilizer use and the miracle of sufficient irrigation are still foreign to them.

In recent years accomplishments have been great in this field, but there is much yet to be done.

Implementation of supervised credit on a nation-wide basis is likely to help a lot on this problem.

(C) Opinions and Recommendations

Improvement of irrigated agriculture is a part of national programs for agricultural and social development in Turkey. So are recognition of the irrigation problem and development of a right understanding of the importance of it. Many years in the past, with scattered single purpose small systems, irrigation did not seem a difficult activity, because its effect did not go beyond the village boundaries, and such utilization of water would have small effect on either upstream or downstream developments.

Today, large multiple-purpose projects have been appearing on the major streams. These and the single-purpose projects constructed on the same streams or tributaries have forced the coordinated operations of river systems. Millions of people are dependent for their livelihood on the irrigation projects. Crop losses through insufficient water supplies may be a serious problem if the projects are not properly operated and maintained. In short, the wise and productive use of water and land resources is an increasingly important engineering activity. Improvement of irrigated agriculture is a part of this activity.

Vital points to be considered in the above-mentioned improvement in Turkey are many. They may be grouped as administrative, technical and financial problems:

From the administrative standpoint, after completion of the construction, the farmers must bear important responsibilities for the operation and maintenance of irrigation projects. This must be accomplished through formation of irrigation districts or similar organizations. It is very important that government help be directed to farmer groups, rather than individuals. Usage of the water must depend on well established water rights. Proper legislation for these purposes must be issued as soon as possible. Coordination among the concerned agencies is a very important feature of the activities. In a developing country, it is more important than the rest of the job. If a satisfactory nation-wide program is not developed, if sufficient organizations are not set up and carefully developed, if state policy (to cover the whole process) is not adapted, large funds spent might be wasted and considerable time lost. This coordination must result in the most beneficial use of land and water. The work programs of the agencies must be prepared on this basis.

From the technical standpoint, training of farmers as wise water users is a task which the government should bear to accomplish irrigation development. Training programs must cover the importance of well organized and well managed operations, good maintenance of the facilities, and close relationship with the project management, as well as proper irrigation practices in the field. Government agencies must coordinate properly in the application of rehabilitation programs in order to fully utilize project capacities and assure uninterrupted water deliveries on old irrigation systems. Land leveling and land drainage must be parallel activities to the improvement of canal networks. Cadastral maps of the project areas must be completed as soon as possible.

On the other hand, irrigation districts or any other enterprises dealing with the handling of irrigation water are expected to operate as a body, providing technical guidance and helping the farmers of the community, rather than to act as a kind of water distributor only. The Sugar Beet Growers Association of Turkey may be cited as a successful example of such leadership.

From the financial standpoint, capital formation is an important factor for efficient farm operations. Financing the improvement of irrigated agriculture must be a joint activity of private enterprise and the government. Enough capital funds must be appropriated, proper utilization of all funds must be secured, and a suitable credit system must be developed. The beneficiaries of irrigation projects must return the cost in annual installments within their repayment capacities, while the government appropriates necessary funds in the national budget.

THE CONTROL AND DISTRIBUTION OF IRRIGATION WATER IN THE UNITED ARAB REPUBLIC

by

Mohamed El-Madany*

Synopsis

The Nile has been, is now, and will forever be the source of life and prosperity to the people living in its valley. It has added to its material gifts valuable knowledge gained during the hydrological studies, and furnished the background to solve many problems of irrigation engineering.

Since days immemorial Egypt has been an agricultural country. Apart from a narrow strip bordering the Mediterranean, the country falls within a rainless area, so no other country within the Nile basin depends so wholly on the river for the irrigation of cultivable lands as does Egypt.

The earliest form of irrigation in Egypt was the basin system, which made use of the flood water for the cultivation of winter crops. It has been practiced throughout Egypt since the dawn of history. But it will be discontinued with completion of the Sadd-El-Aali Reservoir. Early in the nineteenth century most of the lands under this old system were gradually converted to perennial irrigation, under which cash crops could be matured.

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Conversion of the basin irrigation system to perennial irrigation, and the urgent need for agricultural expansion to meet the rapid increase of population, required that the water supply be continuous throughout the year. Thus, several canals were dug and many hydraulic structures were constructed for controlling, carrying and distributing water necessary for this new system of irrigation. At the same time reservoirs were constructed on the Nile to make available a certain amount of extra stored water at the time of surplus for use in time of shortage.

The annual supply of the river Nile varies widely. In some years, it may be short of irrigation requirements, while in others it may be so high as to expose the country to disastrous floods. In summer when the main cash crops: cotton, rice, etc., are grown, the water supply may reach thirty-six milliards m^3 in a low year.

All the storage reservoirs so far constructed store water after the peak of the flood is past for use in the low stage. This type of storage can be extended to some extent, but it is insufficient to meet the demands of low years. The only solution is long-term storage which enables storage from good years to help in bad ones.

The program of the proposed Nile Control Works, that had been laid down by the Egyptian authorities twelve years ago, consisted of: (1) over-year storage reservoirs in the Great Lakes of the Nile for increasing the summer water supply; (2) annual storage reservoirs for flood protection and for providing summer water supply; (3) three diversion channels to avoid losses in the swamp regions. At that time the authorities had the opinion that long-term storage was possible only in the Great Lakes. Creation of the Sadd-El-Aali Reservoir at Aswan, which stands within Egypt's boundaries, replaces all reservoirs for flood protection, shares a good deal in increasing the summer water supply, and rectifies the third diversion canal.

The experience gained during the past century and the advancements made in both hydraulic and irrigation sciences have helped Egyptian engineers to plan the irrigation systems that suit local conditions.

In this paper a short account is given of the methods for controlling the water supply and the operation of the hydraulic structures which have helped in harnessing the flow of the river Nile and the attainment of a fair water distribution.

Also, an attempt has been made to review methods of control and distribution of water to the field, and in the main, branch and distributary canals.

The problem of the field outlet is discussed. Early works in this connection were ahead of the hydraulic knowledge of the time and continued efforts have had to be made to improve them. The hydraulic research conducted to arrive at a solution has been a prolonged undertaking, but some reasonable results have been obtained.

The cause of shortage at the ends of laterals has been determined and remedies proposed.

(A) Regime of the River Nile

The present area under cultivation is six and a half million acres, of which about 0.7 million acres are still under the old system of basin irrigation. The annual water requirement for the present area is about forty-eight milliards m^3. Surplus river discharge escapes to the sea during the flood period. The amount of water passing to the sea is extremely variable, being zero in the low years and not less than 100 milliards m^3 in the highest. In fact, this variable supply may be so short of the irrigation requirements, as to threaten the country with the danger of starvation, as happened in the year 1913/1914, when the supply throughout the whole year did not exceed forty-two milliards m^3, or may be so high as to expose the country to destructive inundations, as happened in the year 1878/1879, when the supply was 151 milliards m^3.

The present requirement for irrigation in Egypt during the critical summer period (February-July) is estimated at some twenty-two milliards m^3 of which seven and a half milliards is water stored in the Aswan and Gebel Awlia Dams. The supply at this period of the year reached thirty-six milliards m^3 in 1879, and dropped at the same period in 1914 to only seven milliards m^3.

(B) Annual and Long-Term Storage

The two contrasting cases mentioned above explain the extent of variation in the natural supply of the river in relation to necessary requirements and show the urgent need of a solution of this problem. However, the problem cannot be solved by annual storage schemes, for the simple reason that the utility of such reservoirs is restricted to the detention of part of the comparatively clear water at a certain stage of the river, to be used only in the same year when the river is at its lowest. In addition, in some low years such reservoirs cannot be filled, with the result that the present irrigation requirements cannot be guaranteed and any further development runs the risk of disaster in low years.

Thus, to give a guarantee against individual low years as well as successions of low years, hold-over storage is the only solution, as it insures the storage of surplus water in excess of requirements in high years, to be drawn upon in years of low supply. For this, a large reservoir capacity is necessary, since we have to add to holdover storage and annual requirements a large capacity for silt storage and an additional amount for flood protection. Hence, the idea of constructing a high dam on the main Nile at a suitable site at Aswan upstream of the present dam, where we can deal with whole supply of the river and store all surplus water.

(C) The Importance of Sadd-El-Aali Reservoir in the Complete Control of the River Nile

When in 1949 the Egyptian authorities first outlined the program for complete control of the river Nile, they were of the opinion that long-term storage and supplementary reserves were only possible in the Great Lakes of the Nile, for the following reasons:

(1) There is vast room for very large quantities, and such room is unavailable elsewhere on the Nile.

(2) Storable water is clear and there is no need for additional large capacities to contain sediments.

(3) Evaporation is balanced by rainfall.

(4) A rise of lake levels does not materially increase the area of water surface.

The proposed new Nile Control Works then considered the following (see map, Plate 1):

(1) Over-year storage reservoirs, for increasing the River summer supply, their component parts are:

(a) Lake Tsana Reservoir.

(b) Equatorial Lakes Reservoirs and Works, which include: Lake Victoria Reservoir; Lake Kioga Reservoir; Lake Albert Reservoir; Jonglei Diversion Canal, to avoid losses into the swamps of the Sadd Regions. This canal will include three channels, the third of which will be used only in low years.

(2) Annual storage reservoirs for flood protection and for providing summer water supply. Their component parts are:

(a) Merower Reservoir.

(b) Wadi Rayan Reservoir.

This policy for utilizing the water resource of the river has been carefully revised in light of the hydrologic investigations conducted for Sadd-El-Aali (High Aswan Dam). Annual storage for expansion in cultivation has been provided by replacing the Merower and Wadi Rayan Reservoirs by Sadd-El-Aali which, with its enormous capacity, can provide sufficient live storage to guarantee: (1) a summer supply, (2) a reserve capacity for full protection against high floods, and (3) a dead storage to allow for the deposition of sediments. Thus the new project will guarantee all the irrigation water demands for the existing and future reclaimed lands, even in the lowest year of supply, and accordingly the third channel of Jonglei Scheme could be dispensed with. No change is suggested toward the program of the holdover storage stated above in the original plan of the Nile Control Works, with the exception that the ultimate capacity of Tana Reservoir would be smaller than originally proposed. In fact, the combination of these Upper Nile projects and the Sadd-El-Aali project secure the maximum possible utilization of the water of the Nile.

(D) Hydraulic Structures

Although many projects for control of the Nile, such as the great reservoir of Lake Moris, date back to remote times, yet construction of the gigantic hydraulic structures that now exist on the river began only during the first half of the nineteenth century. These structures include several dams and barrages, as follows:

(1) *Dams*

All the dams are gravity dams of the sluice type, built of masonry, and the sluices lined with granite ashler to resist erosion. They are constructed on solid rock, with downstream aprons to resist the erosive power of the water and to eliminate the existence of undesirable vortices. All sluice gates are of the stony free roller type. The Aswan Dam was the first to be constructed on the Nile and the most important, being the uppermost key of the Nile water within the boundary of Egypt. The original dam was constructed on the first cataract of the Nile in 1899-1902 to store one milliard m^3 of water. Its foundation was on solid granite rock and it was built of granite masonry with crest level at 109.00 mt, above M.S.L., and with no construction joints. The dam has a total length of 1950 meters, of which 550 meters are solid and the remaining length of about 1400 meters is pierced by 180 sluices at different levels according to the formation of the bed rock, being low in the lower part of the river channel. These channels of different bed levels provide an easy means for the maintenance of the sluices and aprons by switching the flow from one channel to the other.

Soon after the completion of the original dam, careful studies were made of the problem of providing more summer water supply to meet the increasing cotton plantations and a design was accepted to raise the crest of the dam by four meters for increasing its storage capacity to 2.4 milliards m^3. This required strengthening the dam, and the thickened wall was kept separate until time had elapsed to permit it to reach the same temperature as that of the original dam. The fifteen centimeter clearance left between the wall and the dam was then grouted.

The second enlarging of the dam, in 1933, consisted of raising the crest of the dam by nine meters and constructing buttresses between each sluice. The new portion was separated into seven meter-long blocks by means of watertight construction joints. The crest level of the dam at its present stage is at R.L. 123.00 meters and is impounding water to R.L. 121.00 meters. In 1944 a third enlarging of the dam, by increasing its height another eleven meters was proposed. This proposal was finally discarded in favor of the Sadd-El-Aali Reservoir.

Lately, the question arose as to whether or not it is possible to raise the present maximum reservoir level by one meter to provide an additional capacity of 500 million m^3, to meet immediate agricultural expansion. Extensive investigations were conducted to determine the quality of the dam mortar and the actual uplift pressure at the foundation rock. The findings show that to raise the reservoir level by one meter the following measures should be considered:

(a) Restore the mortar of the masonry, which has been found partly porous by the aggressive action of the seeping water.

(b) Reduce the uplift peaks on some parts of the dam.

(c) Reduce as far as possible leakage through the masonry.

To meet these requirements it was found necessary to make an impervious curtain, near the upstream face of the dam and extending down into the rock foundation, by an injection of a suitable grout mix, to impede further percolation and thus minimize deterioration and weakening of the mortar.

Practical experience gained from construction of this dam has led to considerable improvement in the design and construction of the two other dams on the Nile: the Gebel Awlia and Sennar Dams.

(2) *Barrages and Regulators*

Barrages on the Nile and regulators (check gates) on irrigation canals are all of the open type and have masonry floors to resist vertical and horizontal forces and to prepare a sufficient length to resist percolation as well as to protect the channel downstream from erosion. Lip walls are also used in connection with the floors to diminish erosive action of the water. The maximum head is five meters on barrage and four meters on regulators. The span of the openings is five or eight meters in barrages while it never exceeds five meters in regulators.

The openings are equipped with gates of the fixed roller type and the bottom gates are usually of a smaller size. The many investigations and experiments that have been conducted at the Delta Barrage Hydraulic Research Station and the experience gained from field observations at the various barrages revealed useful items, and solved many interesting problems. The salient facts revealed are these:

(a) All vents in a barrage should be of the same span and placed at the same level, with piers rounded in the upstream end and pointed at the downstream end in order to obtain the least resistance to flow and to avoid undesirable back currents.

(b) For the type design of barrages and regulators adopted in Egypt, the best type of floor is horizontal.

(c) The simplest type of anti-scouring devices is to have two lip walls of a height between d/6 and d/8 where "d" is depth of water downstream during the low stage. The first lip wall is to be placed in vents near the downstream end of the piers. The other is to be placed near the end of the solid floor with its slanted side upstream.

(d) In small regulators the flow conditions are much improved by fluming the downstream wing walls.

(e) The discharge from the sluices should always be drowned, a condition which is favorable for calibration as well as for minimizing the scouring effect downstream.

(f) To avoid dangerous effects on both the floor and the natural bed downstream, the discharge from the sluices should pass between the gates.

(g) To allow for adequate flow of water between the two gates, the bottom gate should be smaller than the top.

(h) The upper gate should be placed in the grooves channel upstream from the bottom gate. This helps in directing the flow as it emerges between the two gates toward the surface, thus diminishing the effect of scour on the floor.

(E) MEANS OF CONTROL OF WATER DISTRIBUTION AND METHODS OF REGULATION

(1) *Hydraulic Structures*

In order that the operation of irrigation may be properly conducted, the water supply must be well controlled and distributed fairly to the area under cultivation. The means for controlling the water supply should be practical and should have simple but precise methods for estimating the discharge for an irrigation channel at any moment. In other words, the control must be well calibrated. Accurate calibration is thus the basis of regulating the whole system of water distribution in Egypt.

(a) *Calibration of Dams*

The Aswan Dam was calibrated by both volumetric measurement and models. Sennar and Gebel-Awlia Dams were calibrated by models after the relation between the discharge of a model and its prototype was established by the volumetric measurements at Aswan. The Delta Barrage on the Nile and all head regulations of main and branch canals, nearly one thousand in number, were calibrated by current meters. Generally current meters are substituted by models where the first seems inconvenient.

Regulations on Aswan Dam are conducted as soon as the water of the river becomes clear, i.e., less than 200 parts of sediment per million. It begins by closing the lowest sluices, allowing the downstream level to drop by not more than twenty-five centimeters per day as a safety measure for securing the embankments of the river downstream. This reduction in discharge below the dam continues until the natural flow of the river is equal to the irrigation requirements. Release of the reservoir water begins when the natural flow falls below irrigation demands.

In nearly all the conditions of flow occuring at the Aswan Dam, the downstream level is so low as to give the same discharge as if the water escaped freely into air. The formula for a discharge of this type has been found by experiments to be $Q = CA\sqrt{2g(H\text{-}F)}$ where "C" and "F" are constants, "A" is the area of the sluice opening, "g" is the acceleration due to gravity (taken as 9.8) and "H" is the head above the sill of the sluice. Meters and seconds have been used as units throughout. Except for sluices fully open or nearly so, F = 0.8 x (height of sluice opening).

(b) *The Regulation of the Aswan Dam in Conjunction with the Sadd-El-Aali Reservoir*

The Sadd-El-Aali Reservoir is situated at about seven kilometers upstream from the present Aswan Dam, very well within the area of its storage basin. Due to the expected unavoidable fluctuation of load on the Sadd-El-Aali Dam Power Station, the water level upstream from the Aswan Dam will fluctuate within a range of six meters during a day. This frequent fluctuation in water level makes it very difficult to achieve a uniform release of water below the dam to meet the agricultural requirements.

Apparently, verification of such an objective seems to require an incessant adjustment of the gate opening, a procedure that can best be performed in an automatic way.

Investigations have been conducted as to the possibility of an automatic operation of the present Aswan Dam sluices, in a way that can give the required discharge under the varying upstream water level. The result of this investigation is a simple device (Plate II) which is the subject of a paper submitted to the Sixth Congress on Irrigation and Drainage in January, 1966. It is simply based on the idea of automatically operating the gates of one sluice or more while keeping unchanged the opening of the rest of the sluices required to keep constant the daily average demand.

(c) *Barrages and Head Regulators of Main Canals*

Barrages and head regulators in Egypt are generally controlled by means of steel gates. If the flow through the sluice is definitely clear or drowned, field or model measurements can lead to a formula, relating the discharge to the upstream and downstream levels and gate openings. The calibration formula may be expressed by a nomogram easy and rapid to read (Plate III). When sufficient data were available from already calibrated regulators it was found possible to put the calibration formula in a general form coping with all conditions of regulation. This enabled the mechanization of the calibration work in the form of a special computing machine, the nomogrammeter (Plate IV), which added much to the accuracy of the work and helped increase the number of yearly calibrations. If, however, the downstream water levels are affected by the backwater of a succeeding regulator, the structure can then only be calibrated by a downstream curve. Such a curve should be checked frequently to correct any influence of silting or scouring in the vicinity of the regulator.

Due to the expense involved and the navigation requirements, a main canal cannot be calibrated by means of weirs. However, the downstream water (provided with locks) which were constructed to relieve the old Delta Barrage from excessive head, are actually used as an accurate method for estimating the discharge.

During summer, when the natural supply of the river is below requirement, the regulator barrages keep the upstream water level at the adequate level to command the main canal. On the arrival of the flood, the rule 3:1 is adopted by gradually raising the upstream level until the barrage is fully open. The rule is applied when the river falls, until the maximum permissible head on the barrage is reached. Then, as far as possible, the upstream level should be kept constant. This is essential to facilitate regulation on head regulators of main canals and to avoid filling the barrage pool from the valuable summer water. With the falling river, the regulation on the barrage is effected first by lowering the top gates, starting from the lock side, to ensure safety of navigation. The discharge passing through the barrages must be distributed all over the sluices. No water is allowed to spill over the top gates, as this develops serious vibrations in the structure unless proper aeration is provided.

(d) *Branch Canal Head Regulators*

In branch canals the available head in general is limited, the regulators are too closely spaced, and they affect one another by backwater action, while rapid silting or erosion makes calibration on the basis of a discharge-downstream level relationship entirely unreliable. To calibrate such regulations, standing wave weirs have been built downstream from the regulators and are used for measuring the discharge, while timber logs are used for control of the opening. Characteristics for such weirs have been studied and specified in the Delta Barrage Research Station.

In the Fayoum Province, the general slope of the ground is ample to permit the use of freefall weirs. This system of calibration is quite perfect for proper control and distribution of the water.

The preference of one type of weir to the other depends on the amount of head required. This is demonstrated on Plate V, which is self-explanatory.

To deal with exceptional conditions, the effect of submergency of the C.O.W. Fayoum type has been thoroughly studied. The Diagram on Plate VI gives the necessary reduction in discharge due to various degrees of submergency per meter width of weir.

Another method for accurately calibrating branch canal head regulators is the worm gear gate, with a discharge indicator to give the discharge reading immediately at the point of control (Plate VII). This simple and handy device was the result of a large number of experiments conducted at the Delta Barrage Research Station. Many of the branch canal head regulators in Egypt are now equipped with this instrument.

(e) *Distributary Canal Head Regulators*

The best method of controlling the discharge of these small regulators is by means of movable weirs. It gives the discharge immediately at the point of control. It is of two types, one to be used for depths up to one half meter and the other for depths more than one half meter.

(2) *Canals*

Canals are designed either to carry the discharge of the maximum demand, which is in July and the early part of August, or to discharge only the normal supply, which is maintained during the greater part of the year. In the latter case the canal banks must be designed so as to permit a rise of the water level during the short period of maximum demand produced by a full supply discharge.

The flow of water in canals depends mainly on the time allotted to them for delivering the supply demands resulting from the field duties. The effect is briefly explained for each class of canal as follows:

(a) *Distributaries*

The maximum supply of the distributaries as now generally adopted in Lower Egypt is fifty cubic meters per day per feddan served by the canal. This figure increases gradually as we go south and is based on the assumption that the canal will perform its duty to the utmost in one week.

Meanwhile, the actual flood discharges of the distributary canals are determined by the "water allowance" of the outlets, the latter depending on the system of running the distributaries and the required maximum supply.

The time during which the maximum discharge has to be delivered depends either on the period of maximum demand, if sufficient water is available for a continuous supply, or on the period of maximum supply, when it is only temporarily available. The water allowance of distributaries and outlets must, therefore, be sufficient in either case to meet only temporary conditions and demands and is absolutely independent of the long period average, such as "duty." In other words, the outlets and the distributaries must be capable of supplying the water quantities necessary for the heaviest watering during a given period.

Various improvements of water flow through distributary canal head regulators have also been tried and useful results obtained. The following two are examples:

First, the best angle of fluming and the side walls of a regulator to give optimum discharge (Plate VIII).*

* Irrigation Project Dept., Ministry of Public Works, 1935.

Second, high efficiency flumes in which loss of head is reduced to a minimum (Plate IX).‡ This is effected through giving the flume floor an adverse slope in the diverging part beyond the throat, thereby permitting the control section to adjust itself automatically to the condition of minimum loss of energy. Curve *o a b* represents the relation for a flat-bottomed flume, while the straight line *o c d* represents the corresponding relation for a flume with a hump.

Expressed in rational form, the equation of curve *o a b* is $Q = 0.40\ 2g\ B\ H^{1.5}$.

The limiting value of the submergence D/H for modular conditions was found to be 0.88 in both cases.

According to the present regime in Egypt, the "critical period" occurs in July, when forty percent (or more) of the land is in summer crops, principally cotton and rice, and the remaining area is fallow, which in that month urgently demands a heavy flooding. "Rotation," as a general rule, is still in force in July and the distributaries and outlets are consequently strained to their utmost. The outlets, then, must be able to discharge an average of seventy cubic meters per day per feddan of the gross cultivated area.

However, when the Sadd-El-Aali reservoir is completed, the restriction on a certain percentage of the area to be cultivated at any time of the year will be out of the question, because the requisite demand for a full crop pattern will be in force the year around.

Liberal water allowance for outlets by rotation means economy of water, the watering being done quicker and the field wastage being less.

(b) *Branch Canals*

If a secondary canal which feeds several distributaries is not liable to be subjected to a certain regime of "rotation," its discharges then must be calculated in a way similar to that for distributaries, which cannot be done practically.

‡ Prof. Ali Fathi Aand Abdel Hadi Abu-el-Fetough, Faculty of Engineering, Alexandria.

For instance, consider a canal serving 30,000 feddans all planted to cotton, receiving every eighteen days one watering of 400 cubic meters per feddan. If the landowners are given free choice of the dates of irrigation, they may be inclined to water the total area at once and they will then draw from the canal as much as their outlets will allow them, which is impractical.

The impracticality is due to the simple fact that the daily summer discharge of the Nile and the capacities of the main canals do not allow for such liberties, and the regime of rotations imposed by the government obliges the landowners to irrigate their land in turns, thus reducing the discharges of the canals and bringing their size within reasonable limits.

(c) *Main Canals*

These are seldom subjected to rotation. Their duties are calculated in precisely the same way as the general field duties, but on a far bigger scale.

To obtain the duties at the head regulators of the main canals an allowance for the conveyance losses through the whole of the canal system must be added to the field duties.

(F) The Problem of Field Outlets

(1) *Present Conditions*

The present field outlets are either in the form of clear overfall weirs, previously referred to, as in the Fayoum Governorate where the general slope of the ground is ample to permit its use, or in the form of pipes, which are used in the rest of the country. Clear overfall weirs give very fair proportionality in the distribution of water to adequate areas, but the discharge of the pipe outlets is based on the assumption that the pipes are submerged under a head of twenty-five centimeters. By lowering the level in an offtake channel by use of a pump, the farmer could increase the discharge. Under these circumstances it is hardly surprising that difficulty is often experienced in getting water to the tail of even a repiped canal unless the discharge is increased, resulting in a wastage of water.

Generally speaking, three causes are mainly responsible for shortages at ends of distributaries:

First, the discharges of the distributaries should from time to time be modified according to variation in needs for water supply as crops and seasons change. This in fact requires that the corresponding levels in the distributary canal are equal to those commanding the modified discharges at the offtakes. This is difficult to achieve.

Second, the occasional growth of weeds in many of the canals impedes the flow of sufficient amount of water unless the levels are altered. Such alteration of the water levels will, of course, have its effect on the discharges of outlets.

Third, water misuse.

(2) *Trends Toward the Ideal Field Outlet*

Earnest efforts have been made by various irrigation authorities in the United Arab Republic in their endeavor to achieve the best shape of modular or semi-modular field outlet, of which only three will be mentioned:

(a) The Semi-Modular Field Outlet

The earliest trials (1925-1928) were conducted at the Delta Barrage Experimental Station to improve the present field pipe outlet, which is based on the following:

For canals of ordinary design, that is to say, trapezoidal sections within the limits of depth and bed width used in practice, it can be shown that there is a fairly definite relation between the variation of discharge and water depth for all bed widths and depths, provided the hydraulic slope remains constant, as follows:

Discharge	Corresponding Depth
1.0 Q	1.00 D
0.9	0.95
0.8	0.88
0.7	0.82

During the summer when exact distribution is most important the unavoidable variation in discharge will be from "Q," the full supply, down to about .7 "Q" in any one distributary. If then the depth of water can be made to vary from "D" to .82 "D," for the above variation in discharge, the water slope will remain unchanged and a step toward even distribution will have been made.

As a result of extensive laboratory and field experiments, the formulae for the free discharge of pipe into air may have the form, $Q = C\,A\sqrt{h-.3d}$, where "h" is the upstream level measured down to the center of the pipe at its downstream end, and "d" is the pipe diameter. The value of 0.3d represents the height of the "depression center" an imaginary point above center of pipe. Thus if the outlet is constructed in the form of a pipe with a flume at downstream (Plate X) and the depression center is set at level of 0.65 "D" where "D" is the full supply depth upstream from the outlet, the discharge passing the outlet will be $Q = C\,A\sqrt{h}$, where "h" is the difference between the upstream water level and the depression center of the pipe. In this case, the discharge will be materially independent of the downstream water level provided that it does not rise more than $0.6\ V^2/2g$ above the depression center, which has been verified by experiments.

Now, if the pipe is set with its depression center at 0.65 "D" the following will be the extreme limits:

Upstream	h	Pipe Discharge	Percent
D	0.35 D	$0.59\ CA\sqrt{D}$.	100
0.82 D	0.17 D	$0.41\ CA\sqrt{D}$.	70

That is to say, the outlet situated as above will preserve the required relation between discharge and depth in the canal and will therefore cause the water slopes in the reach above the outlet to remain the same for all changes in discharge between "Q" and 0.7"Q."

In any case, if the discharge is large, a single pipe will require a diameter too large to remain submerged at its upstream end, and the pipe may be laid sloping up without detriment to its action.

Assuming that by good maintenance it is possible to keep the canal in good condition and free of weeds and that misuse can be eliminated, the water slope in any reach will remain invariable in spite of fluctuations of discharge in the head reach, if the sluices of the regulators on the distributary canals are made in the form of the aforesaid improved outlet. Since the water slope in the reach is now theoretically constant in all discharges, a correct distribution to the field offtakes is possible wherever they are situated along the head reach, on condition that the depression centers of all pipe offtakes would be set at a level of 0.65 "D" and therefore on a line parallel to the designed water slope.

(b) The Self-Adjusting Field Outlet

This device was the subject of a paper discussed in the Third Congress on Irrigation and Drainage held in San Francisco in 1957. Since then essential improvements have been introduced to give higher efficiency, and a simple type has been devised to suit field use.

This device in its general form consists of a pipe, weir or flume capable of reducing the effect due to drowning to a minimum, and a mechanism which can automatically adjust the width of the outlet to suit any defined discharge within an ample range of upstream water levels. It also helps in occasionally modifying the discharge of an outlet to suit the various seasonal water requirements or a modified crop pattern. The device is, therefore, a firm trend toward verification of the capital idea of "modular outlet" (Plate XI).

In its up-to-date complete form the device consists mainly of (A) A float (1), the elevation of which depends on the variation of water depth on sill of weir (2). (B) A number of openings, each provided with a vertical pair of leaves of suitable shape (3), erected within protected grooves cut in both sides of the outlet walls, in a way that the leaves can form protuberances of the magnitude requisite for giving the pertinent width corresponding to the varied upstream water level without creating cavities of any form behind them. These cavities that were inherited in the original design caused vibration of the device.

(C) A mechanical monogram (4) to transform the changes of the upstream water levels as felt by the float (1) to the opening flap leaves. The general discharge formula is: $Q = qn = CD^r$ where "Q" is the total discharge; "q," discharge per outlet; "n," number of outlets required; "D," depth of water on sill; "C" and "r" constants verified by experiments

The device may consist of any number of outlets as required to suit the area to be irrigated, and the amount of water duty requisite for any crop pattern.

(c) Improvements in the Local Lifting Appliances

Many efforts have been exerted by the Egyption authorities to improve the various types of local contrivances useable for a small lift. The one which is presently receiving more interest is the tambosha. It is a vertical wheel divided into a number of compartments by spiral walls. Each compartment has an opening at its rim which dips into the water as the wheel turns to fill the compartment with water, then turns up. The compartments empty themselves into the offtake channel through openings located at the center of the wheel (see Plate XII).

The rate of flow that can be obtained with a water wheel of the tambosha type appears to be determined by the area of bucket opening, length of submerged path opening (which varies inversely as the lift), level of water of the supply pool below center of the wheel, and the velocity of the opening through the supply pool, thus:

$$Q = (f)\ A.N.S.L.$$

where Q = rate of discharge, liter/sec.
A = area of one bucket opening, cm^2
N = velocity of bucket, nW/60 No./sec.
n = number of buckets in wheel
w = speed of rotation, r.p.m.
s = length of submerged path of bucket opening

$$2R \cos^{-1} \frac{L}{R}, \text{cm.}$$

L = nominal lift, from water surface to center of wheel cm.
R = nominal radius of wheel, cm.

However, prelimiary experiments have revealed the possibility of applying the following simplified form of equation within an error of ± thirty percent:

$$Q = 2\ Cd\ n\ NBH\ (R - \frac{h}{2})\ \cos^{-1}\ (\frac{H}{R - \frac{h}{2}})$$

Where "Cd" = Discharge Coefficient to be determined by experiments, "B" = width of tambosha, "N" = number of turns per minute of the tambosha, "h" = height of bucket opening, and "H" = lift.

Further experiments are being conducted on another type "C" in which the bucket segments are plates of circular shape and the intake tube projects into the bucket. This is expected to reduce the tendency for water to splash out of the buckets at the higher speed. Tests may indicate that the bucket openings can be further reduced in size. Should this prove feasible the volume of the buckets would be correspondingly increased.

CHAPTER VII

Farm Layout for Irrigated Agriculture

WATER-USE IMPROVEMENT PROJECT

by

Savvas J. Chimonides*

Introduction

Although scarce, water is used in a wasteful manner. Every report made by water use experts who deal with the topic cites the inefficient and wasteful methods of water utilization at the farm level as a major contributory factor to the present low unit income of water.

The project summarized in this report is intended to correct the situation at the farm level in parts of Cyprus. As such, it is one of the necessary steps to improve the whole pattern of water use.

I. Nature and Extent of the Problem

(A) WATER WASTE

At least forty to fifty percent of the irrigation water which reaches the farms of Cyprus, either from wells or surface sources, is wasted. The primary factors responsible for this wastage are as follows:

(1) Conveyance of water through earth channels. Losses are due to deep percolation, evaporation, and excessive weed growth.

(2) Inefficient methods of irrigation, i.e., wild flooding, border irrigation, furrow-basin irrigation, etc.‡ Losses are due to deep percolation below the root zone of the crops being irrigated, surface runoff and weed growth. Losses are greatest with young trees.

(3) Unleveled fields, resulting not only in waste of water but also in poor distribution of it within the root zone.

(4) Two frequent irrigation, resulting in excessive losses from surface evaporation. Also a tendency to over-irrigate exists, which results in heavy losses through deep percolation. In soils lacking good drainage, damage to the crop may result.

(B) WATER-USE EFFICIENCY

A comparison of the amount of water used and the amount of water which should be used

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‡ On lands not properly leveled.

shows the following facts for the main irrigated regions of the island:

Region	*Water Use Efficiency*
Western Messaoria	45 Percent
Eastern Messaoria	62 Percent
Limassol area	51 Percent

All the above areas are irrigated by water extracted from boreholes or wells.

In a semi-arid country such as Cyprus, where water is scarce, every effort should be made to increase efficiency of water use and to select a cropping pattern which will maximize income per unit volume of water. For dams where development costs average twenty-five mils per cubic meter, to waste fifty percent of the water is tantamount to doubling its cost to fifty mils per cubic meter.

The project considered here will cover about 90,000 donums (30,000 acres) in physical terms, or due to some double cropping, 105,000 donums (35,000 acres) in crop terms, irrigated from boreholes. In addition, all the area to be irrigated from dams will be included in the project. This area is estimated at 15,000 donums (5,000 acres).

From the 105,000 donums, priority is given to areas where sea water intrusion is already taking place or is a constant threat; i.e., Famagusta, Limassol and Morphou areas. The above areas are all under high yielding crops, i.e., citrus, vegetables, vines, etc.

II. Project Goals

(A) Expected Benefit to the Country

(1) The main target of the project is to raise water-use efficiency,* of the regions covered, which are irrigated from boreholes, from fifty-three percent to seventy-seven percent for trees and from fifty-three percent to sixty-eight percent for vegetables, in the next four years, and thereby save about twenty-six million cubic meters of water per year. In the project area today there is over-pumping of approximately forty million cubic meters per year. At the end of the project this will be much higher if expansion goes on unchecked. Since an estimated six million cubic meters would have returned to the aquifer through deep percolation, the net saving is twenty million cubic meters per year. This should save from destruction some 12,000 donums, which presently produce a gross income of approximately two million pounds annually.

In the case of dams, virtually all the water saved can be used for expanding irrigation, since there will be no problem of stabilizing the aquifer. Also, the improvement in water-use efficiency can be considerably higher because the topography below new dams is generally such that unimproved irrigation efficiencies would be very low.

(2) A second target of this project is to raise yields by five percent, through improved irrigation practices; i.e., more uniform distribution of the water in the root zone. The greater yields will result in an increased production valued at approximately 427,000 pounds annually. The cost of the whole project is 1,854,000 pounds.

It should be mentioned that there are other, indirect benefits such as stimulation to new industry for pipes, creation of employment, and more gain for the distribution services for handling the additional output.

(B) Expected Benefits to the Farmers

(1) There will be a saving in pumping costs and irrigation labor, in that water not required or saved will not have to be pumped and will not have to be handled. The total saving per year for the twenty-six million tons will be approximately 260,000 pounds annually.

(2) It has been estimated that with the proper frequency, with the right amount of water per irrigation, and with improved systems of irrigation resulting in more uniform distribution of water in the root zone, there will be an overall five percent increase in yields per donum. Essentially this increase may be considered as net and will provide additional net income of about 427,000 pounds annually.

$$* \frac{\text{Consumptive use of crop}}{\text{Total water applied}}$$

(3) Net income from the area of 12,000 donums saved from destruction will be about 700,000 pounds annually.

Total net return to farmers then will be 1,387,000 pounds annually. In other words the successful implementation of the project will directly benefit the farmers by about 1,387,000 pounds net income per year, or 15.4 pounds per donum annually.

The average capital cost is twenty pounds per donum. If this is taken at interest ever the fifteen-year life of the system, then the annual cost is approximately two pounds per donum per year. So the cost/benefit ratio is very favorable.

III. Means for Achieving the Targets

The target mentioned above can be reached by: (a) Replacing all earth conveyance channels by piping in order to avoid losses through deep percolation and evaporation; (b) improved methods of irrigation. The crops involved in this project are primarily citrus (more than half) and vegetables of various types, i.e., potatoes, tomatoes, cucumbers, carrots, melons, etc. Systems to be recommended are as follows:

Young trees: Hose-basin only, with increasing size of basins as trees grow.

Mature trees: Either hose-basin or sprinkler irrigation as circumstances dictate; i.e., spacing of trees, height of the foliage from ground, water quality, etc.

Note that these systems use the same mainlines and laterals, so are easily interchangeable.

Vegetables: Sprinklers, or gated pipes and short furrows.

The hose-basin system is a closed, low pressure system from the well to the individual basins.

The water is brought from the well into the main line, then into the secondary or portable laterals and through rubber or plastic hoses into the basins.

The *advantages* of the system are as follows:

(1) There are virtually no losses in conveyance from the well to the individual basins.

(2) This method can achieve the most efficient distribution of the water in the root zone. By knowing the water requirement of the trees, the available moisture storage characteristics of the soil, and the output of the hose, the quantity applied to each basin can be regulated in terms of minutes. By this means, losses through deep percolation can be minimized. Basins can be constructed by tractors.

(3) An eighty percent water-use efficiency can be achieved.

(4) Women or children as well as men can handle the water.

(5) The even distribution of water will result in increased yields per donum.

(6) Weeds are confined only to basins, and only the root area is wetted. This is important for young trees which occupy only a portion of the overall area.

(7) This method can be applied to any kind of soil and to places where no proper leveling has been made, which is the case with virtually all orchards in Cyprus.

(8) In the case of saline waters, leaching of salts from the root zone can be achieved in the most controlled manner.

Disadvantage: High initial capital required for the installation of the systems. However, amortization of the captial can be achieved in the first three to six years from the benefits listed above.

Sprinkler irrigation system. This is a well known system. An effciency of seventy percent can be achieved, provided that the system is well designed. This method will substitute for the hose-basin system whenever the latter cannot be applied. Due to its high efficiency, priority should be given to the use of this system for vegetables. Whenever this is not possible then gated pipes and short furrows should be used.

Gated pipe system with short furrows. This is a closed low pressure system. The water is brought from the well into the main line and then into the portable gated pipe laterals and through the gates into short closed furrows. There is a gate opposite each furrow. With this system an efficiency of sixty-five percent can be achieved, provided that the land is well leveled and graded and the length of the furrows adjusted according to the leveling, the soil, the root zone and the available head of water.

In Cyprus where plots are generally small, soils frequently shallow, and flows of water often small (ten to 120 cubic meters per hour), there is no history of land leveling to the exacting standards demanded foı efficient irrigation. Consequently much irrigation of row crops is done by what we term the "local method." This consists of short closed furrows running across the slope, fed by frequent cross channels running with the slope and receiving water from a main channel coming from the water source and crossing the top of the field. Where sprinkling of vegetable crops is inapplicable for any reason, a variation of the local method will be used. The land will be leveled to grade insofar as conditions permit, in order to increase the length of furrows between cross channels and thus increase the percentage of cropped area. Then the cross channels will be replaced by gated pipes (leveling will be done to permit flow both directions from the gated pipes to reduce the number of positions they must be moved to), and the main channel will be replaced by a pipe back to the water source. In this way average water-use efficiencies of sixty-five percent can be reached.

(A) Land Leveling for Uniform Distribution of Irrigation Water

As stated, all lands to be surface-irrigated (gated pipe-short furrows) will be leveled to grade as best fits the conditions.

Where sprinkler irrigation is to be used, the land will be smoothed and in some cases leveled to grade for flexibility, i.e., as in the example case of Mohamed Ismail of Meneou, Larnaca district, where both systems will be used interchangeably for vegetables due to switching of water sources. (Saline water comes from the borehole and good quality water from the dam.)

Where hose-basin irrigation is to be installed, smoothing will generally be done basin-by-basin because the trees are already planted. In the case of new plantations, land leveling to grade will be carried out in all cases.

Speaking generally, land leveling is an old practice in Cyprus. For centuries up to and including World War II, bench terracing in the mountainous areas was done by hand, and in the plains leveling was done with wooden tools drawn by oxen.

In the past twenty years land leveling has become mechanized. Today a great variety of machinery and implements are used, ranging from small rubber tire tractors of approximately forty horsepower to heavy crawler tractors of as much as 200 horsepower, and from small blades to big scrapers.

Usually for heavy soils the gradient given is up to two percent; for medium, up to five percent, and for light soils up to eight percent.

The cost of leveling varies greatly according to the depth of cut and distance of transport. In the plains, this ranges from five to fifteen pounds per donum. In foothill areas where bench terracing is done, the costs range from fifteen to twenty-five pounds per donum, and in the mountainous areas, from twenty-five to forty pounds per donum.

In hilly and mountainous areas, soils are frequently shallow, so it is necessary to break the subsoil, both "B" and "C" horizons, which is finally used for cropping.

(B) Advisory Services

There are advisory services to advise farmers on all cultural practices affecting water use. A separate paper is presented under the heading, "Education and Training in Irrigation in Cyprus."

IV. Costs of the Project

The project will continue at least through 1969 and will cost an estimated 1.8 million pounds, divided between farmers and government as follows:

Government	281,000 pounds
Farmers	1,573,000 pounds
Total	1,854,000 pounds

Costs to the government include those of personnel, training, accommodation and equipment for the Water Use Section of the Department of Agriculture and a subsidy to encourage farmers to enter the project and to assure their meeting the project standards.

Costs to the farmers include leveling, piping, booster pumps, water meters, etc.

V. Assistance Given by the Government to Farmers

Financial and technical assistance is given to the farmers for the proper design and installation of the improved systems.

As financial assistance the government offers fifteen percent of the cost as a subsidy for inducement, and through the Central Cooperative Bank it will loan the remaining eighty-five percent. The loan is long term with four and one-half percent interest. Both subsidy and loan are dependent on the installed system meeting the design specifications and standards of the Department of Agriculture. Installation may be carried out by the farmer himself or by a contractor.

As technical assistance, the government, acting through the Water Use Section of the Department of Agriculture, is prepared to accept applications from any and all farmers in the specified areas. These applications are submitted to the Water Use Section through the District Agricultural Officer who gives recommendations regarding the farmer concerned. Trained people from the Water Use Section will then visit the farm, survey and map it, take soil and water samples and all pertinent information and then in consultation with the farmer, design an efficient irrigation system for him. The so designed system, together with cost estimates, is then submitted to the Water Use Advisory Committee for approval. After approval of the plan the farmer gets the loan, which represents eighty-five percent of the cost, from the Central Cooperative Bank. The installation of the irrigation system is checked after completion, by technical personnel of the Water Use Section and of the Extension Service. If the installed system meets the specifications of the plan, the farmer receives fifteen percent of the cost as subsidy.

The Water Use personnel also prepare individual farm irrigation schedules showing the frequency of irrigation and the amount of water to be given per irrigation. Frequency and amount depend on the available moisture storage capacity of the soil, the depth of the root zone, and the water requirements of the crop.

After installation of the system the Extension staff follows the irrigation practices of the farm and reports to the Water Use Section any difficulty that the farmer may find.

In all systems water meters are installed for accurate control of water use.

The project started early in 1965. The applications received up to the end of 1965 represent 632 farmers and cover an area of 11,261 donums (3,754 acres).

The plans already approved represent 196 farmers, and cover an area of 4,187 donums (1,396 acres), with a total cost of 90,000 pounds. Of this amount 13,500 pounds represent fifteen percent subsidy and 76,500 pounds represent eighty-five percent long term loan with four and one-half percent interest.

VI. Costs of Improved Irrigation System

The factors which enter strongly into the per donum cost of improved irrigation systems in Cyprus are primarily as follows:

(1) Size of the field. (Per donum cost varies

inversely with field size.)

(2) Shape of the field. (Per donum cost varies inversely with field regularity.)

(3) Available flow of water. (Cost varies directly with flow; larger pipe sizes.)

(4) Basic leveling of land. (Cost is greater on bench-terraced lands than elsewhere.)

This discussion of costs does not include land preparation (leveling, bench terracing, etc.), which has already been covered. Note also that no distinction is made for type of irrigation system, because the three recommended systems (hose-basin, sprinkling, and gated pipe-short furrow) are all closed pressure systems incorporating much the safe features; therefore they have much the same per donum cost.

Cited below are some actual examples to illustrate the range of costs we have encountered for fields of various sizes, due to the above factors:

(A) Comparison of cost per donum for two fields, each thirteen donums in size. Both are irregular in shape, and neither are terraced. Variability is in water flow.

(1) Cost per donum is twenty-one pounds. (Available water flow is thirty cubic meters per hour)

(2) Cost per donum is thirty-eight pounds. (Available water flow is ninety cubic meters per hour)

(B) Comparison of costs per donum for three fields, each twenty donums in size.

(1) Cost per donum is thirteen pounds. (Shape regular; flow eighteen cubic meters per hour; not terraced)

(2) Cost per donum is twenty-one pounds. (Shape irregular; flow fifteen cubic meters per hour; bench terraced)

(3) Cost per donum is thirty-six pounds. (Shape irregular; flow sixty cubic meters per hour; bench terraced)

(C) Comparison of cost per donum for two fields, each forty-five donums in size.

(1) Cost per donum is ten pounds. (Shape irregular; flow thirty cubic meters per hour; not terraced)

(2) Cost per donum is twenty-six pounds. (Shape irregular; flow seventy cubic meters per hour; not terraced)

(D) Comparison of cost per donum for two fields, each 130 donums in size.

(1) Cost per donum is twelve pounds. (Shape regular; flow sixty cubic meters per hour; not terraced)

(2) Cost per donum is eighteen pounds. (Shape irregular; flow 120 cubic meters per hour; not terraced)

(E) Cost per donum is thirty pounds for a two donum field in the mountainous area. This piece is bench-terraced and is irrigated with a flow of eighteen cubic meters per hour from a nearby dam.

Actual costs or estimates for the 4,040 donums approved in 1965 average eighteen and one half pounds per donum. These costs include both conveyance and irrigation piping and fittings, water meters, booster pumps, etc., and the installation of all. Of the 4,040 donums, 842 donums require leveling at an average cost of nine pounds per donum.

Publications Cited

(1) Planning Commission Secretariat (Government of Cyprus) "A Project for the Improvement of Water Use Efficiency." Issued at Nicosia, August 13, 1963.

(2) Stewart, J. I.: FAO Technical Officer (Irrigation); "Water Use in the Western Messaoria." Issued at Nicosia, September 1, 1965.

APPENDIX I

Mohamed Ismail Farm

Larnaca, Cyprus

The farm is situated six miles from Larnaca town. The area is approximately ninety-three donums (thirty-one acres), of which sixty-three donums are occupied by mature citrus trees and twenty-one donums by vegetables. Tree spacing is twenty feet by twenty feet.

Previously the farm was irrigated by groundwater from borehole No. 1 as shown on the attached map, with a flow of forty cubic meters per hour. A few years ago the quality of water was very good, but today, owing to the overpumping of the aquifer which has resulted in sea water intrusion, NaCl content has increased to 1,750 parts per million. Since last year the farm has a source of good quality water from the dam, with a flow rate of fifty cubic meters per hour.

Soils are deep, of medium texture, and with good drainage, which facilitates the leaching of salts from the root zone.

The systems of irrigation used in the past were borders and basins for the citrus trees and the local furrow method for vegetables. Today, whenever good quality water is available from the dam, trees are irrigated by the hose-basin method and vegetables by sprinklers. During winter excessive amounts are used for the leaching of salts from the root zone. Water from the dam is available until mid-June.

With the pumped water, trees are irrigated by hose-basin and vegetables by the gated pipe-short furrow system.

(A) Benefits from the Improved System

The average water-use efficiency will be raised from fifty-five percent to sixty-seven percent. Higher efficiency is not desired in this instance because of the leaching requirements to control the salinity level in the root zone.

The consumptive use of citrus is 900 cubic meters per donum per year and the average consumptive use for vegetables (tomatoes, potatoes, melons, cabbages) is 460 cubic meters per growing season. The water saved through the improved efficiency is 19,400 cubic meters per year.

(1) Saving in pumping costs (four mils per cubic meter) and irrigation labor (four and one half mils per cubic meter) 19,400 cubic meters by eight and one half mils per cubic meter

165 pounds annually

(2) Five percent increase of the yield

350 pounds annually

(3) Net income of an area equivalent to ten donums to be saved from destruction

400 pounds annually

Increase in Net Income, Total:

915 pounds annually

(B) Cost of the Improved System

The costs as shown on the attached bill of materials consist of:

(1) Piping, fittings, booster pumps, water meters, etc.

Total 1,740 pounds or

20.7 pounds per donum

(2) Leveling for twenty-one donums

Total 147 pounds or

7 pounds per donum

Grand Total 1,887 pounds per donum

Rough breakdown of costs for improved irrigation systems
(hose-basin, sprinkler and gated pipe-short furrows)

Piping and fittings	1,313.305	pounds
Water meter and fittings	47.450	pounds
Booster pump	175.000	pounds
Total	1,535.755	pounds
Miscellaneous three percent	46.245	pounds
Installation ten percent	158.000	pounds
Total	1,740.000	pounds
Leveling twenty-one donums	147.000	pounds
Grand Total	1,887.000	pounds

Average cost per donum is 22.4 pounds

(C) Irrigation Schedule

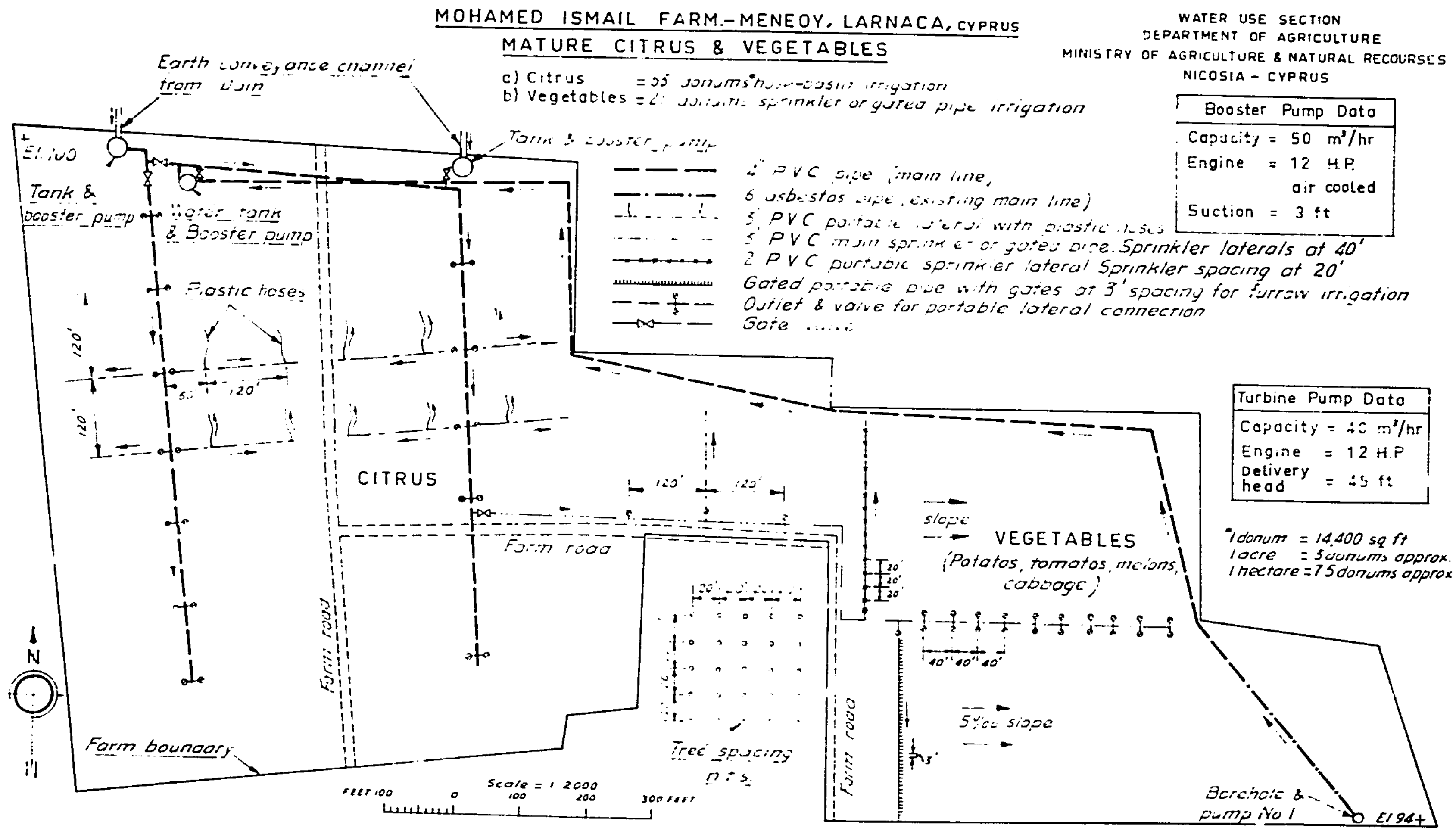
This includes frequency of irrigation and amount of water per irrigation per donum and per basin. (Each basin is occupied by one tree.)

Irrigation efficiency above seventy percent is not desirable in this case, due to the leaching requirements brought about by the salinity of the well water. Frequency of irrigation should be based on sixty percent readily available moisture depletion, i.e. 2.8 inches. One inch per donum equals thirty-four cubic meters.

For a tree spacing twenty feet by twenty feet the number of trees per donum is thirty-six. Six hoses of one inch diameter operating simultaneously will handle the flow of forty cubic meters per hour, each hose with an output of seven cubic meters per hour. When operating with water from the dam which is supplied at a flow rate of fifty cubic meters per hour, seven hoses will be required.

The water needed at seventy percent irrigation efficiency per day per donum, per irrigation per donum, per irrigation per basin or tree, the frequency range, and the time (minutes) that the water should flow from the hose into each basin, are as follows:

Month	Seventy percent efficiency m^3/day/ donum	Frequency range (days)	Amount needed per irrigation per donum (m^3)	Thirty-six basins (trees) per donum: Water needed per basin or tree (m^3)	Hose output $= 7\ m^3/hr$: Time of flow from hose into each basin (minutes)
April	3.93	33 - 38	129 - 149	3.5 - 4.1	30 - 35
May	5.40	23 - 28	124 - 151	3.4 - 4.1	29 - 35
June	6.60	18 - 23	118 - 151	3.2 - 4.2	27 - 36
July	8.16	14 - 19	114 - 155	3.1 - 4.3	26 - 36
August	9.32	12 - 17	111 - 158	3.0 - 4.4	25 - 38
September	6.80	18 - 23	122 - 156	3.3 - 4.3	28 - 36
October	4.86	26 - 31	126 - 150	3.5 - 4.1	30 - 35



MOHAMED ISMAIL FARM.-MENEOY, LARNACA, CYPRUS
MATURE CITRUS & VEGETABLES
WATER USE SECTION
DEPARTMENT OF AGRICULTURE
MINISTRY OF AGRICULTURE & NATURAL RECOURSES
NICOSIA - CYPRUS
c) Citrus
b) Vegetables
sprinkler or gated pipe irrigation
Booster Pump Data
Capacity = 50 m³/hr
Engine = 12 H.P. air cooled
Suction = 3 ft
Turbine Pump Data
Engine = 12 H.P.
Delivery head
Earth conveyance channel
Tank & booster pump
Water tank & Booster pump
Plastic hoses
CITRUS
Farm road
Farm boundary
VEGETABLES
(Potatos, tomatos, melons, cabbage)
slope
5% slope
Tree spacing
n.t.s.
Borehole & pump No 1
El 94+
Sprinkler laterals at 40'
Sprinkler spacing at 20'
Gated portable pipe with gates at 3' spacing for furrow irrigation
Outlet & valve for portable lateral connection
Gate
*1 donum = 14,400 sq ft
1 acre = 3 donums approx.
1 hectare = 7.5 donums approx.
Scale = 1 : 2000
FEET 100 0 100 200 300 FEET
N

Improved Irrigation System

(hose-basin, sprinkler and gated pipe-short furrows)

Item	Size	Unit price	Pounds
(1) Pipes and Fittings for Water Conveyance from the Borehole to the Water Tank.			
2,100 feet (105 pieces) Z.P. Plastic Pipes	4 inch @	2.200/piece	231.000
5 pieces Z.P. Plastic Line Elbows	4 inch	550/piece	2.750
110 pieces Z.P. Plastic Couplers	4 inch	650/piece	71.500
(2) Pipes and Fittings for Main Lines			
2,220 feet (111 pieces) Z.P. Plastic Pipes	4 inch @	2.200/piece	244.200
141 pieces Z.P. Plastic Couplers	4 inch	650	91.650
3 pieces Z.P. Plastic Line Elbows	4 inch	550	1.650
2 pieces Z.P. Plastic Tees	4 inch	600	1.200
17 pieces Z.P. Outlets	4 x 3 inch	1.300	22.100
17 pieces Galvanized Iron Nipples	3 inch	250	4.250
16 pieces Brass Dorot Valves	3 inch	6.500	104.000
1 piece Brass Gate Valve	3 inch	2.500	2.500
8 pieces Z.P. Starters	4 inch	1.220	9.760
4 pieces Brass Gate Valves	4 inch	3.500	14.000
2 pieces Z.P. End Plugs	4 inch	650	1.300
1,240 feet (62 pieces) Z.P. Plastic Pipes	3 inch	1.500	93.000
81 pieces Z.P. Plastic Couplers	3 inch	600	48.600
2 pieces Z.P. Plastic Line Elbows	3 inch	450	900
13 pieces Z.P. Plastic Outlets	3 x 2 inch	1.100	14.300
13 pieces Galvanized Iron Nipples	2 inch	80	1.040
13 pieces Brass Dorot Valves	2 inch	2.400	31.200
3 pieces Z.P. Outlets	3 x 3 inch	1.100	3.300
3 pieces Galvanized Iron Nipples	3 inch	250	750
3 pieces Brass Dorot Valves	3 inch	6.500	19.500
1 piece Z.P. End Plug	3 inch	550	550
1 piece Z.P. Starter	3 inch	1.000	1.000
(3) Hose-Basin Laterals			
600 feet (30 pieces) Portable Plastic Pipes	3 inch	1.410	42.300
30 pieces Couplings	3 x 1 inch	990	29.700
12 pieces Nipples	1 inch	50	600
6 pieces Brass Gate Valves	1 inch	300	1.800
12 pieces Brass Threaded Couplers	1 inch	150	1.800
6 pieces Brass Hose Bends	1 inch	200	1.200
6 pieces Hoses eighty feet long	1 inch	50/foot	24.000
24 pieces Mazak Plugs	1 inch	50	1.200
3 pieces Elbow Starters	3 x 3 inch	1.700	5.100
3 pieces End Plugs	3 inch	600	1.800
(4) Sprinkler Laterals			
900 feet (45 pieces) Portable Plastic Pipes	2 inch @	1.050/piece	47.250
45 pieces Couplings	2 x ¾ inch	725	32.625
45 pieces Nipples	¾ inch	50	2.250
45 pieces Sprinklers (Moderate pressure type, size of nozzle 5/32 inches, operating pressure twenty-five p.s.i. capacity of sprinkler 3.43 G.P.M. diameter covered seventy-six feet		520	23.400
3 pieces Elbow Starters	2 x 2 inch	1.460	4.380
3 pieces End Plugs	2 inch	550	1.650
(5) Gated Pipe Laterals			
300 feet (15 pieces) Plastic Gated Pipe (5 gates each)	3 inch	3.900	58.500
15 pieces Couplings	3 x ¾ inch	990	14.850
15 pieces Mazak Plugs	¾ inch	40	600
1 piece Elbow Starter	2 x 3 inch	1.700	1.700
1 piece End Plug	3 inch	600	600
(6) Water Meter Installation			
4 pieces Galvanized Iron Bends	4 inch	1.650	6.600
2 pieces Galvanized Iron Flanges	4 inch	425	850
1 piece Water Meter	4 inch	40.000	40.000
(7) Booster Pump		175.000	175.000
		Total:	pounds 1,535.755

APPENDIX II

Stamatis Mavropoulos Farm

Limassol, Cyprus

This farm is situated three miles from Limassol town. The area is approximately 129 donums (forty-three acres), of which 114 donums (thirty-eight acres) are occupied by mature citrus trees. Tree spacing is twenty-one feet by sixteen feet (forty-two trees per donum).

Previously the farm was irrigated by groundwater from two boreholes as shown on the attached map. A few years ago the quality of the water was very good, but today, owing to the over-pumping of the aquifer which has resulted in sea water intrusion. NaCl content has increased in the one borehole to 4,000 parts per million, while at the other the salts have remained at 450 ppm NaCl. As a result of the high salinity, the one borehole with 4,000 ppm is out of use today. However, using the hose-basin method and the borehole of 450 ppm, which has a flow rate of fifty cubic meters per hour, the whole farm may be irrigated.

Since last year, Stamatis Mavaropoulos has a supplemental source of good quality water from the river, with a flow rate of sixty cubic meters per hour.

Soils are deep, of medium to heavy texture, with good drainage which facilitates leaching of salts.

The systems of irrigation used in the past were flooding and basins. Leaching of salts will be done during winter time with the river water. Water from the river is available until the end of June.

(A) BENEFITS FROM THE IMPROVED SYSTEM

The water-use efficiency with the old systems mentioned was approximately fifty-two percent. With the hose-basin system, efficiency will be raised to seventy-five percent.

The consumptive use of citrus is 900 cubic meters per donum per year. The water saved through the improved efficiency is 57,000 cubic meters per year.

(1) Saving in pumping costs (five mils per cubic meter) and irrigation labor (three and seven tenths mils per cubic meter) 57,000 by eight and seven tenths mils per cubic meter
496 pounds annually

(2) Five percent increase of the yield
684 pounds annually

(3) Net income of an area equivalent to twenty-five donums to be saved from destruction
1,250 pounds annually

Increase in Net Income, Total:
2,430 pounds annually

(B) COST OF THE IMPROVED SYSTEM

The costs as shown on the attached bill of materials consist of piping, fittings, booster pumps, water meter, etc. Total: 2,131 pounds.

The average cost per donum is 18.7 pounds.

Rough Breakdown of Costs of Improved Irrigation System Hose-Basin

Piping and fittings	1,639.900 pounds
Water meter and fittings	66.200 pounds
Booster pump	175.000 pounds
Materials Total	1,881.100 pounds
Miscellaneous three percent	56.433 pounds
Installation ten percent	193.753 pounds
	2,131.286 pounds

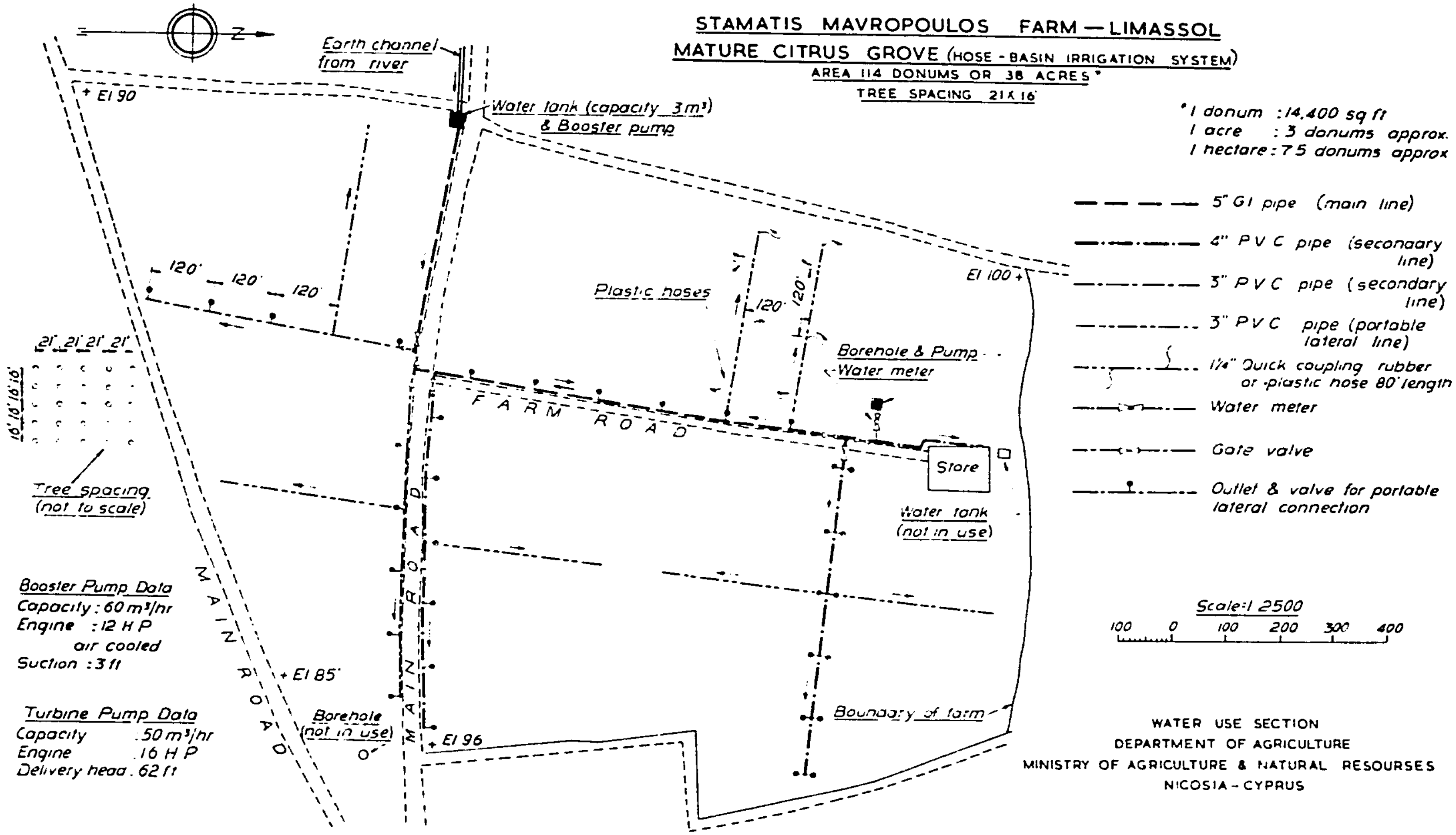
(C) IRRIGATION SCHEDULE

This includes frequency of irrigation and amount of water per irrigation per donum and per basin (tree). Irrigation efficiency is taken as seventy-five percent. Frequency of irrigation is based on sixty percent depletion of the readily available moisture, i.e. 3.6 inches.

For a tree spacing twenty-one feet by sixteen feet the number of trees per donum is forty-two. Six-seven hoses of one and one-fourth inch diameter operating simultaneously will handle the flow of fifty-sixty cubic meters per hour, each hose with an output of nine cubic meters per hour.

The water needed at seventy-five percent irrigation efficiency per day per donum—per irrigation per donum, per irrigation for each basin or tree, the frequency range, and the time (minutes) that the water should flow from the hose into each basin are as follows:

Month	Seventy-five percent efficiency m^3/day/donum	Frequency range (days)	Amount needed per irrigation per donum (m^3)	Forty-two basins (trees): Water needed per basin or tree each irrigation (m^3)	Hose output = 9 m^3/hr: Time of flow from hose (minutes)
April	3.68	42 - 47	154 - 174	3.7 - 4.1	24 - 27
May	5.05	30 - 35	151 - 176	3.6 - 4.2	24 - 28
June	6.17	24 - 29	148 - 179	3.5 - 4.3	23 - 29
July	7.63	19 - 24	145 - 183	3.4 - 4.4	22 - 29
August	8.70	17 - 22	147 - 191	3.5 - 4.5	23 - 30
September	5.90	24 - 29	141 - 171	3.3 - 4.0	22 - 26
October	4.50	34 - 39	153 - 175	3.6 - 4.1	24 - 27


STAMATIS MAVROPOULOS FARM — LIMASSOL
MATURE CITRUS GROVE (HOSE - BASIN IRRIGATION SYSTEM)
AREA 114 DONUMS OR 38 ACRES*
TREE SPACING 21 X 16'
*1 donum : 14,400 sq ft
1 acre : 3 donums approx.
1 hectare : 7.5 donums approx.
5" G I pipe (main line)
4" P V C pipe (seconaary line)
3" P V C pipe (secondary line)
3" P V C pipe (portable lateral line)
1¼" Quick coupling rubber or plastic hose 80' length
Water meter
Gate valve
Outlet & valve for portable lateral connection
Scale: 1 2500
100 0 100 200 300 400
WATER USE SECTION
DEPARTMENT OF AGRICULTURE
MINISTRY OF AGRICULTURE & NATURAL RESOURSES
NICOSIA - CYPRUS
Earth channel from river
Water tank (capacity 3m³) & Booster pump
El 90
El 100
El 85
El 96
120' 120' 120'
Plastic hoses
120' 120'
Borehole & Pump
Water meter
FARM ROAD
Store
Water tank (not in use)
MAIN ROAD
MAIN ROAD
Boundary of farm
Borehole (not in use)
21' 21' 21' 21'
16' 16' 16' 16'
Tree spacing (not to scale)
Booster Pump Data
Capacity : 60 m³/hr
Engine : 12 H P air cooled
Suction : 3 ft
Turbine Pump Data
Capacity : 50 m³/hr
Engine : 16 H P
Delivery head : 62 ft

Improved Irrigation System Hose-Basin

(1) Main Lines			
1,360 feet Galvanized Iron Pipes	5 inches @	450/foot	612.000
2 pieces Galvanized Iron Bends	5 inches	3.750/piece	7.500
12 pieces Galvanized Iron Tees	5 inches	2.250	27.000
5 pieces Galvanized Iron Nipples	5 inches	1.000	5.000
3 pieces Brass Gate Valves	5 inches	6.000	18.000
10 pieces Galvanized Iron Flanges	5 inches	600	6.000
3 pieces Galvanized Iron Reducing Nipples	5 x 4 inches	1.550	4.650
2 pieces Brass Gate Valves	4 inches	3.500	7.000
9 pieces Galvanized Reducing Nipples	5 x 3 inches	1.500	13.500
2 pieces Brass Gate Valves	3 inches	2.500	5.000
3 pieces Starters	4 inches	1.220	3.660
2 pieces Starters	3 inches	1.000	2.000
7 pieces Brass Dorot Valves	3 inches	6.500	45.500
1,600 feet (80 pieces) Z.P. Plastic Pipes	4 inches	2.200	176.000
102 pieces Z.P. Plastic Couplers	4 inches	650	66.300
3 pieces Z.P. Plastic End Plugs	4 inches	600	1.800
2 pieces Z.P. Plastic Line Elbows	4 inches	550	1.100
14 pieces Z.P. Outlets	4 x 3 inches	1.300	18.200
14 pieces Galvanized Iron Nipples	3 inches	250	3.500
14 pieces Brass Dorot Valves	3 inches	6.500	91.000
1,200 feet (60 pieces) Z.P. Plastic Pipes	3 inches	1.500	90.000
75 pieces Z.P. Plastic Couplers	3 inches	600	45.000
2 pieces Z.P. End Plugs	3 inches	550	1.100
11 pieces Z.P. Outlets	3 x 3 inches	1.100	12.100
11 pieces Galvanized Iron Nipples	3 niches	250	2.750
11 pieces Brass Dorot Valves	3 inches	6.500	71.500
(2) Hose-Basin Laterals			
1,600 feet (80 pieces) Portable Plastic Pipes	3 inches @	1.410	112.800
80 pieces Couplings	3 x 1 inch	990	79.200
28 pieces Nipples	1 inch	50	1.400
14 pieces Brass Gate Valves	1 inch	300	4.200
28 pieces Brass Threaded Couplers	1 inch	150	4.200
14 pieces Brass Hose Bends	1 inch	200	2.800
14 pieces Hose 80 feet long	1¼ inch	75/foot	84.000
66 pieces Mazak Plugs	1 inch	40	2.640
5 pieces Elbow Starters	3 x 3 inches	1.700	8.500
5 pieces End Plugs	3 inches	600	3.000
(3) Water Meter			
1 piece Water Meter	5 inches	50.000	50.000
2 pieces Galvanized Iron Flanges	5 inches	600	1.200
4 pieces Galvanized Iron Bends	5 inches	3.750	15.000
	Total:	pounds	1,706.000

IRRIGATION DEVELOPMENT OF THE KHUZESTAN REGION

by

M. Yazdi*

Summary

In times past, the waters of the five major rivers flowing from the Zagross and Bakhtiari mountains through the great plain of Khuzestan assured prosperity for the splendid cities of the plain and its flourishing agriculture.

This period of good fortune was followed by many centuries of agricultural standstill. The fertile plain of Khuzestan, then the breadbasket of the country, turned into a desolate, arid land, and until recently its natural resources remained untouched.

After prolonged studies and investigations toward rehabilitation, it was decided to develop the water resources of the area. It has been estimated that by the construction of a series of fourteen dams on the rivers of the Khuzestan, six million kilowatts of electricity may be produced and one million hectares of land irrigated.

The responsibility for the execution and management of this irrigation development rests with the Khuzestan Water and Power Authority.

The construction of a multi-purpose dam on the Dez River, completed in 1962, was a first step toward fulfilment of this undertaking. The Pahlavi Dam has a potential of generating ultimately 520 thousand kilowatts of hydro-electric power and capacity for storage of 3.3 billion cubic meters of water, sufficient to irrigate 125,000 hectares of land.

For the efficient and economic development of the agricultural aspects, it was decided to undertake initially the development of 22,000 hectares as a Dez Pilot Project, and later transfer the information and experiences gained to the Greater Dez Project, namely 125,000 hectares irrigable by the Pahlavi Dam.

For the delivery of regulated flow to the farmlands of the area, a modern irrigation network was constructed, consisting of 183 kilometers of canals, laterals and sub-laterals, with a water control system for the diversion of flow into the network.

A field trial farm was established to demonstrate proper irrigation methods and beneficial

* Department of Irrigation Operation and Maintenance, Ministry of Agriculture, Iran.

use of water, also improved methods of agriculture by use of better seed, fertilizer, machinery, insecticide, etc.

Thirty-five trained village agents, living in the villages of the pilot project, guide and assist the farmers in carrying out the instructions of the agricultural technicians.

The provision of short, medium and long-term credit at low rates of interest enables the farmers to purchase better seed and agricultural implements.

The health and sanitary condition in the villages is also a major concern of the project. A mobile health unit caters to the medical needs of the farmers and their families.

With the cooperation of the Ministry of Education, some twenty-eight schools have been built in the pilot area to educate the farmers of tomorrow.

It has not been the intention of the Khuzestan Water and Power Authority to revolutionize the traditional methods of farming in the area overnight, but rather to achieve an increased standard of social and economic progress through the gradual introduction of new ideas and through constant training and guidance of the farm population of the Dez Project.

Physical Aspects

The Khuzestan region, home of 2,500,000 inhabitants, is located in the southwest of Iran and comprises approximately one-eleventh of the total area of the country. This region includes the Ostan of Khuzestan, a substantial part of Lorestan, Kermanshah, Isfahan and Fars.

The climatic condition of the Khuzestan plain varies from arid to semi-arid, with extremely hot, dry summers, temperatures reaching between 48° C and 52° C in the shade, and mild winters with infrequent frosts. Humidity in general is low, particularly in the upper regions. Precipitation varies in different locations. In a normal year the average rainfall is approximately 350 millimeters, occurring between the months of November and April.

The potential of natural resources and access to the free ports of the world make this region an important commercial and industrial asset to the country.

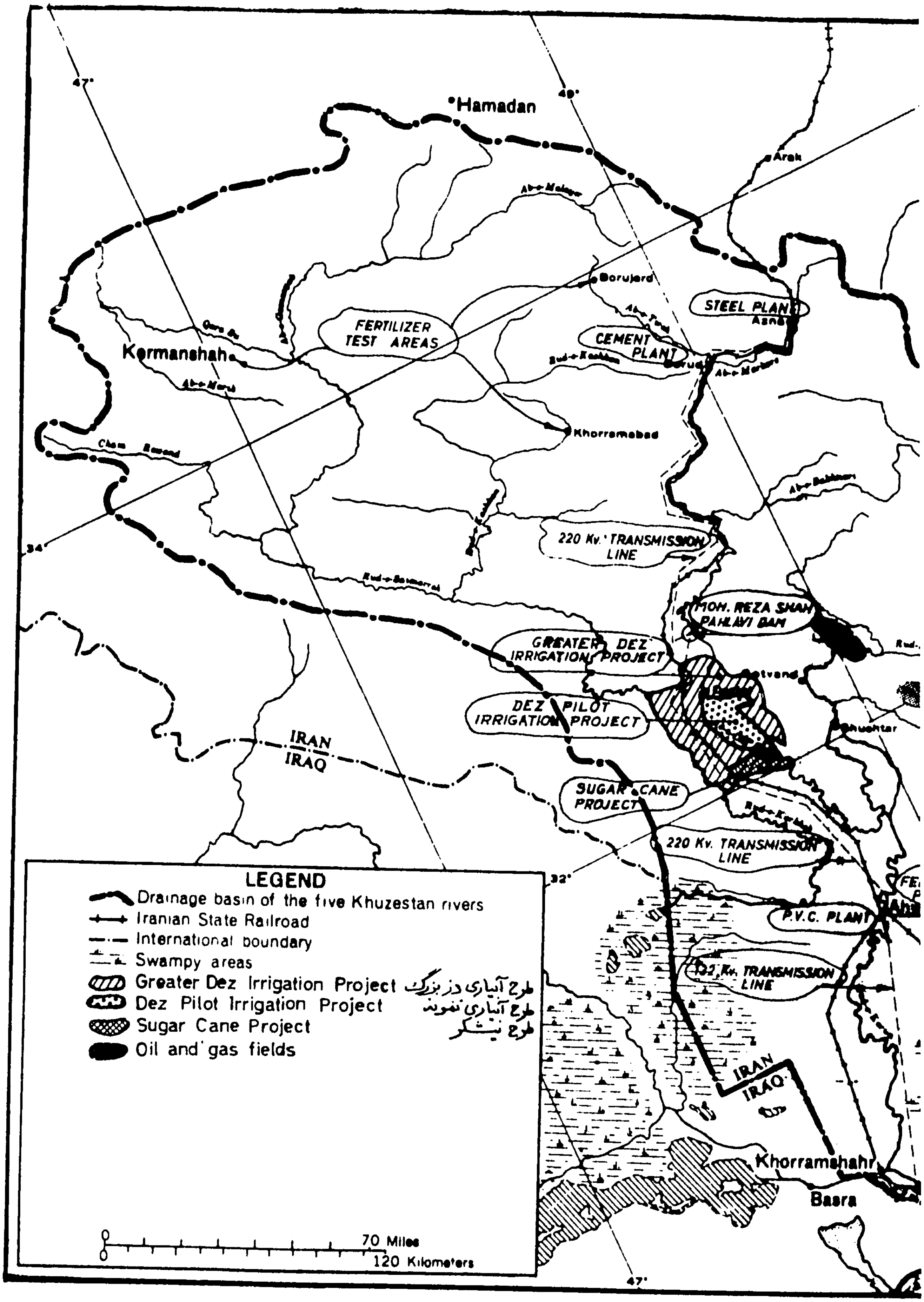
The strategic location of the province with navigation possibilities on the Lower Karoon, and major seaports such as Khorramshahr and Bandar Shapour, has facilitated the connection of the country with the world markets.

The population of the Khuzestan is mostly concentrated in the southwestern plain. Sixty-five percent of the inhabitants are engaged in agricultural activities wherever soil and water conditions allow. Although much of the Upper Khuzestan plain is sparsely populated, the emphasis on farming in that area is more pronounced than in the southern section of the province.

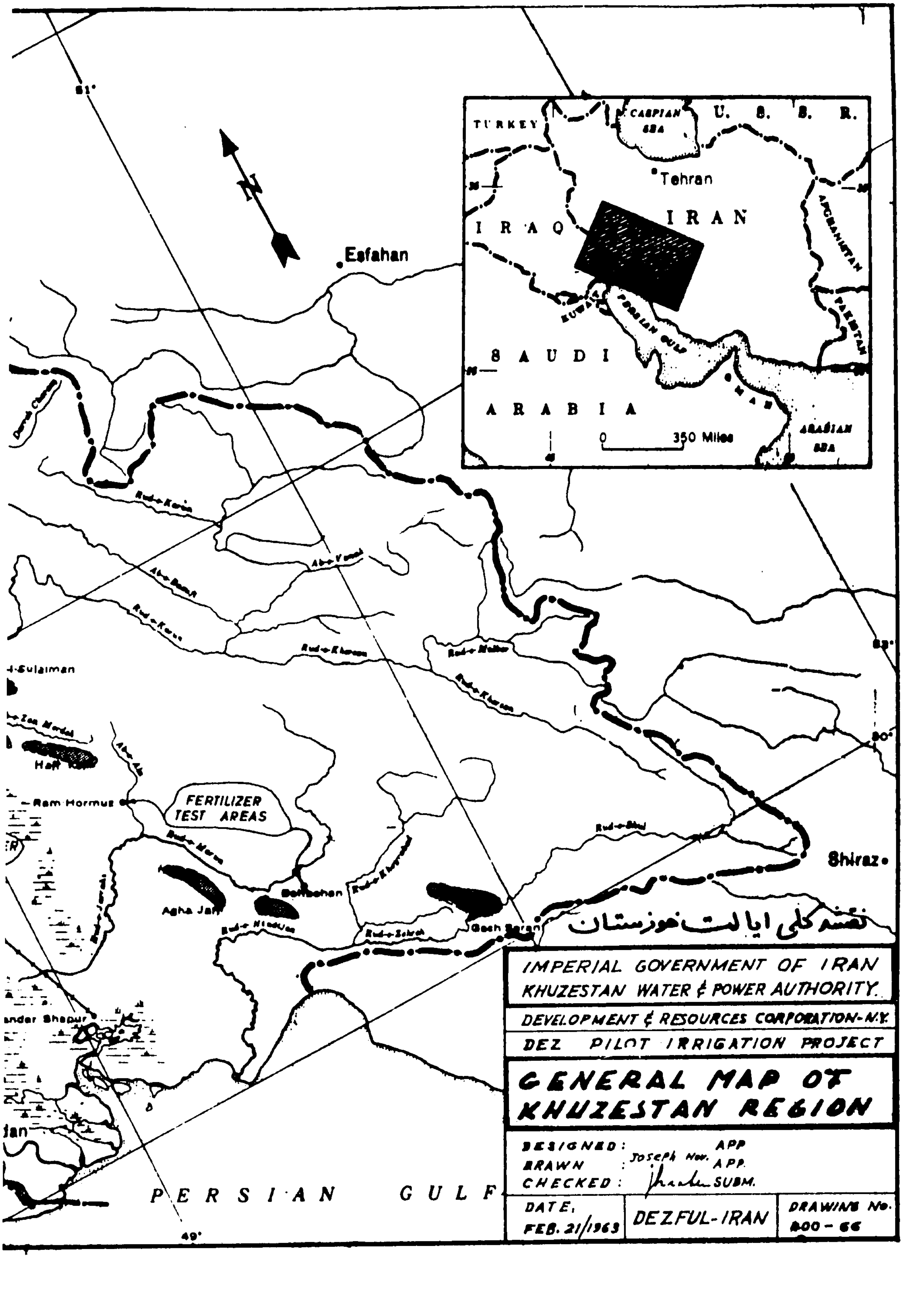
The Khuzestan region embraces the drainage of five rivers, namely: Karkheh, Dez, Karoon, Jarrahi and the Hindijan, flowing from the Zagross and Bakhtiari mountains southward through the great plain to the Persian Gulf. To develop the area, detailed studies and consultations were made with internationally known firms regarding the pattern of development to be adopted.

As a result, it was proposed to develop the water resources of the area for the provision of sufficient water to the thirsty lands of the Khuzestan and to modernize agricultural practices to further increase the food supply. The proposal submitted to the Government of Iran suggested the construction of fourteen multi-purpose dams, centering around the Karoon, Karkheh and Dez rivers, the completion of which would make possible the generation of six million kilowatts of hydro-electric power and the irrigation of one million hectares of land.

The construction of the first dam on the Dez River was completed in 1962, in less than two years, and named after His Imperial Majesty, Shahanshah Aryamehr. Behind this 203-meter high, concrete arch type dam, some 3,300 million



Hamadan
Arak
Borujerd
Kermanshah
FERTILIZER TEST AREAS
STEEL PLANT
CEMENT PLANT
Khorramabad
220 Kv. TRANSMISSION LINE
MOH. REZA SHAH PAHLAVI DAM
GREATER DEZ IRRIGATION PROJECT
DEZ PILOT IRRIGATION PROJECT
IRAN
IRAQ
SUGAR CANE PROJECT
220 Kv. TRANSMISSION LINE
P.V.C. PLANT
IRAN
IRAQ
Khorramshahr
Basra
LEGEND
Drainage basin of the five Khuzestan rivers
Iranian State Railroad
International boundary
Swampy areas
Greater Dez Irrigation Project طرح آبیاری دز بزرگ
Dez Pilot Irrigation Project طرح آبیاری نمونه
Sugar Cane Project طرح نیشکر
Oil and gas fields
70 Miles
120 Kilometers



TURKEY
CASPIAN SEA
U. S. S. R.
Tehran
IRAQ
IRAN
AFGHANISTAN
PAKISTAN
SAUDI ARABIA
PERSIAN GULF
OMAN
ARABIAN SEA
0 350 Miles
N
Esfahan
Rud-e-Karun
Ab-e-Vanak
Ab-e-Bazuft
Rud-e-Karun
Rud-e-Khersan
Rud-e-Khersan
Rud-e-Maher
Rud-e-Shul
Haft Kel
Ram Hormuz
FERTILIZER TEST AREAS
Rud-e-Marun
Behbehan
Agha Jari
Rud-e-Hindian
Rud-e-Zohreh
Gach Saran
Shiraz
Bandar Shapur
PERSIAN GULF
49°
نقشه کلی ایالت خوزستان
IMPERIAL GOVERNMENT OF IRAN
KHUZESTAN WATER & POWER AUTHORITY
DEVELOPMENT & RESOURCES CORPORATION-N.Y.
DEZ PILOT IRRIGATION PROJECT
GENERAL MAP OF KHUZESTAN REGION
DESIGNED: APP
DRAWN: Joseph Nov. APP.
CHECKED: SUBM.
DATE: FEB. 21/1963
DEZFUL-IRAN
DRAWING No. 800-66

cubic meters of water may be stored. This harnessed force has a potential of generating 520,000 kilowatts of electricity and an ultimate capacity of irrigating 125,000 hectares of land, which eventually will be developed under the Dez Project scheme.

The accumulation of this large quantity of water has not only made regulated delivery possible, but has also acted as a control for floods, thereby saving millions of dollars yearly in damages. Prior to the completion of the Pahlavi Dam, the annual damage from the floods in the central and lower parts of the Khuzestan was estimated at over one million dollars. The flood that occurred in the Spring of 1963 proved the significant value of the control feature of this dam. Another benefit derived is that the flow in the Karkheh River, which in the past years has frequently experienced extreme shortage of water, may be increased in the amount of thirty to forty cubic meters, double the previous summer discharges.

The completion of the irrigation network for the Dez Project will make possible a double cropping pattern of agriculture for the entire 125,000 hectares. At present only twelve percent of the total area is under crop (rice, sesame and vegetables), and only seventy-two percent is planted to winter crops (wheat, barley and some vegetables).

Dez Pilot Irrigation Project

To reach the goal of full development of irrigated agriculture and to gain experience and accumulate adequate information, it was decided to undertake the development of a pilot area, representative of the total Dez Project.

Some 22,000 hectares of the project area, located on the left bank of the Dez River and immediately south of Dezful, was chosen for this work. Modern agricultural and irrigation practices are being conducted on the 20,000 hectares of net irrigable land of the pilot area.

Before the commencement of the development activities, roads were practically non-existent and consisted mainly of unimproved tracks, animal and foot paths. Today a total of eighty-eight kilometers of main and secondary roads have been constructed, connecting the fifty-eight villages of the pilot area, and providing ready access to the major markets for agricultural products.

The pattern of irrigation in the past was limited to thirteen independent canals and the diversion of water to the fields was made by temporary construction of brush and stone dams, which often were destroyed with the first heavy rains and required costly reconstruction. Also the cleaning of these canals involved a considerable amount of manual labor. The combination of excessive flood damage during the winter months and the inadequate water flow in the summer season inhibited the demonstration of initiative and investment in farming enterprises.

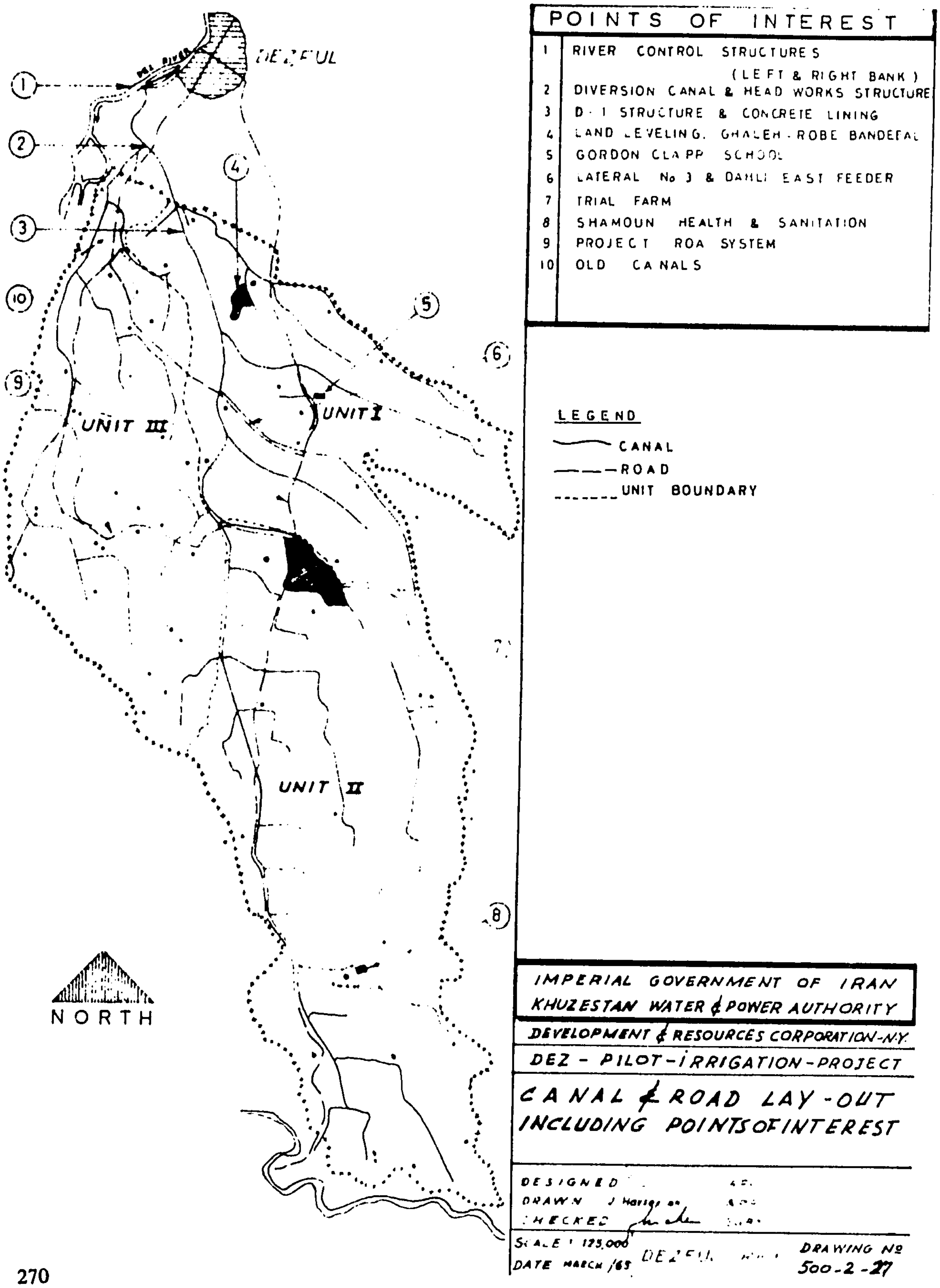
Parallel with the completion of the Pahlavi Dam, it was imperative to rehabilitate the old inefficient system. To this end, the Khuzestan Water and Power Authority launched the construction of the new irrigation network now in operation in the pilot area.

This system includes:

(1) A river diversion structure with a 205-meter concrete capped crib dam with spillways for floods up to 2,000 cubic meters per second, a left bank control structure, and a one-kilometer dike connecting the spillway and the left bank control structure. The earth dike contains a soft plug of about 300 meters length of slightly lower elevation, designed to fail in case of floods exceeding 2,000 cubic meters per second, in order to protect the structures and the irrigation system.

(2) Diversion of the water in the pilot area is conveyed by a 1.7 kilometer diversion canal between the left bank control structure and headworks. The headworks regulate the river diversions into the pilot east and west branch canals. The capacity of the diversion canal is sixty-seven and one-half cubic meters per second.

(3) The Alam Canal (pilot east canal), twenty-seven kilometers in length, has a capacity


POINTS OF INTEREST
1 RIVER CONTROL STRUCTURES (LEFT & RIGHT BANK)
2 DIVERSION CANAL & HEAD WORKS STRUCTURE
3 D-1 STRUCTURE & CONCRETE LINING
4 LAND LEVELING, GHALEH-ROBE BANDEFAL
5 GORDON CLAPP SCHOOL
6 LATERAL No 3 & DAHLI EAST FEEDER
7 TRIAL FARM
8 SHAMOUN HEALTH & SANITATION
9 PROJECT ROA SYSTEM
10 OLD CANALS
LEGEND
CANAL
ROAD
UNIT BOUNDARY
UNIT I
UNIT II
UNIT III
NORTH
IMPERIAL GOVERNMENT OF IRAN
KHUZESTAN WATER & POWER AUTHORITY
DEVELOPMENT & RESOURCES CORPORATION-N.Y.
DEZ - PILOT - IRRIGATION - PROJECT
CANAL & ROAD LAY-OUT
INCLUDING POINTS OF INTEREST
DESIGNED
DRAWN
CHECKED
SCALE 1 125,000
DATE MARCH /65
DRAWING No
500-2-27

of fifty-four cubic meters and is designed to serve three-fourths of the pilot area and the 7,000 hectares Dahli East district which is outside the eastern boundary of the project.

(4) The west branch canal, twelve kilometers in length, has a capacity of thirteen and one-half cubic meters per second and serves the northwestern part of the pilot area and delivers to the cultivated areas in the Dez River flood plain.

(5) A total of 122 kilometers of laterals and twenty kilometers of sub-laterals convey the water from the two branch canals to the 225 individual headgate units, which vary in size from sixty to 140 hectares per unit. Of the total length of 183 kilometers, about fifteen percent has been constructed with protective concrete lining where the soil is pervious or where steep grades would cause excessive velocity. For the remainder of the system, compacted clay lining was used.

(6) Structures, all constructed of reinforced concrete, include: twenty-four division structures, six heavy traffic bridges, forty-six spillways and waste outlets, thirty-nine lateral and sub-lateral turnouts, 111 checks and drops, 225 headgates and 222 Parshall flumes to measure the water delivered to each headgate unit.

Regulated flow was first delivered to eight villages of the northern part of the pilot project in 1963. As a result of the regulated flow, the area of summer crops as reflected in Table 1, increased by 250 percent of that planted in the preceding three years. Table 2 shows the increase in hectarage planted during the summer of 1964 when twenty-two villages of the pilot area received regulated flow. By the summer of 1965 all of the fifty-eight villages of the pilot area were receiving regulated flow. Table 3 indicates this increase in hectarage.

A comparative study of the above tables clearly indicates the steady increase in the hectarage under crop. In addition, confident of receiving regulated flow all the year around, the farmers have been encouraged to purchase fertilizer and machinery and to carry out land leveling operations. In Table 4 the increase in the yield crops from 1959 to 1964 is shown for the Dez Pilot Irrigation Project.

Table 1

Comparison of Summer Crop Hectarages in eight Villages which have received Regulated Flow in Summer 1965, 1964, 1963 with 1962 and 1961

CROP	1961		1962		1963		1964		1965	
	Hectare	Percent	Hectare	Percent	Hectare	Percent	Hectare	Percent	Hectare	Percent
Rice and Nursery	539.0	16.0	578.5	17.2	742.4	23.3	704.2	22.1	707.1	22.2
Sesame	6.0	0.2	4.9	0.1	58.6	1.8	244.2	7.7	378.9	11.9
Mung Beans (Vetch)	1.0	0.0	7.7	0.2	72.2	2.3	288.5	9.1	204.4	6.4
Blackeye Beans	—	—	0.8	0.0	35.9	1.1	83.0	2.6	64.9	2.05
Forage Crops	—	—	2.3	0.0	17.5	0.6	62.4	2.0	47.5	1.5
Vegetables	40.5	1.2	35.6	1.1	60.4	1.9	68.9	2.1	96.8	3.05
Garden	87.0	2.5	81.0	2.4	85.6	2.7	88.5	2.8	88.5	2.8
Cotton	—	—	—	—	7.1	0.2	—	—	—	—
Sweet Corn	—	—	—	—	—	—	—	—	—	—
Total Hectare and Percent	673.5	19.9	710.8	21.0	1079.7	33.9	1539.7	48.4	1588.1	49.9

Table 2

Comparison of the Summer Crop Hectarages in Twenty-two Villages Under Regulated Flow in Summer 1964 with Summer 1963, 1962 and 1961

CROP	1961 Hectare Planted	1961 Percent Planted	1962 Hectare Planted	1962 Percent Planted	1963 Hectare Planted	1963 Percent Planted	1964 Hectare Planted	1964 Percent Planted
Rice and Nursery	1779.0	17.0	1697.0	16.2	2046.4	19.9	1932.8	19.7
Sesame	14.4	0.1	58.4	0.5	179.0	1.7	361.2	3.7
Mung Beans (Vetch)	2.2	0.0	79.7	0.8	158.4	1.5	504.6	5.1
Blackeye Beans	—	—	1.3	0.0	44.6	0.4	122.5	1.2
Forage Crops	—	—	12.2	0.1	58.8	0.6	103.3	1.0
Vegetables	86.5	0.8	54.2	0.5	104.0	1.0	153.0	1.6
Garden	251.5	2.4	246.2	2.3	263.2	2.6	280.8	2.9
Cotton	—	—	9.2	0.0	25.1	0.2	5.1	0.0
Sweet Corn	—	—	—	—	—	—	1.2	0.0
Total Hectare and Percent	2133.6	20.3	2158.2	20.4	2879.5	27.9	3464.5	35.2

Table 3

Comparison of Dez Pilot Summer Crops in 1965 with 1964, 1963, 1962 and 1961

CROP	1961 Hectare	1961 Percent	1962 Hectare	1962 Percent	1963 Hectare	1963 Percent	1964 Hectare	1964 Percent	1965 Hectare	1965 Percent
Rice and Nursery	4110.5	19.0	3965.2	18.4	4276.0	20.0	4060.8	19.7	3971.4	19.1
Sesame	235.0	1.0	71.0	0.3	258.7	1.2	508.1	2.5	1640.6	7.9
Mung Beans (Vetch)	57.0	0.2	103.5	0.5	274.5	1.3	781.7	3.8	764.8	3.7
Blackeye Beans	—	—	1.3	—	46.0	0.2	130.1	0.6	252.0	1.2
Forage Crops	—	—	12.2	—	129.0	0.6	187.6	0.9	222.0	1.1
Vegetables	294.0	1.4	185.0	0.9	323.2	1.5	354.9	1.7	502.2	2.4
Garden	429.0	2.0	423.3	1.9	448.0	2.1	492.1	2.4	469.4	2.2
Cotton	—	—	9.2	—	44.7	0.2	5.1	—	16.5	0.07
Sweet Corn	0.9	—	—	—	—	—	3.5	—	—	—
Total Hectare and Percent	5126.4	23.6	4770.7	22.0	5800.1	27.1	6523.9	31.6	7839.8	37.7

A striking feature in the change-over from the old to the new system was the fact that no irrigation interruption was caused during the peak season when the major change-over occurred.

Channels have been designed for that portion of the area which will require drainage, and to date a substantial part has been completed.

To operate the new irrigation system and to regulate the diversion of the Dez River water into the new system, a department of irrigation operation and maintenance has been created. The primary responsibility of this department is to deliver water to the 225 headgate units serving the fifty-eight villages of the pilot area and to maintain the system.

A classroom training course was initiated to train the operational personnel of this department. For one year the candidates received instructions in hydrology and water management and were then trained in the field in the performance of the technical phases of their duties. The maintenance crew was given training in use of the new equipment and in modern maintenance techniques.

Table 4

A Comparison Chart Showing the Yield of Crops in the Dez Pilot Irrigation Project

Crop	1959 kg./ha.	1964 kg./ha.
Wheat	675	1600*
Barley	735	1800*
Broadbean	925	1600*
Rice	1500	3000*
Sesame	220	800*
Berseem Clover	———	65000‡
Alfalfa	———	45000‡
Sorghum	———	65000‡
Sudan Grass	———	40000‡

* Improved yield (for average yield over all pilot areas refer to Table 6).

‡ These crops were weighed in green and were introduced by KWPA.

Today the staff of the operation and maintenance department cooperates with the village production service to ensure equitable and timely delivery of regulated flow to all parts of the pilot area under crop production. Measurements of drainage outflow, observation of groundwater fluctuations, and collection of meteorological data are also prominent functions of this department.

Under the present development stage, funds budgeted for the operation and maintenance of canals and roads of the project amount to approximately fourteen dollars per hectare. It is anticipated that by mid-1966, the collection of base and sur charges will completely cover the expenses of operating this department. It is also foreseen that completion of the irrigation network for the 125,000 hectares of the Dez Project will result in lower costs of operation—perhaps down to nine dollars per hectare.

To receive the utmost benefit from this system and to ensure maximum beneficial use of the abundant regulated flow, the Khuzestan Water and Power Authority could not confine its activities to the construction of canals and roads. Necessary steps were therefore taken to establish and implement modern practices of farming by the introduction of machinery services, new crops, improved seeds, fertilizer, efficient irrigation, land leveling, harvesting methods, harvest transport, etc.; also the creation of a credit program and the establishment of a health, education and sanitation center for the area.

To this end, 200 hectares of land was acquired in the heart of the project, as a trial farm to conduct detailed experiments on seed increase and crop production entirely new to the area. The field trial farm serves as a model for the farmers of the surrounding villages.

The above modern practices are implemented in the entire pilot area villages through the services of university-trained village agent leaders. A number of village agents, employed by the Khuzestan Water and Power Authority and residing in the villages, carry out the day-to-day program of guiding and helping the farmers in their daily tasks of irrigation and farming practices.

The establishment of Khuzestan Water and Power Authority Credit Service is a fundamental program, assisting the farmers to meet the expenses incurred in carrying out their cultural activities based on modern methods, and to prevent them from having to borrow money at high rates of interest from elsewhere.

A total of 1,600,000 dollars has been allocated for the Pilot Project Credit Section. From this sum a total of 800,000 dollars has been set aside as short-term credit loan for the basic needs of the farmers, such as purchase of fertilizer, better seed, and payment to hired labor. With few exceptions, this loan is repaid in kind and not in cash. In the pilot area there are 1800 farmers and 200 landowners utilizing the short-term credit facilities. The remaining 800,000 dollars are allocated for medium and long-range credit loans. The farmers are using this loan for purchase of machinery and land leveling operations. From this fund, loans have been made to farmers and landowners who are establishing modern poultry and livestock units.

The annual cost of operating the credit section, including transportation, staff salaries, etc., amounts to approximately 40,000 dollars. Presently two-thirds of this cost is provided through the six percent interest paid by the farmers on

loans received. With the growth and expansion of the agricultural activities in the area, it is hoped that in the near future the interests from the loans granted will completely cover the expenses incurred and the credit service will be financially self-supporting.

The improvement of health, education and sanitary conditions within the pilot project villages and its contribution to the success of the program has not been overlooked. Medical field units have been in operation within the project, providing medical service to the farmers and their

Table 5

Estimated Gross Income for Dez Pilot Irrigation Project
(Pre-Project Development — 1959)

CROP	Hectares	Yield	Price	Gross Income	Total Gross Income
Winter Crops		kg./ha.	Rls/kg.	Rls/ha.	(1000s Rials)
Wheat	10,500	675	6.0	4,050	42,525
Barley	2,000	735	4.0	2,940	5,880
Vegetables	284	——	———	60,000	17,040
Broad beans	275	850	9.0	7,650	2,103.75
Summer Crops					
Rice	3,573	1,600	7.0	11,200	40,017.6
Sesame	262	200	14.5	2,900	759.8
Vegetables	336	———	———	60,000	20,160
Vetch	50	300	11.0	3,300	165
				Total	128,651.15
					(or U.S. $1.7 million)

(Garden is not included)
One dollar U.S. equals seventy-five rials

Table 6

Estimated Gross Income for Dez Pilot Project — 1965

CROP	Hectares	Yield	Price	Gross Income	Total Gross Income
Winter Crops		kg./ha.	Rls/kg.	Rls/ha.	(1000s Rials)
Wheat	10,500	1,250	7.5	9,375	98,437.5
Barley	2,063	1,500	6.0	9,000	18,567
Vegetables	352	———	———	75,000	26,400
Broad beans	566	1,100	14.0	15,400	8,716.4
Forage Crops	680	15,000*	2.5	37,500	25,500
Summer Crops					
Rice	3,415	2,200	8.0	17,600	60,104
Sesame	1,640	700	18.0	12,600	20,664
Vegetables	502	———	———	75,000	37,650
Mung Beans	765	600	8.0	4,800	3,672
Forage Crops	222	15,000*	2.5	37,500	8,325
				Total	308,035.9
					(or U.S. $4.1 million)

(Garden is not included)
One dollar U.S. equals seventy-five rials
* Dry weight

families. A number of surveys have been conducted by the medical field unit, verifying social progress as a direct result of the present irrigation development program in the area. Some twenty-eight schools have been built with the cooperation of the Ministry of Education, in which literacy corps personnel teach academic and agricultural subjects.

A comparison of Table 5, Pre-Project Estimated Gross Income, and Table 6, Estimated Gross Income for Pilot Project for 1965, shows an increase in the gross value of agricultural products of 2,400,000 dollars. Approximately thirty percent of this sum represents the net profit of the farmers, while the remaining seventy percent covers the cost of labor wages, farm machinery, seed, fertilizer, etc. This expenditure was also a means of promoting employment in the area, thus raising the economic status and financial stability of the farmer. In the next few years when the total area of the pilot project is under crop, a much higher margin of income will be realized by the farmers.

In conclusion, it should be emphasized that the present development taking place in this section of the country, through the sincere effort and initiative of a group of well trained and educated Iranians, has brought about a significant change in the face of the Khuzestan Province.

The successes achieved confirm the feasibility of extending this program over the balance of the 125,000 hectares of Dez Project as originally proposed, and eventual development of the one million hectares of irrigable land when construction of the remaining thirteen dams has been effected.

FARM SIZES CONSIDERING SOCIAL AND ECONOMIC ASPECTS IN IRRIGATION PROJECT AREAS IN TURKEY

by

Hamit Buyurgan and Fikret Ercan*

Summary

Farm size is an important factor in the development of irrigated agriculture. This importance does not come only from economic aspects but also from social aspects. There are obvious differences between small and big farms in irrigated areas, comparing their irrigation and crop intensity and crop yields per unit area, being in favor of the small farms. On the other hand, small farms cannot produce enough income to cover the farmer family living cost.

At present the majority of the farms are small in irrigation project areas in Turkey. The surveys made for planning 'purposes in irrigation project areas showed that the distribution of farms according to their sizes changes largely from one region to another. But generally the farms having a size between 0.1 and five hectares are dominant in each region. As an average in eight agricultural regions, 65.9 percent of farms have a farm size between 0.1 and five hectares. This percentage reaches to eighty-seven percent between 0.1 and ten hectares. These farms cultivate only 46.8 percent of total irrigable land investigated.

Future farm size is an important factor for the evaluation of the benefit and repayment capacity of an irrigation project. Since a land reform will take place over a long period, and most probably will take into consideration an optimum farm size, it is reasonable to use the optimum farm size criteria in project benefit evaluation.

A new approach to agricultural economic studies for the purpose of project benefits evaluation, using modern computer techniques, was applied recently in Lower Sakarya and Susurluk projects in Turkey, by TAMS, consulting firm for these projects. In these studies the optimum

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farm size was determined, using the following method:

In the initial step, the relative physical suitability of individual crops to specific soils and the relative productivity of suitable crops were determined. In a second step, the rotations were determined. In a third step, the rotations having between seventy and 100 percent productivity were chosen. In the final step, optimum farm sizes were determined for each soil body or soil body group according to these criteria: (1) full or nearly full family employment; (2) a minimum farm family income; (3) long-term demand for agricultural commodities. The optimum farm sizes calculated with this method varied between 3.8 and 15.6 hectares in the different soil bodies.

Since the majority of agricultural farm units are small, the enlargement of these units is necessary. There is not enough private land to be used for enlargement of the small farms in Turkey. To enlarge the small farms by using the reserve land is possible only by enactment of law. For this reason the "Land Reform" draft has been prepared. Since this legislation has not been enacted yet, certain individual land consolidation projects have been started in the meantime in order to increase the agricultural productivity in irrigated areas. Land consolidation works have been underway since 1961. But due to lack of legal measures, these land consolidation activities have not been carried out in a large area. Land consolidation projects covering 454 hectares and with a total cost of 1,256,844 T.L. have been executed thus far. Several requests have been made by farmers for land consolidation in different regions of Turkey. But due to certain problems, these surveys and projects have not been carried out. Because, the present regulation is inadequate to carry out these activities, any land consolidation is dependent on the full agreement of the land owners.

The main problem is the lack of laws concerning land consolidation. Other problems are the lack of cadastral surveys in many project areas, land disputes on ownership rights, and the objections of the land owners.

To solve the problems, first of all the necessary legislative measures must be taken. Therefore, a bylaw has been prepared. However, a separate land consolidation law seems necessary in the future, because the present bylaw is not able to settle all the problems of land consolidation.

Introduction

The development of irrigated agriculture has an important place in agricultural development. This paper sets forth briefly the importance and the problems of farm sizes in irrigated agriculture, describing the actual situation of farm sizes in the irrigation project areas in Turkey and giving a method for the determination of optimum farm size. It considers social and economic aspects, and necessary works to realize the optimum farm size in any irrigation project area.

The Importance of Farm Sizes in Irrigated Agriculture

The purpose of an irrigation project is to increase the agricultural productivity of the project area. In most cases and especially in the large irrigation areas, the supply of irrigation water does not give a satisfying result. Farmers could not irrigate all of the irrigable lands of a project area and they could not realize the intensive farming as it was planned. There are several reasons for this. Farm size is an important one. This importance does not come only from economic aspects but also from social aspects. In the small farms, due to shortage of land, farmers tend to apply a one-crop farming. This type of farming produces a smaller yield from a unit area and causes deficiencies on the balance of soil nutrients over the long term. These small farms cannot produce enough income to cover the farm family living costs. On the other hand, large farms tend to be less intensive with irrigation. Fallow lands are always seen in the large farms in irrigated areas. Generally, irrigation and crop intensity and crop yields per unit area are less than for the small farms.

As is briefly explained above, it seems necessary to realize an optimum farm size, varying with the location and cropping pattern of the irrigation project areas.

Distribution of Farm Units According to Their Sizes in Irrigation Project Areas

To determine the distribution of farm units according to their sizes, a careful survey has been conducted in each project area which has been investigated for planning purposes to date. The results of these surveys are shown, by agricultural regions, in Tables 1 and 2 and Figure 1.

Table 1 shows the distribution of farm units according to their sizes by agricultural regions. The percentage of farm size, by groups, changes largely from one region to another. About 65.9 percent of the farm units have a size between 0.1 and five hectares, considering the average of all regions. Eighty-seven percent have a size of between 0.1 and ten hectares. As can be seen in Table 2, eighty-seven percent of all farms cultivate only 46.8 percent of the total irrigable land investigated.

Determination of Optimum Farm Size for the Evaluation of Project Benefits

In under-developed countries, agricultural development depends largely on land reform and land consolidation. These are also the bases of future farm sizes in irrigation project areas. Since land reform takes place over a long period and most probably will take into consideration an optimum farm size, it is reasonable to use the optimum farm size criteria in project benefit evaluation. Up to now the following method has been used by DSI in agricultural economic

Table 1

Distribution of Farm Units in DSI Project Areas According to Their Sizes by Agricultural Regions

Agricultural Regions		Farm Size Groups (Hectare)							
		0.1-2	2.1-5	5.1-10	10.1-15	15.1-20	20.1-50	50.1 and over	Total
I	Number..........	18087	20636	10233	1756	644	592	101	52049
I	Percent	34.8	39.6	19.7	3.4	1.2	1.1	0.2	100.0
II	Number..........	8863	13092	5842	769	320	176	33	29095
II	Percent	30.5	45.0	29.1	2.6	1.1	0.6	0.1	100.0
III	Number..........	—	—	—	—	—	—	—	—
III	Percent	—	—	—	—	—	—	—	—
IV	Number..........	18721	11867	3648	745	247	283	71	35582
IV	Percent	52.6	33.3	10.3	2.1	0.7	0.8	0.2	100.0
V	Number..........	2263	2737	2137	607	263	140	8	8155
V	Percent	27.8	33.6	26.2	7.4	3.2	1.7	0.1	100.0
VI	Number..........	4881	4456	4308	2660	1119	1826	218	19468
VI	Percent	25.1	22.9	22.1	13.7	5.7	9.4	1.1	100.0
VII	Number..........	495	2086	3786	1945	1255	1638	331	11536
VII	Percent	4.3	18.1	32.8	16.8	10.9	14.2	2.9	100.0
VIII	Number..........	3494	7789	10156	2401	1130	1060	198	26228
VIII	Percent	13.3	29.7	38.7	9.2	4.3	4.0	0.8	100.0
IX	Number..........	15367	19384	9245	2781	1613	2481	1061	51932
IX	Percent	29.6	37.3	17.8	5.4	3.1	4.8	2.0	100.0
X	Number..........	—	—	—	—	—	—	—	—
X	Percent	—	—	—	—	—	—	—	—
Total	Number..........	72171	82047	49355	13664	6591	8196	2021	234045
Total	Percent	30.8	35.1	21.1	5.8	2.8	3.5	0.9	100.0

Table 2

Distribution of Total Area Cultivated According to Farm Size Groups by Agricultural Regions

Agricultural Regions		Farm Size Groups (Hectare)							
		0.1-2	2.1-5	5.1-10	10.1-15	15.1-20	20.1-50	50.1 and over	Total
I	Area (Ha)......	27131	73259	77258	22040	11304	20758	15087	246837
I	Percent	11.0	29.7	31.3	8.9	4.6	8.4	6.1	100.0
II	Area (Ha)......	13294	46478	44108	9647	5622	6154	4944	130247
II	Percent	10.2	35.7	33.9	7.4	4.3	4.7	3.8	100.0
III	Area (Ha)......	—	—	—	—	—	—	—	—
III	Percent	—	—	—	—	—	—	—	—
IV	Area (Ha)......	28082	42128	27545	9349	4342	9913	10593	131952
IV	Percent	21.3	31.9	20.9	7.1	3.3	7.5	8.0	100.0
V	Area (Ha)......	3395	9718	16137	7613	4623	4907	1236	47629
V	Percent	7.1	20.4	33.9	16.0	9.7	10.3	2.6	100.0
VI	Area (Ha)......	7322	15818	32528	33382	19631	63995	32631	205307
VI	Percent	3.6	7.7	15.8	16.2	9.6	31.2	15.9	100.0
VII	Area (Ha)......	743	7407	28587	24405	22022	57414	49690	190268
VII	Percent	0.4	3.9	15.0	12.8	11.6	30.2	26.1	100.0
VIII	Area (Ha)......	5241	27651	76677	30138	19838	37168	29687	226400
VIII	Percent	2.3	12.2	33.9	13.3	8.8	16.4	13.1	100.0
IX	Area (Ha)......	23050	68812	69801	34896	28316	86959	159078	470912
IX	Percent	4.9	14.6	14.8	7.4	6.0	18.5	33.8	100.0
X	Area (Ha)......	—	—	—	—	—	—	—	—
X	Percent	—	—	—	—	—	—	—	—
Total	Area (Ha)......	108258	291271	372641	171470	115698	287268	302946	1649552
Total	Percent	6.6	17.6	22.6	10.4	7.0	17.4	18.4	100.0

studies: in areas where the difference between the size of land owned and land operated in small, future farm size is assumed to be equal to actual size of land owned. In cases where the difference was important, i.e., the size of land owned was too small compared to the size of land operated, a farm size corresponding to the available labor capacity of the farm families was assumed.

Here, a method used recently for the determination of optimum farm size in Lower Sakarya and Susurluk project areas in Turkey will be explained. To give a better understanding of the effect of the multiple variables involved in determining project benefits and repayment capacities, a new approach to agricultural economic analysis, using modern computer techniques, was applied for these projects. The crop-soil matching accomplished in the computer program applied in this study bridges a gap between the soil classification and economic evaluation.

The initial step of this method is to determine the relative physical suitability of individual crops to specific soils. Soil data collected in land classification were recorded on cards for each log of the project areas. Other crop cards were prepared showing the relative yield response of each crop to soil differences. The comparison of soil data with crop response data showed which crops were physically suitable for each soil site. The relative productivity of suitable crops was determined at levels of 100, ninety, eighty and seventy percent of local high average yields.

The results of comparing specific crop responses to specific soil characteristics,* log by log, made possible the separation of soil logs into forty-one groups in Lower Sakarya project area. Each group represented a distinct soil body with respect to the specific crops it could grow within seventy percent of high average local yields.

Second step is to determine the rotations. The rotations studied represent permutations in groups of two, three or four of the following crops:

(a) Sugar beets or tobacco

(b) Corn or potatoes

(c) Dry beans, representing relatively low money-yield vegetables

(d) Green beans, representing higher money-yield vegetables

(e) Wheat-onion double crop, representing a cereal-vegetable double crop

In addition to the above, a one-crop farm for each of the twenty-eight crops was studied.

The third step is to choose the rotations. In this study the rotations having between seventy and 100 percent productivity were chosen.

The final step is to determine the optimum farm size for each soil body or soil body group, and socio-economic effects on these sizes. For this purpose three criteria were established: (1) full or nearly full family employment; (2) a minimum farm family income calculated on the basis of family size and age classes;† (3) long term demand for agricultural commodities in these project areas .

To define full family employment, it was necessary first to define family labor. The calendar of operations for each crop is comprised of: (1) work to be done by family; (2) work that can be done by either family or contract labor; (3) work that has to be contracted. The first category alone was entered in the computation of farm sizes.

Sizes of one-crop farms offering full employment were used as a basis for assigning plot sizes to the crops in a rotation. In each rotation the most economical crop other than vegetables was chosen. Among all crops the most productive ones were assigned with the same weight as their one-crop farm size. Available family labor in excess of that needed for the main crop in peak month is assigned to be used in the remaining crops in the rotation. The area of the secondary crops in the rotation is calculated according to the family labor not needed in the major crop. Farm size was determined by totaling plot sizes of the crops in the rotation.

After determining farm sizes for each rotation and the net income of such farms, the farm sizes which provide or exceed the minimum family living allowance were selected. Then the total production of such farms on each soil body were calculated and this production checked with the total long-term demand in the project area.

The optimum farm sizes calculated by this method in Lower Sakarya project area are shown in Table 3.

Work Necessary to Realize the Optimum Farm Size in the Irrigation Project Area

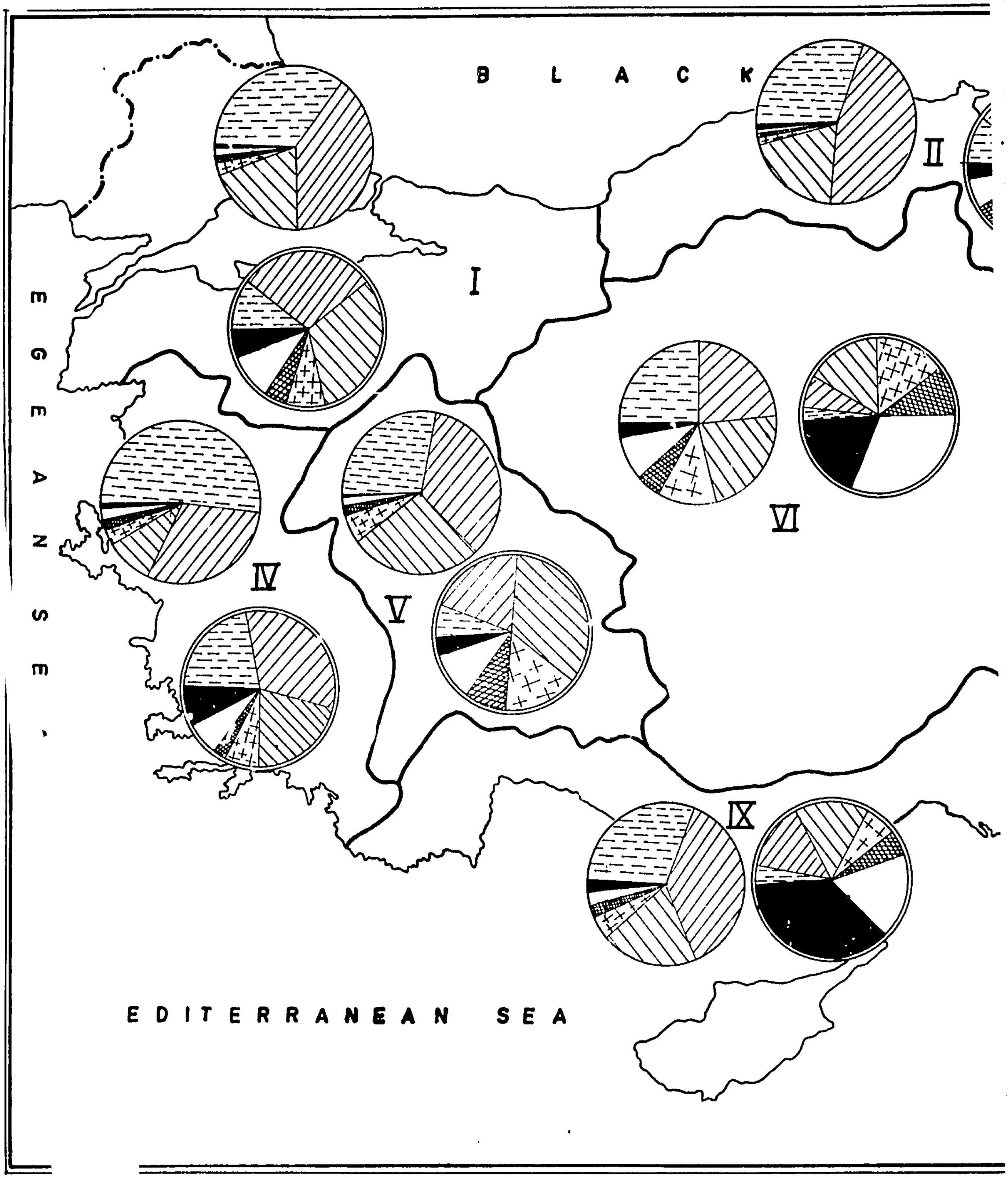
(1) *Enlargement of Small Holdings*

As mentioned before, the majority of the agricultural holdings are too small in the irrigated area of Turkey (65.9 percent of holdings have less than five hectares and 30.8 percent have less than two hectares).

According to the agricultural census of 1963 there are a total three and a half million holdings which total 25,772,448 hectares. The average size of holding is 4.9 hectares. In general this amount of area for each holding might be enough to get a decent living in the irrigated regions, but not enough under dry land conditions.

* Soil characteristics considered in this study were texture, depth, salinity, pH, slope, internal drainage and available water holding capacity.

† The minimum acceptable living allowance according to Tax Law 193 is based on the following: For the head of household, $180; other family members over fourteen years, $108; children fourteen years and under, $72.


B L A C K
E G E A N S E
E D I T E R R A N E A N S E A
I
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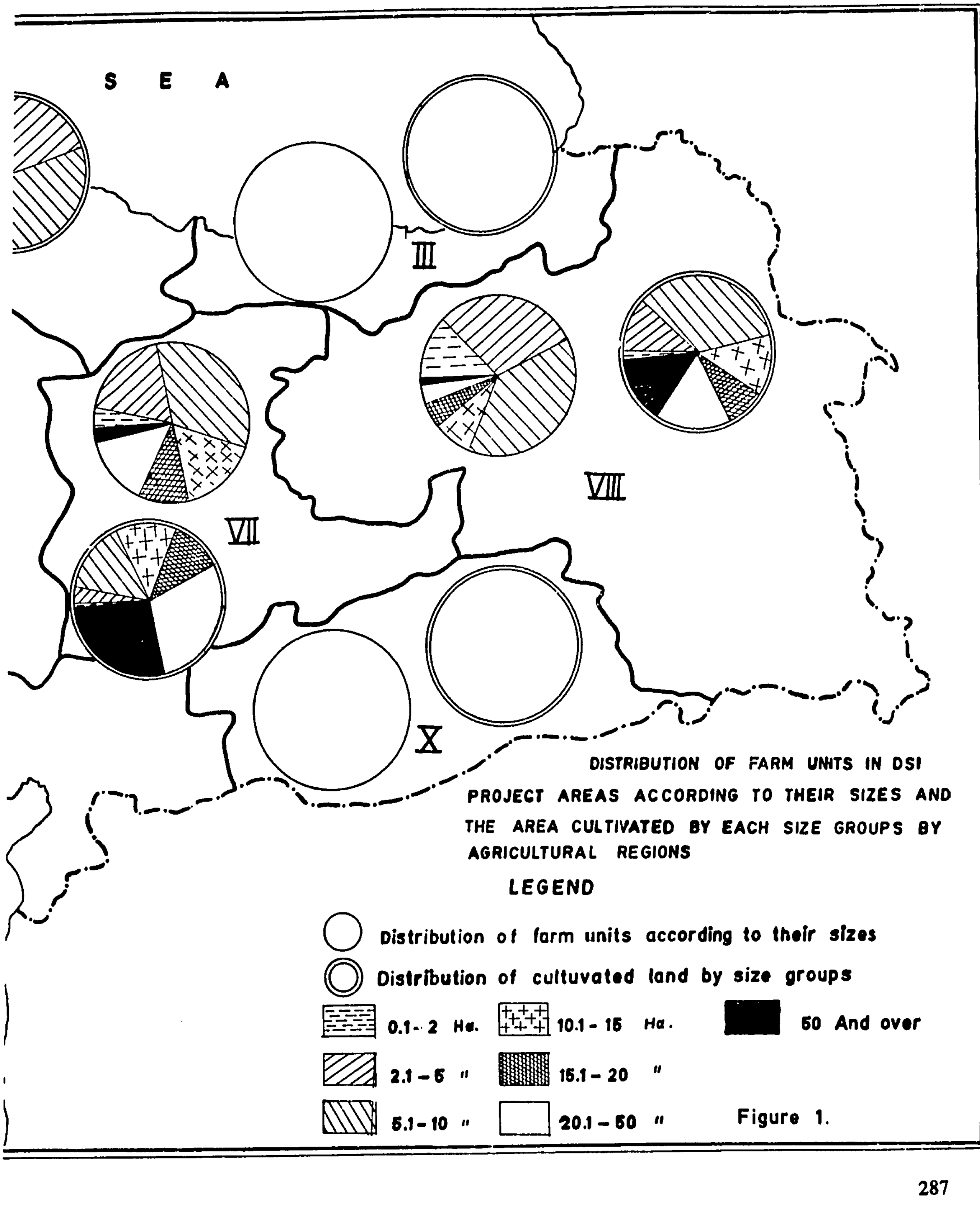
S E A
III
VII
VIII
X
DISTRIBUTION OF FARM UNITS IN DSI PROJECT AREAS ACCORDING TO THEIR SIZES AND THE AREA CULTIVATED BY EACH SIZE GROUPS BY AGRICULTURAL REGIONS
LEGEND
Distribution of farm units according to their sizes
Distribution of cultuvated land by size groups
0.1 - 2 Ha.
2.1 - 5 "
5.1 - 10 "
10.1 - 15 Ha.
15.1 - 20 "
20.1 - 50 "
50 And over
Figure 1.

Table 3

Optimum Farm Sizes in Lower Sakarya Project Area

Rotations	Optimum Farm Size (Hectare)	Soil Bodies
Sugar Beets - Wheat - Potatoes - Dry Beans	7.5	0. 1. 65. 73. 113. 185
Sugar Beets - Wheat - Green Beans - Potatoes	7.6	9. 33. 41. 146
Corn - Sugar Beats - Wheat - Green Beans	8.8	17. 89. 97. 154. 169. 172. 216. 218. 221. 222. 223. 226
Wheat - Green Beans - Potatoes	6.3	25. 999
Sugar Beets - Wheat	7.4	141
Corn - Wheat	8.0	213
Wheat - Potatoes	5.7	181
Wheat - Green Beans	8.0	131. 209. 212. 219. 600
Sugar Beets - Green Beans	8.2	135. 137. 140. 601
Potatoes - Dry Beans	4.0	179
Green Beans - Potatoes	4.4	74
Rice	3.8	225
Sugar Beets	6.8	144
Wheat	15.6	220

As shown above, a major problem in the agrarian structure is the great number of undersized holdings. In this case, enlargement of small holdings is necessary and it is the first step that must be taken.

There are two sources of land available in Turkey to be used for enlargement of small farms. One is the land owned or claimed by the state as Treasury land and the other is the excess land belonging to the large private farmers.

According to the cadastral surveys about seven percent of the total land is registered as state land, but half of this land is disputed and consists of scattered parcels. The state land that could be used for the enlargement of small sized farms or for land consolidation is usually located far from the dwelling centers.

It is therefore necessary to expropriate some of the land owned by large farmers to be used for enlargement of small farms. This is only possible by law. For this reason the "Land Reform" draft has been prepared. Although the land reform legislation has not yet been enacted, certain individual land consolidation projects have meanwhile been started in order to increase the agricultural productivity in irrigated areas.

(2) *Land Consolidation Activities Conducted Since 1961*

Two projects completed in 1963 covering 320 hectares at a total cost of 785.230 TL., including irrigation and drainage practices. These projects were mentioned at the Fifth Seminar in 1964.

A third project, executed in the Antalya region in Aksu irrigation project at Alayli village in 1964. Costs involved in the implementation of the Alayli Project are as follows:

Land leveling	122,320 TL
Farm Irrigation and drainage system and permanent water control structures	307,539 TL
Road construction	41,755 TL
Total cost	471,614 TL

9 TL = $1.00 U.S.

The land consolidation was achieved by getting the agreement of all the land owners in the Alayli Project area. The land consolidation did not change the amount of land owned by each farmer but decreased by 46 percent the total number of plots in the project area. Before land consolidation there were 132 land owners representing seventy-five farm families owning a total of 134 hectares in 146 plots. The average plot size has been increased eighty-four percent, from 0.931 hectare to 1.718 hectares.

In addition to the above activities the Turkish Government and the UN FAO together made a pre-investment survey in the Antalya region to develop the region. The surveys of the project comprise comprehensive studies of the three provinces of Antalya, Burdur and Isparta. Land consolidation has played an important role in the improvement of the agricultural structure. Therefore, two pilot project areas have been selected, in which to undertake land consolidation activities. One of these areas is the Antalya Y-3 area and the other one is the Incirdere village in Burdur province.

Farmers objected to the land consolidation after the completion of necessary surveys and before the land classification works for the reallocation plan in the Y-3 area. For this reason we could not get any cooperation from the farmers. Therefore it was postponed until preparation of the final plan and projects.

The irrigation development and land consolidation project was prepared in 1964 and was intended to be implemented in 1965 for the second pilot project in Incirdere. This project has been prepared on the basis of agreement of the farmers. However, the project implementation has been delayed due to disapproval of ten percent of the total land owners with regard to the plans contemplated. Due to the lack of a necessary bylaw, this project was not implemented in 1965, despite the approval of ninety percent of the land owners.

(3) *The Main Problems in Land Consolidation*

(a) *The lack of legal measures.* Land consolidation activities were started in 1961 in a limited area in Turkey. Unfortunately due to the lack of legal measures, land consolidation activities have not been carried out in a large area. There are some provisions authorizing consolidation of fragmented land in civic law (article 678) and organic law (number 7457) of the General Directorate of soil conservation and farm irrigation. But land consolidation procedures are not clear enough, due to the lack of an explanatory bylaw supplementing these regulations. Therefore, land consolidation activities generally depend on a total approval of the land owners. And such a total consent of land owners is almost impossible.

(b) *The lack of a cadastral survey and land registry.* First, it is necessary to survey the ownership situation of the plots chosen for land consolidation.

There are roughly 36,000 villages in Turkey.

A cadastral survey of only 5558 villages had been completed by the end of 1965. This is 15.44 percent of the total.

Land consolidation activities have not been started due to the lack of a cadastral survey in the several project areas. Cadastral surveys take a long time; therefore, irrigation project development has been conducted without consolidation of the fragmented holdings, and the investment cost of the projects has been higher than for the projects which include land consolidation.

Another problem is the general occurrence of the purchase and sale of lands during the survey and project planning. Together with the delay in registration, these purchases and sales cause many uncertainties in the land ownership situation.

(c) *Land disputes.* Generally after the cadastral surveys are completed many litigations take place in the project area. Land consolidation work cannot be started unless these litigations are settled.

There are no definite statistics on the land subject to litigations in Turkey. However, according to the studies in Antalya region, twenty-six percent of the total parcels and forty-one percent of the total area belonging to 100 villages are disputed. Also, according to the cadastral surveys which have been conducted so far, the forty-seven percent of the parcels and fifty-five percent of the land registered under the title of the state are disputed in Turkey.

(d) *Objections of the land owners.* Reallocation of the land must be accomplished on the basis of full agreement with the land owners concerned. Due to the lack of law or regulations on land consolidation it is difficult to get the full agreement of all the land owners. Some of the land owners have objected to the land consolidation projects. The motives of the objections are not clearly expressed by the land owners. From meetings and many interviews with farmers it is understood that there are many motives for objections. Some of the reasons are:

—Fear of repayment by the land owners of cost of the investments for land consolidation operations.

—Fear of the eventual expropriation or compulsory cession of land partly or entirely by the government.

—Fear of an exchange between good and bad fields.

Fear of government control of cultivation (seeding, planting, harvesting, crop rotation, irrigation, maintenance, etc.) at the end of the execution of the project; a fear that farming will not be practiced on the freehold tenure basis.

In projects implemented so far it has been explained to farmers that the things they fear will not occur.

There are also political motives and personal interests, especially by those who illegally have control over certain lands.

(4) *Dealing with the Problems*

To solve the problems concerning land consolidation mentioned in the previous paragraphs, and to undertake large projects in Turkey, first of all the necessary legislative measures must be taken. Therefore, a bylaw based on article 2 of law 7457 has been prepared. However, a separate land consolidation law seems necessary to prevent certain problems in the future, for it is thought that the present bylaw is not able to settle all the problems of land consolidation.

CHAPTER VIII

Small Projects

REHABILITATION OF BOHLAN LATERAL HELMAND VALLEY PROJECT, AFGHANISTAN

by

Moh'd H. Parwana*

The lands under the Shamalan Unit of the Helmand Valley Project are on the west side of the Helmand River and west of Bost. Stretching some sixty-five kilometers, north to south, the area varies in width from less than one kilometer to a maximum of ten kilometers.

Topography of the Shamalan area as a whole is quite favorable for efficient irrigation with the exception of the depressed areas and those with only small differences in elevation between the land surface and the river. Most of the lands lie on first and second benches with a few hundred acres on the third bench. The elevation difference in the first two benches is some two to three meters, and the Shamalan is on or near this demarcation for some fifty-four of the sixty-five kilometers of the canal. The first eleven kilometers of the canal are on the third bench between its headgate on the Bogher Canal and its entrance onto the flood plain at about Station 11.

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The soil is mostly deep silt loams and fine sandy loams, with some clay loams, and is underlain by permeable sands and gravels at depths of one to six meters or more. The bulk of the Shamalan land is potentially the best in the Helmand Valley, and was once probably the most productive.

There are an estimated 190 kilometers of major laterals in the system, most of which are centuries old and in which there are very few water control structures.

The Bohlan lateral was one of these old laterals which were reconstructed. The work is discussed in this paper.

General Description

The Bohlan lateral is located in the Shamalan Project area and delivers water to approximately 1600 acres of land.

The lateral turns out of the Shamalan Canal at Station 13 + 363 in a thirty-six-inch diameter turnout. It runs generally in a southerly direction for a distance of 3.1 kilometers, at which point it divides into two branches, one branch going to the east across a main deep drain then south for about six more kilometers; the other branch continuing in a southerly direction for about seven kilometers. The flow at the main canal turnout was estimated at twenty-five to thirty cubic feet per second: the east branch, fifteen to twenty cubic feet per second, and the west branch, about ten cubic feet per second.

The lateral was one of the very old original hand-dug ditches maintained by the farmers. It followed a meandering course throughout most of its length, with many sharp curves to impede the flow and complicate maintenance. Spoil material from hand cleaning over the many years was piled high on both banks of the lateral, leaving room for only narrow foot paths. The inside of the ditch was a mass of weeds and grass, which further impeded the flow of water. There were no water control structures in the entire length of the lateral, with the exception of the turnout from Shamalan Canal, three pipe crossings over "A" Drain and two pipe culverts under the Bost-Marja road. Turnouts were non-existent. The farmers simply cut the bank where it suited them and dammed up the lateral with brush and mud to get the water out. This naturally led to numerous disputes over water and a condition where the farms near the head of the lateral had plenty of water while those below the end were perpetually short. The Bohlan research farm and the Bohlan livestock farm were critically short of water most of the time, and police action was required at times to get any water to these areas.

In recognition of the inefficiency of the system and all the attendant problems, a decision was reached in 1964 that the lateral would have to be rebuilt and water control structure provided so that water could be equitably and efficiently distributed. After preliminary studies of the engineering, construction and financing problems, it was decided that rehabilitation would be done by the Operation and Maintenance Department of the Helmand Valley Authority utilizing, in the main, its own equipment. However, some equipment was obtained on a rental basis from the Afghan Construction Unit, a division of the Helmand Valley Authority.

After a decision was reached as to what organization would be responsible for doing the work and financing arrangements were completed. through use of "PL-480" monies, work was initiated. Details follow:

Engineering and Design

A reconnaisance on foot and horseback was made of the lateral to get an idea of what work should be done to rehabilitate the lateral. It was decided that surveys could be kept to a minimum and still meet the needs for design. Bench marks were established at about one-kilometer intervals and a plane-table survey made of the lateral, showing alignment and physical features that would affect design. Cross-sections were taken at 200-meter intervals. These were plotted both as a profile and as cross-sections and were used for layout of lateral grades. The high waterline of the old ditch was used as the design water surface. Hydraulic properties computed from Manning's formula for the various reaches of the new lateral are as follows:

Stationing is in kilometers

Hydraulic properties are in English units

Station 0 + 000 to 2 + 230

Q = 35 cfs
S = –.0003
B = 5 feet
D = 2.65 feet
V = 1.43 ft/sec
FB = 1.55 feet

Station 2 + 230 to 3 + 100 Bk.

Q = 35 cfs
S = –.0006
B = 5 feet
D = 2.25 feet
V = 1.86 ft/sec
FB = 1.55 feet

Station 3 + 210 Ah. to 5 + 650

Q = 20 cfs
S = .00051
B = 4 feet
D = 1.95 feet
V = 1.52 ft/sec
FB = 1.50 feet

Station 5 + 650 to 6 + 200

Q = 20 cfs
S = .0003
B = 4 feet
D = 2.20 feet
V = 1.26 ft/sec
FB = 1.50 feet

Station 6 + 200 to 6 + 600

Q = 20 cfs
S = .00065
B = 4 feet
D = 1.83 feet
V = 1.70 ft/sec
FB = 1.50 feet

Station 6 + 600 to 6 + 950

Q = 20 cfs
S = .0015
B = 4 feet
D = 1.45 feet
V = 2.25 ft/sec
FB = 1.50 feet

Station 6 + 950 to End (About 2 Km.)

Q = 12 cfs
S = Varies

It was felt that a minimum of control for grade and alignment should consist of a single set of grade stakes at fifty meters offset from the edge of the ditch bank and marked with the berm elevation only. (The berm elevation is the top of the finished lateral bank before actual ditching operations.)

The reconnaissance of the lateral revealed dozens of cuts through the bank to deliver water to the numerous small plots of land. Turnouts could not be economically installed at all of these points. Combining several deliveries into one, served by a fifteen-inch metergate turnout, was the logical choice. This reduced the number of turnouts required to sixteen, which included one twenty-four-inch to the east branch of the lateral. One check structure was required at Station 3 + 100 to control the water surface elevation for the twenty-four-inch turnout to the east branch. After the work was completed and the lateral put into operation it was necessary to install another check to control water to a turnout at Station 3 + 770. Finally, the culvert under the Marja road, which was originally of fourteen-inch diameter, had to be replaced by a twenty-four-inch one to pass twelve cubic feet per second of water to the livestock farm.

Construction Phase

From necessity the construction operations on the job had to be kept as simple as possible, because of limited funds and equipment. With the exception of three major changes in alignment the old ditch line was followed. This was done, first, so that the existing farm distribution systems would not be disrupted to any great extent; second, to minimize right-of-way problems, and third, because spoil material was available along the old ditch banks to build the new embankment. Sharp curves were straightened out wherever possible for better alignment. Trees and brush growing along the ditch were removed by farmers in most cases, although many stumps were left to be removed later by equipment. Grass and weeds were burned when possible.

Equipment used for the job consisted of two D8 Cats with dozer, two Briscoe ditchers, a Cat 12 motorgrader, a truck crane, air compresser and jackhammers, and miscellaneous hand tools.

After removal of trees and brush the dozers knocked down the old ditch banks to the established grades and to the width required to contain the new ditch section plus a road.

Some material had to be borrowed in a few cases, or excess material dozed along the line, to make up for shortages in some areas. This was not a serious problem although in one case a carry-all would have been handy to move dirt 100 to 150 meters. The small quantity did not justify bringing in a special piece of equipment. The old meandering alignment was straightened out and smooth curves put in. This was done "by eye," with no survey control for alignment.

Three major changes in location were made to shorten the length of the lateral. In two of these changes the new alignment was constructed through waste lands and the old alignment left to be leveled off and used by the farmers. In the third case, right-of-way for the new alignment was exchanged for the old alignment, which was leveled by the equipment and is now being farmed. No special attempt was made to control moisture and compaction on the new embankment. The ditch section was moist from the previous irrigation season, and we felt that compaction from the movement of equipment was sufficient and was certainly much better than the previous embankments. Berm grades were checked periodically by hand level during construction and when reasonably close—within ten centimeters—were considered satisfactory. The berm grade was the elevation of the embankment required before the actual ditch section was excavated, so that the excavated material would bring the bank up to finished grade.

After about three kilometers of embankment was prepared, a V-ditch was dug by the motor grader to serve as a guide for the ditcher. Again alignment was established "by eye" with no survey control. Ditching operations were then carried out, using two Cats pulling the Briscoe ditcher. The number of passes required to bring the ditch down to grade was dependent on the moisture conditions and degree of compaction of the embankment. It varied from about eight to as many as sixteen passes. Grades were checked during the ditching operations as before, and when reasonably close were considered satisfactory. In this fashion the lateral was constructed by reaches. Loose boulders of conglomerate were encountered at about Station 4 + 800, which made it necessary to drill and shoot. This took three days of work but did not delay construction. When the lateral reached the Bohlan research farm the roadway was eliminated. The total length of lateral rebuilt was nine kilometers. This included two kilometers in the livestock farm south of the Marja road.

When ditching operations were completed on a reach of lateral the construction crew moved in and installed turnouts and checks. The turnouts were standard fifteen-inch diameter metergates with sixteen-foot pipe. Headwalls of masonry were constructed to support the embankment at the turnouts and to serve as cutoff walls for water. One twenty-four-inch diameter turnout was also installed at Station 2 + 950 to deliver water to the east branch of the lateral. Check structures were standard precast concrete salvaged from other areas and reinstalled in the Bohlan lateral. One twenty-four-inch concrete pipe culvert was installed under the Marja road to pass twelve cubic feet per second of water. The old fourteen-inch culvert was removed and some of the pipe salvaged. On the east branch of the lateral one twenty-four-inch crossing of A-drain was removed and salvaged, as was a thirty-six-inch culvert under Marja road. These two structures were no longer needed because water will now be supplied by the rehabilitated south branch of the lateral.

As soon as a reach of lateral was completed it was carefully primed to minimize possibility of washout during operation. Priming was done by irrigation operations forces rather than construction people.

The major construction work began on December 10, 1965, and was completed by February 5, 1966, which was in ample time to deliver water for the irrigation season. Some minor construction and corrective work followed for several weeks, such as rebuilding headwalls of two turnouts, installing a check structure, installing drain inlets, raising the banks in a few reaches to get the required height, grading and shaping of roadway, and digging of farm ditches.

Contract Administration

An agreement for rehabilitation of the Bohlan lateral was signed on December 16, 1964, by the Operations and Maintenance Department, HVA Agriculture Department, and USAID. This agreement spelled out generally the work to be done, equipment charge rates, wages, materials charges, and overhead charges. It provided that an initial deposit of Afs 500,000 be placed in the O & M account and the O & M submit weekly cost reports to substantiate expenditures. The final payment of Afs 400,000 was deposited when the initial funds were expended. At the completion of construction a final cost report was submitted.

Within the O & M organization, daily time cards were turned in for equipment and labor and also for amounts of materials used. These were consolidated into daily cost records, so that a running account of expenditures was kept. This phase of the job appeared to be well organized both in the field and in the office.

The cost of the job was Afs 925,560. This did not include the cost of the metergate turnouts because they had been previously purchased by AID for just this purpose.

Conclusions and Recommendations

Some lessons can be learned from the work done on the Bohlan lateral. I believe it has been proven beyond a doubt that satisfactory rehabilitation of old irrigation systems can be done on a very limited budget and with a minimum of equipment. Overhead costs can be reduced by eliminating all but the absolutely necessary in surveying and engineering. The surveying done on this job was adequate for the purpose. The same system can probably be used with little or no modification on similar rehabilitation work in the future. The design of a new ditch is not difficult. The designer should have a good background in the field of irrigation design, with practical experience in rehabilitation of old systems. He will find that in design, compromises will have to be made between what is technically desirable and what can be practicably constructed with available equipment, labor and materials.

ACU—Afghan Construction Unit
HVA—Helmand Valley Authority
70 Afghanis—1 U.S. Dollar
Afs—Afghanis

PROBLEMS IN PLANNING AN IRRIGATION PROJECT IN CYPRUS

by

K. C. Hassabis*

Summary

In common with other countries of the Near East, Cyprus has a limited quantity of rain, which falls during a short winter season at irregular and variable intervals. Under such conditions irrigation of almost all crops on the island is indispensable for a good return.

The practice of irrigation in Cyprus goes back into antiquity. In the past thirty or so years many small irrigation projects were constructed, and increasing attention was devoted to development and utilization of the water resources of the island. Until very recently the scope of the various irrigation projects was relatively small. The associated problems, especially those of repayment and operation, were simple and relatively easy to solve. However, in the past four or five years more comprehensive projects were embarked upon impounding of reservoirs and the chief among these were the development of associated distribution systems. These projects brought in their wake a number of problems requiring realistic solutions compatible with the envisaged aim of the development of agriculture. The success of such schemes was not to be based upon the adoption of *theoretically* desirable measures—difficult to obtain under present conditions—measures that would impose a severe burden on certain sections of the public. These problems included those of repayment, of operation, of the size and extent of the irrigation project, and naturally that of selecting a particular scheme for priority over others, giving due regard to the limited resources available. The adoption of the most suitable crops and of efficient irrigation practices, the necessity of land leveling, the availability of land suitable for development without requiring heavy expenditure in the immediate vicinity of the project, and the existence of water rights are all matters requiring close attention and solution at the planning stage of a project. This paper reviews the most important of these problems in Cyprus, and the manner in which they are faced. Where no satisfactory solution has been reached yet, we shall present the problem and its implications, and would be glad to

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hear the comments and suggestions of those present.

I. General Review

The availability of water for irrigation is of vital importance to the agriculture of a semi-arid country like Cyprus where: (a) the rainfall is meager and cannot satisfy the water requirements of agricultural crops; (b) the land available for cultivation is limited, and usually sub-divided into small holdings, thus making it necessary to endeavor to create such conditions as will permit the cultivation of high cash value crops, and (c) agriculture forms the basis of the economy of the island.

It is estimated that the net income per acre from crops without any irrigation, mainly cereals, is anything between no return at all, when there is no rainfall at the critical time, and six to nine pounds. In contrast to this, the net income from crops grown where irrigation is available varies from the minimum figure of eighteen pounds in the case of cereals. Forty-five pounds to sixty pounds for potatoes, and rising steeply to 240 pounds or more per acre in the case of citrus. In certain areas of the island it is possible to grow early vegetables, and in this case it is possible to obtain considerably higher returns. Thus the decisive impact of the availability of irrigation water upon the income of the farmer in particular, and upon the economy of the island as a whole, becomes obvious.

It has been the consistent policy of the Government of Cyprus to devote a major part of the resources at its disposal to develop and utilize to the maximum possible extent the available water resources for irrigation purposes. These resources are described in the "Country Report on Cyprus Water Resources and Development," presented to this seminar by Mr. Konteatis.

In this paper we shall concentrate on the main problems involved in the planning of irrigation projects involving the construction of dams for impounding surface runoff, and the associated distribution systems. The necessity of constructing such schemes is obvious. The average annual rainfall over the island is only about nineteen inches, almost all of which falls at irregular intervals during a short winter season. Intensities are usually low and produce little runoff. It is only after sudden storms or protracted rainy spells that any appreciable runoff is produced. Under these conditions the "rivers" of Cyprus are dry for most of the year, but are given to sudden flood flows during the winter or occasionally in the early spring. Such flows may last from a few hours to a few weeks. In the upper reaches of rivers having their origin in the Troodos mountain complex there is a limited amount of continuous flow fed by numerous small springs. This flow is diverted by river intakes before it reaches the plains and is utilized for the irrigation of vegetables and deciduous trees. Where the rivers cross the plains, many intakes have been constructed for the diversion of part of the flood flow, but because the occurrence of such flows may be, and usually is, at times when crops require no irrigation, it is possible to effectively utilize only a small fraction of the surface runoff. The remainder is permanently lost to agriculture by flowing to the sea—except for a small amount which percolates through permeable strata and recharges underground aquifers, from where it is later pumped and used for irrigation. It is to reduce the loss to the sea of this very precious and scarce resource that the extensive program of dam building has been undertaken by the Government of Cyprus in the past few years. The capacity of most of these dams is relatively small, compared to similar works in other countries, because it is limited by topographic conditions, and by the availability of water. Construction cost per unit of stored water is usually much higher than elsewhere, but its immediate beneficial impact upon the agricultural output of the near vicinity is so great that, other factors permitting, it is intended to continue with this program of dam building as a matter of priority.

The problems involved in these projects may be broadly classified into economic, agricultural, engineering, administrative and social. These are naturally inter-dependent, and the close cooperation of the economist, the agriculturist, the engineer, the administrator, the sociologist and the farmer himself is required from the very inception of any project. This cooperation, and the pooling together of the various skills and knowledge, will decide whether eventually the project will successfully fulfill its purpose.

II. Economic Problems

These involve the financing and repayment of the costs of the project, and the economic repercussions the construction and operation of a project will have upon the immediate and direct beneficiaries particularly, and upon the society of the country generally.

Until recently the irrigation schemes constructed were on a small scale, financial outlay was small, and the matter of financing and repayment were dealt together. The eventual beneficiaries formed themselves into an irrigation division and requested the authorities to carry out a particular scheme. If after investigation by the Department of Water Development, it was recommended, then the scheme was financed partly by government and partly by the beneficiaries. The government share was between three-fourths and two-thirds of the cost, and was paid in cash. The irrigation division contracted a long-term loan again from the government, for paying its share of the cost. The Department of Water Development prepared the plans and carried out the construction of these schemes, which on completion became the property of the irrigation division and were operated and maintained by it. This policy still applies to minor schemes. Practical rules were devised and applied as to what expenditure was justifiable per unit of land to be benefited.

With the undertaking of more ambitious projects involving the expenditure of large sums of money, this simple procedure was no longer applicable. Furthermore, it was considered necessary that the government be able to ensure that irrigation water made available at such considerable expenditure would be used efficiently and in the most productive way feasible. It was therefore decided that the government undertake to finance completely all major irrigation projects involving the construction of dams and extensive distribution systems.

The question of recovery of the cost of a project is much more complicated. As yet no final policy has been formulated, although much careful study is being devoted to this question. The principle has been accepted, however, that the government will subsidize substantially these projects and will endeavor to recover only part of the cost from the direct beneficiaries of the project, i.e., the farmers who will get the water for surface irrigation. A difficult decision in this matter is what portion of the cost should be recovered from the irrigators. It must at the same time be low enough to encourage agricultural development and promote stabilization, yet high enough to discourage inefficient and wasteful use of the water. It has been suggested that government subsidy of such projects should be fifty percent of the cost, including the estimated cost of operation and maintenance. However, as shown in Table 1 such a policy would render the cost of irrigation water so high that the farmer could hardly afford using it, especially at the initial stages of development of tree plantations, when his income would be negligible and his expenditure on land preparation higher. It might be possible to work out an average cost price per unit of available water for all projects and charge a uniform rate all over the island, thus recovering fifty percent of the cost on an aggregate basis, but keeping everywhere the rate at a sufficiently low level to encourage development. In such a case this would mean no actual government subsidy on certain projects and a disproportionately high subsidy on others. This is not so unfair as at first would appear, since the entire island community—the greater portion of which derives no direct benefits whatsoever from these schemes—is required to bear the government share of the cost through taxation.

The writer believes that it might be preferable to avoid a rigid, inflexible policy for all projects, irrespective of the circumstances in each particular case, but rather endeavor to have certain guiding principles which would allow flexibility and consideration of the problems arising in each particular project. Then development of that area envisaged in the project will remain attainable, and the overall government subsidy will be kept at a reasonable level. Thus it will be possible in projects which serve existing plantations or annual crops, and where the cost per unit of water is low, to recover the entire project cost, or a very substantial part of it. But in newly developed areas, it is best for the first few years to keep the water charges at a lower level than what they are estimated to be eventually, until the new trees give full returns.

It might here be mentioned that no project constructed on this basis, that is, entirely financed by government, has as yet been put into operation. This is an important point, on which more will be said shortly. Since 1963 six such dams have been constructed or are under construction. The first phase of the distribution system of one of them, the Trimithios-Kiti Dam, is in the final stage of completion. The distribution systems of three more projects are scheduled to start this year, and it is anticipated that they can be put into operation early next year.

In calculating the annual cost of a project—the basis on which the percentage of expenditure to be recovered from the direct beneficiaries will be calculated—the following items are included: Estimated or actual cost of the dam, including compensation; the cost of the distribution system, and the cost of engineering services and supervision, where consulting engineers are engaged for the design, and foreign engineers are engaged for the supervision of construction of a project. Where this work is done by the staff of the Water Development Department, the last item is omitted. Another item usually included, at the planning stage when the benefit-cost ratio only is calculated, is the expenditure incurred by the farmer himself for any land leveling or improvement necessary, and the distribution system within the farm. All these items are amortized over a period of forty years at five percent interest rate. To the resulting figure we add the annual cost of maintenance and operation, which combined at present is assumed to be two percent of the total initial cost of the dam and distribution systems.

As this is a crucial point on which the charge to the farmer is to be based, some pertinent remarks may be in order: The useful life of a dam is likely to be of the order of 100 years, while that of the distribution system is usually much shorter. A fair and more usually acceptable amortization period would be fifty years rather than forty. Where a development project may be financed by having contracted a loan through international development agencies with a lower rate of interest, it is fairer that the same terms should be applied when calculating the annual costs of the projects. Then the assumption made on the level of the maintenance and operation costs of these single purpose, relatively simple and fairly compact projects appears to the writer to be far too high. As assumed, it amounts to one-fourth of the total calculated annual cost. The operation of smaller schemes, although under different principles and conditions, leads to the belief that a much lower figure for this item would be more realistic. However, once these schemes are put into operation and with the passage of a short transition period, during which the most efficient and economic manner of operating each scheme will no doubt be evolved, it will be possible to arrive at the cost of operation and maintenance fairly easily. Meanwhile, it may be feasible to consider recovering this part of the cost the ensuing year, when actual costs will be available. Another point to be considered is this: After a dam is completed and with the first filling, it may be discovered that certain costly works are necessary before it can function satisfactorily. Such expenditure should be regarded as part of the initial capital investment, rather than as a maintenance cost, and a suitable allowance made for it in the original budget.

The manner in which the water is sold and charged to the farmer is a factor in the administration of the project. It involves both engineering and agricultural considerations. We shall try to review it briefly at this stage: The simplest way of dealing with this is to measure the water delivered to each farm outlet and charge a rate per unit of water delivered. However, in Cyprus where the size of individual plots is very small—anything from less than one-half acre to three acres—the installation cost of individual measuring devices is prohibitive. Of course it would be conducive to efficient and less wasteful use of irrigation water, but as in all engineering problems we have to compromise and adopt something less than the best solution. Where the number of individual owners is small and the holdings large enough, individual meters are to be installed. Although no final policy has been formulated on this matter, it seems probable that the charge to the farmer will have to be based on the area of the land and the kind of crops irrigated. In addition to this charge for water actually consumed each year, a basic charge should be made for all land covered by the distribution network, whether in any particular year it receives irrigation water or not. This practice is frequently adopted on projects of a similar nature elsewhere and its justification is obvious. With the quantity of available water variable and limited, the distribution system has to cover a larger area than it is possible to guarantee water supply for every year. But since the service of these lands is made possible, and the value of these lands do increase as a result, it is the purpose of this basic charge that all lands within the system should contribute toward part repayment of the costs incurred.

The problem of priorities in choosing a particular project in preference to others, when both financial and technical resources are limited, is a complex one since many factors besides economics are inevitably involved. While many projects may appear to be economically feasible, the magnitude of the initial expenditure in relation to the extent of the derived benefits, and their indirect effect upon the national economy, have to be carefully considered. While going ahead with major projects involving the expenditure of considerable amounts of money, smaller schemes must not be neglected. In such schemes it would be possible to keep the old system of contributory financing. Many such schemes can be quickly built and satisfactorily operated, with pronounced beneficial results, without having to go through the slow and cumbersome process adopted for the major projects. It would be a pity if such small, unspectacular projects were neglected.

We have dwelt at some length on the economic problem involved in planning, since this is usually the most critical factor, and the one presenting the greatest complexity.

Engineering and Agricultural Problems

In Cyprus the Water Development Department deals with the engineering aspects of a project, while the Agricultural Department, through its Water Use, Soil Survey and Land Use, and Land Improvement Sections, deals with all agricultural aspects of the project. Since the work of these two government departments is closely related, close cooperation is maintained throughout all stages of planning and operating a project.

The location of a dam is dictated by geological and topographic conditions, and the availability of water and land suitable for development with the minimum expenditure. Once the engineer has satisfied himself that he can build a dam at a particular site, and the problems of transporting and utilizing the water to be impounded have been reviewed, he turns his attention to the study of the quantity of the water he can expect to impound. Although rainfall records of quantity but not of intensity are readily available, runoff figures are sadly lacking. Those that do exist from the past few years are usually unreliable, for a variety of reasons. Such a situation is one that usually confronts an engineer anywhere, so he has to use his experience, knowledge of local conditions and judgment to arrive at a fairly reasonable result. It is not to be wondered therefore that we do get as many estimates of available runoff as there are engineers who have tackled this question. Although efforts are being made to remedy this lack of factual information, the fact remains that at the time you need this information you cannot have it, and must fall back on empirical judgment. When this matter is somehow settled, and the capacity of the reservoir decided upon, it is time to examine how and where you are going to best utilize this water. This decision is made in conjunction with the specialists from the Department of Agriculture who, having selected the land suitable for development, must reach a decision as to what crops can best be grown in that area. Having established a probable crop pattern, one may proceed to the design of the main conveyor system, and begin considering how he eventually will make the water available to the great number of small individual plots included in the area. There is no question that land consolidation might simplify matters and put them on a more rational and economic basis. But since such a prospect appears rather remote at present, such a desirable possibility must be discounted in the design of the detailed distribution network. It is necessary at this stage that the farmers to be affected should be brought well into the scheme, and its effects discussed at length with them. Otherwise the full benefits of the project may never be attained.

There is a tendency to adopt exacting design standards, to minimize water losses and get accurate measurements of water delivered to each farm. This considerably increases the costs of the project. It is essential that this be borne in mind and reasonable solutions be accepted. As long as the design of a particular distribution system can be made flexible enough to allow future extensions and improvement, lining of the distributary canals or piping to the individual plots need not be carried out in the first instance, assuming that the losses involved will not be excessive.

In view of the small quantities of water involved—usually around ten cusecs—the conveyor systems adopted at present are rectangular reinforced concrete canals or asbestos cement pipes, depending on site conditions. Other forms of concrete lined canals will be used in one project and there is a possibility that prefabricated concrete canals may be made locally available in the future.

The Water Use Section of the Department af Agriculture has done much valuable work in studying the water requirements of the most common crops in various localities in Cyprus, and the efficiencies attainable under different methods of prevailing irrigation practices, taking into account the normal monthly distribution and incidence of rainfall. Table 3 gives a summary of the total annual requirements for different irrigation efficiencies.

Administration and Operation Problems

As stated earlier, no government-financed project has yet been put into operation, so the practical problems to be faced in each particular case have not yet become apparent. But it is believed that whatever method of operation is originally adopted will have to be revised and modified eventually in the light of experience gained with time. The willing cooperation of the user has to be ensured, and the help of an agricultural officer conversant with irrigation demand patterns will be necessary, especially at the initial stages, until things begin to run smoothly. Local offices must be established, equipped with technical staff able to deal without delay with matters of emergency maintenance and the routine running of a group of neighboring projects.

At present the appropriate district administration serves as liaison between farmers concerned and the various technical departments with headquarters in Nicosia, the capital of Cyprus. It also initiates possible projects for further study by the technical departments.

The efficient running of a project is of course a prerequisite for its success, and the machinery evolved must be kept as simple as possible, consistent with the magnitude of a project and the particular local conditions.

Water rights: An administration problem which causes considerable trouble is that of water rights. The existing law requires that all existing water rights to be injuriously affected by the construction of any new works should be ascertained and set down in a register, with a view of providing the owners with an amount of water equivalent to such rights.

Where these rights refer to water taken through an intake on a stream or river which flows only occasionally and at irregular intervals in winter, as is usually the case, it is doubtful whether such rights can be assessed satisfactorily.

The writer suggests that where the proposed project will affect all those who may claim any previous usage of the free flow of the river—and

Table 1

Project	Initial Cost (In Pounds)	Annual Cost (In Pounds)	Area Irrigated in Average Year (acres)	Initial Cost per Acre (In Pounds)	Estimated Annual Cost per Acre (In Pounds)	Water Rate (Cost)	Scope of project and crops
Polemidhia	970,000	76,000	650	1,500	117	33	To replace supply from Agrotiri aquifer to existing plantation which has been partly rendered unsuitable by sea intrusion. Forty percent citrus, thirty percent vines, thirty percent garden vegetables.
Kalopanayiotis	380,000	29,700	190	2,000	156	59.4	To bring new area under cultivation 100 percent Deciduous trees (new plantations). Extensive leveling necessary at ninety pounds per acre.
Argaka-Magounda	400,000	31,300	440	910	74	22.4	To extend cultivation of summer crops.
Pomos*	413,000	32,200	374	1,105	86	29.2	To introduce spring and summer crop cultivation.
Ayia Marina*	158,000	12,000	73	2,170	165	53.4	To extend cultivation of spring and summer crops.
Mavrokolymbos	550,000	43,500	605	910	72	21.75	To extend cultivation of spring and summer crops.
Kiti	260,000	20,400	667	390	31	15.75	To extend cultivation of spring and summer crops.
Yermasoyia	1,500,000	117,000	2,000	750	58.5	13	To extend cultivation of spring and summer crops and of trees and to provide supplementary irrigation water to existing citrus plantations.

Note: Cyprus Unit of area: One donum equals 14,400 square feet equals one-third acre.

thus provide them with a much more certain and reliable source of supply, and with a much more economic exploitation of this water—it should be made a condition for proceeding with the project, that all those claiming water rights should abandon them subject to their being included in the new project, and thereafter they shall be treated in the same way as all other owners. This is not an unfair suggestion, for whereas in future they will be ensured with a reliable supply at the most suitable time they require, previously their supply was quite uncertain and liable to all the whims and vagaries of weather. Objections or inquiries to such a measure should be resolved and settled at the early stages of planning, but one or two minor objections should not be allowed to prejudice the construction of an otherwise beneficial project.

Concluding Remark

We have dealt briefly with various problems arising in the planning of irrigation projects in Cyprus. Each one demands careful consideration and detailed study to arrive at a satisfactory answer. I am sure that many other problems have not been mentioned. We hope to hear the comments and edifying remarks of those present who have a wide experience and have had to face and solve similar problems.

Table 2

Net Income per Acre for Some Typical Crops

Crop	Net Income per Acre in Pounds
Valencia Oranges	255
Jaffa Oranges	105
Apples	1,095
Pears	417
Plums	234
Peaches	414
Tomatoes	126
Melons	105
Cucumbers	72
Beans	99
Potatoes	60
Carrots	135
Vines	69
Artichokes	150

SEASONAL CROP REQUIREMENTS WITH DIFFERENT EFFICIENCIES

Drg. No. FV/IR/9/2

LOCAT.	SEASON OF IRRIG.	CROP	DAYS OF IRRIG.	ANNUAL CROP REQUIREMENTS IN THOUSAND IMPERIAL GALLONS / DONUM							
				40%	45%	50%	55%	60%	65%	70%	75%
PLAIN AREAS (MORPHOU)	Winter	Barley	75	83	74	66	60	55	51	47	44
		Wheat	90	120	107	96	88	80	74	69	64
		Peas - Broad Beans	105	155	138	124	113	103	96	89	83
		Cabbage-Cauliflower	90	146	130	117	106	97	90	83	78
	Spring	Potatoes	105	181	160	144	131	120	111	103	96
		Carrots	75	122	109	98	89	82	76	70	66
	Summer	Tomatoes	135	356	316	284	259	237	219	203	190
		Melons-Water Melons	120	280	249	225	204	187	173	159	150
		Cucumbers	105	230	206	185	168	154	142	132	123
		Cow-Peas	120	310	276	249	226	207	191	177	166
		Onions	105	230	206	185	168	154	142	132	123
		Ground-Nuts	150	374	332	299	272	249	230	213	199
		Artichokes	150	271	242	218	198	181	168	156	145
	Autumn	Potatoes	90	206	183	165	150	137	126	117	110
		Carrots	75	142	126	114	103	95	88	81	76
		Horricot Beans	105	254	226	203	185	169	156	145	135
	Perennial	Citrus	210	503	446	401	365	334	309	287	268
		Vines	105	263	234	211	192	176	162	150	141
		Deciduous	180	471	420	378	343	314	291	270	252
		Lucerne	255	724	644	580	529	483	446	415	386
HILL AREAS (SAITTAS)	Spring	Potatoes	75	125	111	100	91	83	77	71	66
	Summer	Tomatoes	120	315	280	253	229	210	194	180	168
	Autumn	Potatoes	90	215	191	172	157	143	132	123	115
		Beans	90	215	192	173	157	144	133	124	115
	Perennial	Deciduous	150	321	285	257	232	214	197	184	171
		Vines (Table)	90	211	187	168	153	140	129	120	112
		Citrus (Evrykhou)	210	450	399	359	327	299	277	257	239

Based on figures by S.T. Chimonides Febr. 1964

TABLE 3

A.- Dams constructed before 1963 ▬

No.	NAME	TYPE	HT.	M.G.	YEAR
1	Kafizes	Masonry	75	25	1953
2	Ayios Loukas	Earth	11	100	1955
3	Gypsos	"	11	22	1955
4	Pyrgos (Tyll.)	Con. Grav.	60	30	1957
5	Trimiklini	"	105	75	1958
6	Prodhromos	Earth	20	25	1962
7	Morphou	"	37	450	1962
8	Lefka	Con. Grav.	80	80	1962
9	Geunyeli	Earth	50	230	1962
10	Athalassa	"	42	174	1962

B.- 1963 Projects ▭

	No.	NAME	TYPE	HT	M.G.
*	11	Argaka-Magounda	Rockfill	135	253
	12	Ayia Marina	"	108	66
	13	Kanli Keuy	Earth	63	245
	14	Mia Milea	"	71	74
	15	Ovgos	"	52	186
	16	Pomos	Rockfill	126	189
*	17	Tremithios	Earth	74	355

C.- 1964 Projects ⊏⊐

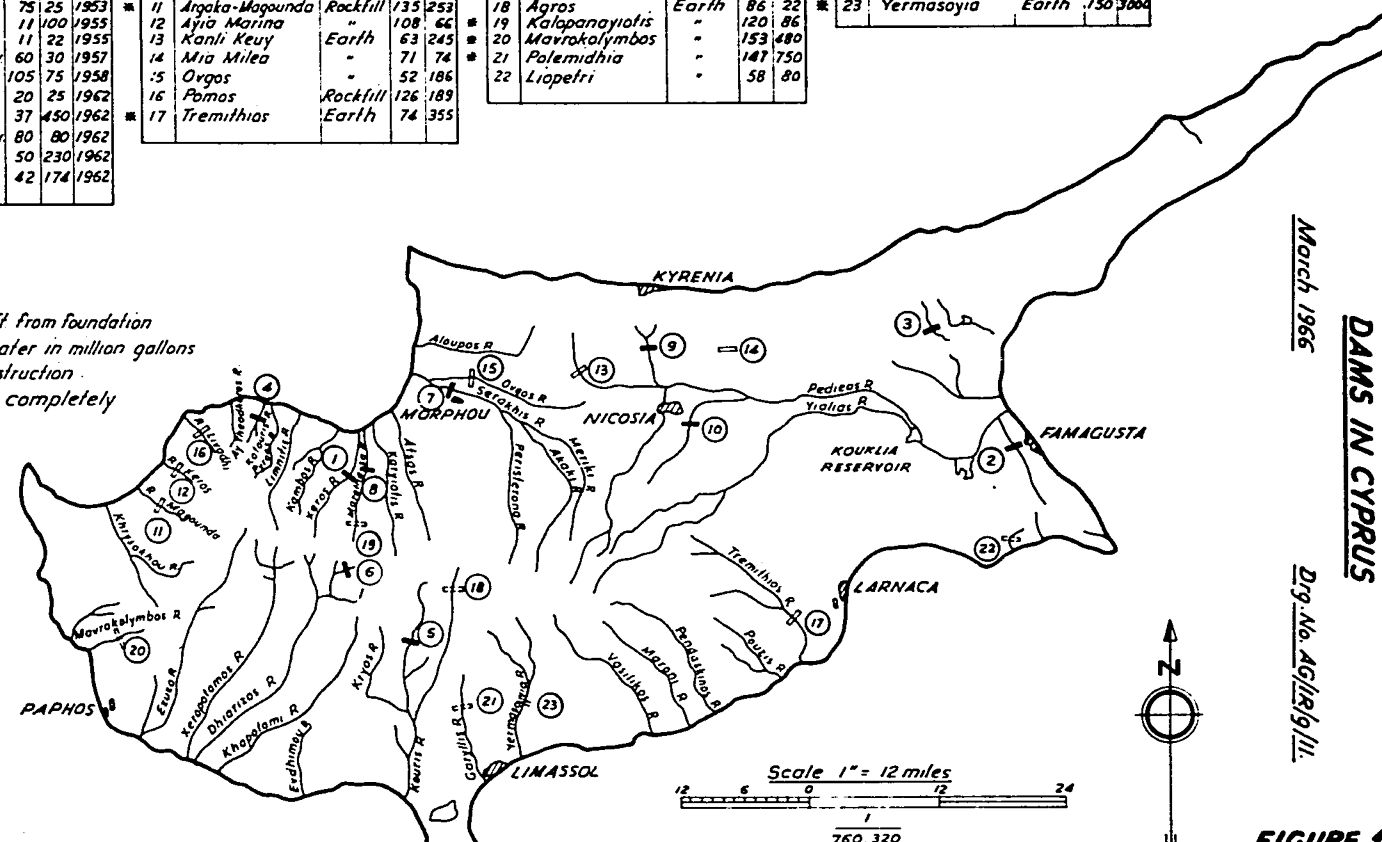
	No.	NAME	TYPE	HT	M.G.
	18	Agros	Earth	86	22
*	19	Kalopanayiotis	"	120	86
*	20	Mavrokolymbos	"	153	480
*	21	Polemidhia	"	147	750
	22	Liopetri	"	58	80

D.- 1965 Projects ═

	No.	NAME	TYPE	HT	M.G.
*	23	Yermasoyia	Earth	150	3000

NOTE:

HT. Refers to height in ft from foundation
M.G. Means capacity of water in million gallons
YEAR. Is the year of construction.
* Projects financed completely by Govt.



DAMS IN CYPRUS

March 1966

Drg. No. AG/IR/9/II.

FIGURE 1

SMALL IRRIGATION PROJECT IN IRAN

by

Mohamad Ali M. Rejali*

Introduction

As was discussed in the Fifth Seminar, after destruction of a great part of the Ghazvin region by the earthquake of 1962, the Government of Iran assigned the Ministry of Water and Power to make a short reconnaissance survey of the region and propose an overall development plan for its rehabilitation. After a few months of investigation the Ghazvin Authority, which was then established for this purpose, submitted a comprehensive plan for the development of this area, based generally on the exploitation of the groundwater reservoirs of the region to irrigate as much of the fertile soil as possible. The plan made provision for a three times increase in the per capita income of the farmers of the region.

According to this reconnaissance investigation, the total groundwater reservoir of the area could yield an estimated increase of ninety million cubic meters which was wasting. If this were extracted and utilized properly, 19,000 new hectares of land could be irrigated by this water. The area under irrigation would increase from 56,000 hectares to 75,000 hectares. Besides, some measures were proposed for improving agricultural practices on the other 56,000 hectares, introducing new high value crops, and eventually increasing the income of the area three-fold, or from \$200 per family to \$600.

The total expense for the survey of the area, drilling experimental production wells, and the land development, was estimated at around forty million dollars. The region was divided into nine sections with regard to the availability of water and type of soil. It was understood that the two sections most damaged by the earthquake should be given the highest priority and improved before other sections. Investigations showed that it would require two years to develop the two mentioned sections and complete the hydrological, soil, water, agricultural and other investigations for starting the second phase of development. An additional four years would be required to develop the other six sections and complete the project.

When this report was submitted in the Fifth Irrigation Practices Seminar, many of the partici-

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pants showed a great interest in this undertaking and suggested that the progress of this project be discussed in the following seminars. Since few countries in the world are presently extensively involved in the development of their groundwater resources, it would be a good example of a large groundwater development and a project based primarily on groundwater utilization. The shortcomings and limitations of this project are probably of the same nature as those appearing in groundwater development in other countries. Participants engaging in similar projects in their respective countries may expect to be confronted more or less with the same kind of difficulties, since our countries are rather similar. The solutions we have found for many of our problems are rather interesting and in many instances perhaps the only ones possible.

The following is a general description of the physical aspects of the project:

Water Resources

It was planned to develop the area by utilization of ninety million cubic meters of groundwater presently flowing out of the area. This water was to supplement the shortage in the region where the water was most needed and where the farmers needed more assistance. It was also decided that all the ghanats or horizontal galleries, which convey the phreatic water to the surface, be improved and remain under control of the farmers. The total flow of the ghanats was measured as 280 million cubic meters per year. After completing the second phase of investigation the following changes were to be made in the preliminary plans with respect to water development.

After a thorough survey of the groundwater resource it was concluded that, although the effect of groundwater varies from region to region, it is safer and more convenient to formulate a program for the combined development of ghanat and groundwater. Since at present the flow of ghanats is utilized about 260 days annually and the rest of the year the water flows to the swamps unused, it was suggested that the long range plan should consider systematic drying up of ghanats and replacing them with wells. However, since the total value of the present ghanats is estimated at about one and a half million dollars, and since in some places the ghanats do not have any pronounced effect on deep wells, the economic feasibility of such replacement should be considered most seriously before the commencement of the plan. Furthermore, the ghanats were already dug by the displaced landlord and are being freely utilized by the residing farmers, whereas, if replaced by wells the government has to bear the cost of drilling the deep wells and the farmers have to pay more for the operation and maintenance of pumps and motors. According to estimates made so far, a gradual change will not be overly costly, and by adopting modern techniques of farming and by introducing new crops the farmers will be able to pay the cost.

Therefore the project is proposed to be developed in two stages, "A" and "B." During stage "A" (1964-1971) a total of 270 million cubic meters of existing groundwater will be developed. During stage "B" (1971-1975) ninety million cubic meters of surface sources and an additional ninety million cubic meters by over-pumping of groundwater will be developed, providing the decision is made regarding the implementation of the Taleghan trans-basin diversion project. The total amount of water made available for agricultural development in stages "A" and "B" will be 450 million cubic meters per year with over-pumping, or 360 million cubic meters per year without over-pumping.

Under stage "C" of the program it has been assumed that 240 million cubic meters yearly of Taleghan river will be conveyed into the area, and that the over-pumping of ninety million cubic meters per year practiced during stage "B" will be discontinued. As a result, the total amount of water available for agriculture at the end of stage "C" will be about 600 million cubic meters per year.

The villages located on the uplands and hills, where the pumping is either not possible or is very expensive, will be instructed technically and assisted financially to continue with their ghanats and to supplement the moisture of the soil as much as possible by utilizing flash floods.

The soil of the areas in the periphery of the swamps, which contains the greatest number of ghanats, is of the lowest quality. The income from this type of soil is hardly sufficient to pay for the comparatively high cost of pumped water. Therefore it is suggested to either move the inhabitants of this region to other localities or assist them in improving their ghanats and continuing their present way of livelihood.

The surface water resources of the region are inadequately utilized at present. The regions having the highest reserves of groundwater also have the most surface water. The plan will consider the development of the resources, aiming at using the surface water in the areas where the groundwater reserves are least.

In the reconnaissance report the area was divided into eight sections with respect to water and soil resources. Now, through collecting more information and making more intensive computations with regard to these two resources, the area is divided into five sections. A separate water and soil development program is proposed for each of these sections.

Utilizing hydro-geological studies, the effect of pumping each well on its nearby ghanat has been estimated. Different tables and graphs were prepared to show the relationship between the height of water in the ghanats' mother well, and the water level in the well at the different stages of pumping.

Studies show that the effect of pumping on some ghanats located in the plane will be such that they will go dry within one or two years after the commencement of pumping, that the ones located on the highlands, using the phreatic water, will not be affected.

Provisions are made to gradually replace the decrease in the flow of ghanats by well water. After ten years the major portion of ghanats will stop flowing and the whole region, except uplands, will be irrigated by pumps or from the river.

Agricultural Resources and Planning

The agricultural plan has been proposed for stages "A" and "B" only, since it is considered premature to embark on agricultural planning for stage "C."

According to the reconnaissance program the total area under cultivation was supposed to be increased by 19,000 hectares through utilization of only ninety million cubic meter of groundwater. The greatest portion of the newly irrigated lands was to be planted to trees. Some improvement measures were also to be taken for the increase of the total agricultural output of the region.

The present program suggests that some 30,000 hectares of new land be brought under cultivation during stage "A." This will be comprised of 5,000 hectares of wheat and 5,000 hectares of pulses, with the remaining 5,000 hectares lying fallow. Of approximately 22,000 farm families of the area, some 11,000 will be allocated farms of 1.3 hectares of orchards and field crops, and the remaining families will be allocated farms without orchards on a somewhat larger area of about one and a half hectares. The average annual water allocation per farm at this stage will be about 12,000 cubic meters. By the end of stage "B" the average allocation of water per farm will be 20,400 cubic meters.

The agricultural program for stage "B" envisages two alternatives, one based on the provision of an additional ninety million cubic meters, and the other based on the provision of an additional 180 million cubic meters obtained by temporarily over-pumping the groundwater to the extent of ninety million cubic meters per year.

The cultivated area of land corresponding to each of these alternatives is given in Table 1.

Table 2 shows the number of family farms, types of farms and water allocation for stages "A" and "B."

Investment and Expected Income of Farm Families

The final analysis of cost and prices shows that in respect to income derived per unit of water used, orchards represent the most profitable branch of agriculture. Nevertheless, the extent of the orchard area has been determined in the program to best suit anticipated market demands. Vegetables and cereals rank second and third. Sheep and poultry also show great possibilities for development and marketing.

Table 3 indicates the estimated quantity and value of annual produce after development in stage "A" reaches full production.

Investment in Stage "A" (1965-1971)

The total investment for developing the land and orchards under stage "A" will amount to about 13.7 million dollars. The present value of these investments is about 11.2 million dollars. These investments include cost of land preparation, planting, tending the orchards up to fruit-bearing stage, and fees for use of tractors and accessories. It does not include the investments in developing water resources or establishing an organizational framework, for water purchases, marketing, financing, tractor services, instructions, etc. The investment per family will amount to about $600.

Income in Stage "A"

At this stage the total water development will not be achieved and the orchards will not be in production in most of the area. Table 4 summarizes the anticipated income of the area in this stage. The average farmer's income at the end of stage "A" is estimated at $550.

Investment in Stage "B"

The additional capital to be invested in stage "B" (1971-1976) is about 10.2 million dollars.

Income in Stage "B"

On the assumption that by this time most of the orchards are fruit-bearing, the land is fully developed, and the farmers are benefiting from the most modern techniques of farming, the income of the area is estimated as indicated in Table 5. Table 6 shows the total income per farm family at stage "B."

Special Features and Problems of the Project

(1) The method of investigation and the computations are of the types which are used in most parts of the world for large undertakings. However, one of the most interesting features of this project is that, perhaps for the first time in Iran, two ministries, the Ministry of Water and Power and the Ministry of Agriculture are combining their efforts and working mutually for the development of the area. There are nearly ten different teams working on this project, a few from each ministry, but they cooperate very closely. Unfortunately, in many of the other projects such cooperation between the teams from different ministries is not apparent. As a matter of fact there is no adequate harmonization between the activities of various Iranian ministries, even though all are working for the same goal which is the increase of income. It is often observed that after surface or groundwater is developed in a certain region by the Ministry of Water and Power, little action is taken by the Ministry of Agriculture for developing and planting the land to thus utilize the water. This project is an indication that if the ministries work cooperatively for a particular purpose, the end result will be of great benefit to the nation.

To improve the administration of the project a special organizational structure has been proposed:

(a) The establishment of a high council by the ministries concerned, to act as a joint policy making committee for the area.

(b) The extension of the jurisdiction and functions of the Ghazvin Development Authority to cover all matters of development operation and management connected with the implementation of the program, and to establish effective coordination between it and any other authorities that may assume such functions in the area.

(2) Because present laws are rather ineffi-

Table 2

Farm Areas, Crops and Water Allocations per Family at End of Stage "B"

Description	With orchard planted in Stage "A"	With orchard planted in Stage "B"	Without orchard, with existing vineyard	Without orchard or vineyard	Total
	Type of farm				
Number of Families	11,200	6,580	2,830	1,670	22,280
Alternative "A": Without Over-pumping					
Average area in hectares					
New orchards	0.5	0.5	nil	nil	0.4*
Field crops and fallow	1.0	1.3	1.3	1.8	1.2*
Total hectares	1.5	1.8	1.3	1.8	1.6*
Annual water allocation, cubic meters	16,000	16,000	11,000	16,000	average 15,300
Alternative "B": With Over-pumping					
Average area in hectares					
New orchards	0.5	0.5	nil	nil	0.4*
Field crops and fallow	1.7	2.0	2.0	2.6	1.9*
Total hectares	2.2	2.5	2.0	2.6	2.3*
Annual water allocation, cubic meters	21,000	21,000	16,000	21,000	average 20,400

* Weighted average of farms in area.

Table 3

Estimated Quantity and Value of Annual Produce after Development in Stage "A" Becomes Fully Productive

Crop	Quantity tons	Value per ton in Rials	Total value in Rials 1,000	Total value in $1,000	Percentage of total produce value
Orchards					
Apples	69,000	7,200	496,000	6,600	31
Pears	16,000	7,200	114,200	1,500	7
Quinces	2,100	7,200	15,100	200	1
Peaches	19,100	7,200	137,500	1,850	9
Vegetables and field crops			822,850	11,000	52
Total			1,586,950	21,150	100 percent

cient for the proper development of water resources of the region, it is recommended that legal and administrative measures be introduced in order to make development and control of ground and surface water possible.

(3) As was stated in the text of the report; the soil and water resources of two zones of the region are rather limited and thus full development is not possible. Therefore some policies must be adopted to develop the high class lands of another zone where the groundwater supply is sufficient for the resettlement of families. According to the investigations made this would be the most economical measure and would provide for a better livelihood for these people.

(4) Our agricultural economics analysis shows that, with the high cost of water and other agricultural items, farmers cannot easily pay development costs, such as drilling, motor and pumps, land leveling, construction of ditches, etc. Therefore a policy needs to be adopted concerning recovery of the capital invested for development. A policy is also required as to whether charges to the farmers for water and agricultural services should be uniform for the whole region or vary with the actual cost in each zone.

(5) Since intensified pumping will result in drying up of many ghanats, how should the government compensate for the value of ghanats? The policy adopted by the government in this respect should be known before going ahead with development activities.

(6) Planning and construction is needed for sanitary domestic water supplied at present from ghanats.

(7) Investigation of the neighboring rivers is needed at the earliest date possible, to determine the possibility of utilizing these resources for further development of the region.

(8) Since water is the limiting factor in development of the area, a specific quantity of water must be allotted to each farm family. With the allocated amount of water the size of agricultural units is very small, but a cropping pattern is selected to provide for the anticipated income. Small sizes of holdings and scarcity of water have forced the planners to suggest collective agriculture in the region. Each thirty or more hectares of orchard are owned by all the farming families in one village and the like. This system introduces serious problems of management. To solve the problems, especially at this stage of the development, since farmers are illiterate and lack the feeling of cooperation, some regional extension offices are proposed. These offices would have charge of managing the farms, operating and maintaining machinery, and training the farmers for collective farming.

Table 1

Extent of Newly Cultivated Land at End of Stage "B"

CROP	Newly cultivated land (without over-pumping) (hectares)	Newly cultivated land (with over-pumping) (hectares)
Orchards	8,400	8,400
Vegetables	6,100	6,100
Sugar beet	4,100	9,000
Wheat	4,100	9,000
Pulses	4,100	9,000
Fallow	4,100	9,000
Total	30,900 hectares	50,500 hectares

Table 4

Anticipated Annual Income from Areas Developed under Stage "A"

Mode of estimating	Total income in Ghazvin area in million Rials: Farms with orchards	Farms without orchards	Total	Estimated income per family: Farms with orchards Rials	Farms without orchards Rials	Average income in Rials	in dollars
Conservative estimate	138	137	275	12,300	12,300	12,300	165
Optimistic estimate	182	204	386	16,200	18,400	17,300	230
Conservative estimate after development	350	156	507	31,300	14,100	22,800	315
Optimistic estimate after development	586	251	837	52,300	22,600	37,500	500

Table 5

Net Income from Developed Land, Stage "B"
(According to Farm Types)

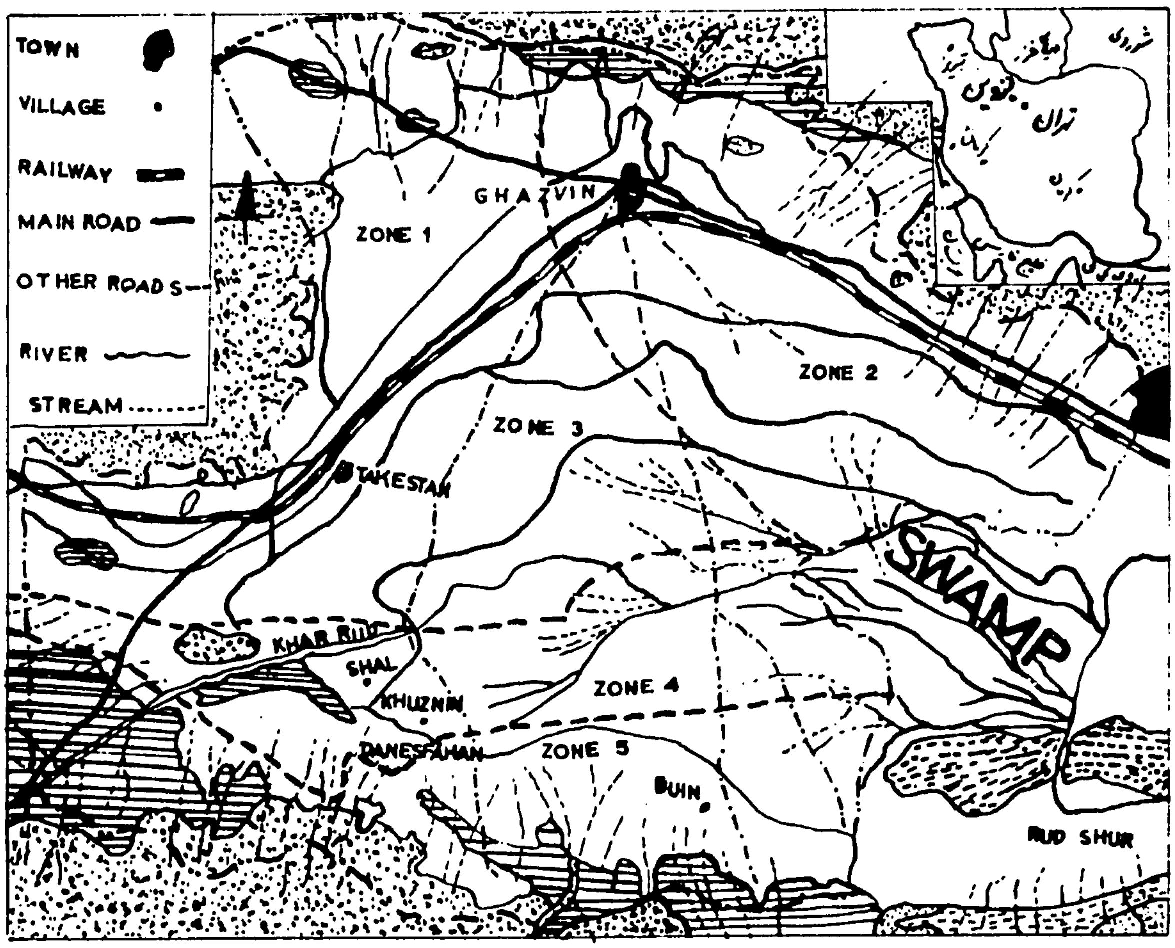
Item	Overall Ghazvin area income: Farms with orchards in Rials	Farms without orchards in Rials	Total: In Rials millions	Total: In dollars 1000	Income per farmer family: Farms with orchards in Rials	Farms with orchards	Average: in Rials	Average: in dollars
(a) Income from development not involving over-pumping								
Net income in 1975	392*	87	479	6,385	22,000	9,400	21,500	290
	((615))	(129)	(743)	(9,904)	(34,600)	(28,500)	(33,300)	(440)
Net income when fully productive	592	87	679	9,051	33,300	19,400	30,500	400
	(975))	(129)	(1,103)	(14,703)	(54,800)	(28,500)	(49,500)	(660)
(b) Income from development involving over-pumping								
Net income in 1975	514	118	632	8,426	22,300	26,300	28,400	380
	(830))	(183)	(1,012)	(13,460)	(46,700)	(40,600)	(45,400)	(600)
Net income when fully productive	714	118	823	10,970	40,200	26,300	37,400	500
	(1,190)	(183)	(1,372)	(18,289)	(66,900)	(40,600)	(61,600)	(820)

* Note: Unbracketed figures represent conservative estimates; bracketed figures represent optimistic estimates.

Table 6

Total Income per Farmer Family, Stage "B"

Description	Without Recourse to Over-pumping		With Recourse to Over-pumping	
	Rials	Dollars	Rials	Dollars
Net income in 1975 from newly developed lands.......	21,500 (33,300)		28,400 (45,400)	
Net income in 1975 from sheep farming......................	6,500		6,500	
Total net income in 1975..............	28,000 (39,800)	370 (530)	34,900 (51,900)	465 (690)
Total net income when orchards become fully fruit-bearing (subsequent to 1975)............	37,000 (56,000)	490 (750)	43,900 (68,100)	585 (910)



WATER DEVELOPMENT PROJECTS IN THE SOUTHERN DESERT OF JORDAN

by

Dr. S. A. Shammoot, William Barber, T. Qalyoubi*

Introduction

About 87 percent of the total area of the Hashemite Kingdom of Jordan is classified as desert, inhabited by less than three percent of the total population of the country.† The number of nomads in Jordan living in the desert has been decreasing in recent years, due to:

(1) Peace and security that were established in the desert stimulated some farming on small scale where good soil and water were available.

(2) A fair percentage of the Jordanian Army are nomads who upon leaving the army settle in a village or city and start a new life.

(3) The development of a wide network of highways helped link all parts of the country. Thus it became easy for the nomads to move to urban areas to work and settle there in drought years.

The Ministry of Agriculture has established several pilot farms in some areas inhabited by nomads for the purpose of demonstration, training and to serve as centers for the distribution of improved seeds, livestock and fruit seedlings.

In 1961 the Government of Jordan established a bedouin settlement program around water resources developed or improved by the Central Water Authority.

The Jafer Project

This project is located in the southern desert of Jordan, 225 kilometers southeast of Amman. The area is about 400 square kilometers with a gentle slope toward its center where the project is located. The project site is about 866 meters

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† The 1961 census of population.

above sea level. Annual rainfall is about fifty millimeters. Vegetation cover is sparse and of the stony desert type that supports few flocks of sheep and camels.

In 1962 the Central Water Authority drilled a deep well to supply drinking water for the inhabitants and their livestock. The results of drilling were promising and further hydro-geological investigations were proposed.

A pilot farm of forty donums was established near well No. 1. Programs of field experiments on soil drainage and reclamation, date of planting and crop suitability for the local conditions have been conducted since 1963. The Ministry of Agriculture and the FAO signed an agreement in 1964 to support a pilot project for the purpose of improvement of animal husbandry in the southern part of Jordan. The agreement also included extending aid for the objectives of the project which are summarized in the following:

(1.a) To create emergency feed reserves for 90,000 sheep in the southern part of the country.

(b) To supply supplemental feeding for pregnant and milking ewes during dry periods of the year.

(c) To conduct demonstrations on lamb fattening.

(2) Protection and improvement of natural ranges.

(3) Land reclamation.

(4) Settlement of nomads in the reclaimed areas. Employment of the nomads willing to settle is the policy of the Ministry of Agriculture in order to train them for future management of their farms and animals.

Soil studies conducted by the German Geological Mission in Jordan indicated: (1) About 54,000 donums are suitable to produce crops not susceptible to low temperatures during the winter season. (2) Climatic conditions and the accumulation of groundwater in the Jafer depression led to the formation of saline and alkaline soils. Due to the high Ca and Mg content of the groundwater, salts of these cations accumulated in the soils. In most of the investigated soils sodium salts do not exceed the amount of soluble salts of Ca and Mg. (3) Most of the soils of the area are derived from alluvial deposits. They vary in texture from sand to heavy clay. Among the 54,000 donums recommended for irrigation, about 28,000 donums of nonsaline alkali soils can be reclaimed by irrigation, leaching and gypsum amendment. About 12,000 donums are slightly saline soils. After improving drainage and leaching conditions, about 14,000 donums may be classified as class I soils.

Leaching studies showed that about 800 cubic meters per donum were sufficient to leach the salts to a depth of 150 centimeters. Soil amendments like gypsum and sulphate of iron should be applied to improve the soils and help leaching of salts.

Further plans involve the release of land for nomads who are willing to settle and start a new life. Purchase of land by settlers will be permitted after five years of training in farming. The government will provide the irrigation water, loans, and extension services. The farm size is proposed to be fifty donums. A total of 400 J.D. net income is expected for each settled family from both farming and livestock production.

Agricultural studies such as date of planting, plant varieties suitable for the area, leveling, leaching and water duty were promising.

Geological and hydro-geological studies of Al-Jafer area. There are about eighteen shallow hand-dug wells in the Jafer community. Some of them are productive and some are filled with debris. The average total depth of these wells is about 15 meters and the static water level ranges from eleven to thirteen meters from the ground surface.

Al-Jafer area is a topographic depression with drainage leading in to it from all directions, especially from the west, northwest and north, where rainfall is higher.

It is mostly covered by alluvium derived from the chalks, limestones and cherts of the belqa group.* A very large playa, over 100 square kilometers, occurs in the center of the area. Desert type of eroding agents such as water and wind have attached the primary deposits of the belqa series, washing out the softer marls and leaving behind the hard and resistant cherts and limestone fragments as secondary deposits. This gives rise to a "desert pavement."

The alluvial deposits over this large area of Jafer show a generally well sorted structure as they grade from a degrading stream near the Jafer playa. They are coarser grained along the playa fringes, while the finest clayey silty sediments occur in the center of the playa east of the Jafer police station.

The general structure of the Jafer area is an elongated basin-like structure, where the axis of elongation trends almost east-west. Just to the west of this major basin, a smaller north-south depression occurs, which apparently is associated with the anti-clinal arch west of it.

The Jafer Basin terminates in the northeast and east by a series of northwesterly trending folds, and to the south by a large escarpment overlooking the southern desert of Jordan. In the west several smaller superimposed folds and faults occur, whose occurrences and complexity increase as the wadi Araba Rift valley is approached.

From the study of the lithology of the sixteen boreholes drilled in the area, three formations have been recognized:

Unit I: This is predominently composed of thinly interbedded dark brown chert. This unit is of an unknown thickness, as the top of it has been eroded.

Unit II: This unit lies below Unit I. It is mostly an impervious soft marl formation. A thick limestone ledge of about ten meters thickness separates Unit I and Unit II. This unit is of variable thickness ranging from twenty to eighty-five meters.

Unit III: This is the lowermost formation encountered by test drilling, but has not been penetrated because of its thickness. It is composed of thinly laminated, very fine grained, dark grey-to-black bituminous marl and shaley marl interbedded blue-black bituminous marl.

Hydro-geology: Jafer has a radial type surface drainage leading into it from all directions. Occasional intense floods occur in these wadis, especially from west and northwest of Jafer. The area has a very low annual rainfall. At the Jafer police post it averages thirty-five millimeters per year.

It is probable that most of the recharge comes from the west and northwest, where the rainfall is slightly higher, as indicated by the hydraulic gradient of the groundwater from the northwest to the southeast.

The productive area at Jafer is limited to the area beginning from the Jafer police station and well No. 7 and extending ten kilometers to north and northwest of the Jafer police station. This area has very good permeability and coincides with the westerly basin occurring here. Groundwater in the easterly basin is saline.

The shallow aquifer in Jafer derives its groundwater from two sources: (1) direct rainfall and (2) runoff from areas outside of the geological catchment zone. The aquifer crops put in a ring around the playa, but much of this catchment area does not contribute to the Jafer well field. All the area to the east and south of the playa add no recharge. Omitting this area, a total of 770 square kilometers of geological catchment area contributes to the aquifer. The average annual rainfall over the area is thirty-five millimeters. It is doubtful whether more than one percent of this rainfall contributes to recharge. Assuming this, a total of 270,000 cubic meters of recharge takes place from direct rainfall. How-

* Balqa group: group rock consisting of marl, phosphate rock, chalky limestone and chert.

ever, the surface area draining into the playa which would pass over the geological catchment area is about 5000 square kilometers. Rainfall ranges from thirty-five millimeters in about half of this area to 350 millimeters in the northwest corner.

An estimated annual recharge of about 3,750,000 cubic meters occurs in the shallow aquifer.

Gaa El-Desi Project

With the cooperation of the UNFAO the wadi Utum area was studied for hydrological, hydrogeological and geological purposes by the Sandstone Project and the Central Water Authority. The soils of the area are still under investigation. Available information on the soils indicated that enough land to use the water produced from the drilled wells is available and suitable for irrigation farming. A pilot farm such as that of the Al-Jafer project is proposed in order to determine the soil and climate agricultural potentialities. Future plans are similar to those of the Al-Jafer project.

Groundwater potential. Assessment of the groundwater potential of the wadi Utum groundwater basin is within the terms of reference of the project to investigate the sandstone aquifers of East Jordan. It is thought that the area of the basin is about 3,500 square kilometers. The saturated thickness of the sandstone aquifer ranges up to about 900 meters. In some parts of the basin the static water level is less than 100 meters below ground surface, and high yielding wells can be constructed. Water of very high quality occurs in the basin, total salinities as low as 220 ppm having been recorded. Moreover, soils of quality suitable for irrigation are also present in the area. Preliminary investigations indicate that the basin is receiving some recharge and a water balance study has been designed. The plan of operations allows for only six wells to be drilled in the area, of which four have been completed or are currently being drilled. Taking into account the two wells drilled prior to the project, the density of control points is about one well for each 440 square kilometers. It is considered that the above density of test wells is inadequate for assessment of the groundwater potential of the basin. Arrangments are now being made to amend the plans of operations so that a full pre-investment drilling investigation can be conducted.

Geology. The German Geological Mission to Jordan has prepared a stratigraphical breakdown of the sedimentary rocks of the area, based on color, weathering characteristics and palaeontology. Unfortunately, these units are not easily recognizable in borehole cuttings. A broader subdivision based on lithology, which has groundwater significance, has been adopted by the project. The stratigraphical succession in the basin is shown in Table 1.

The paleozoic rocks are overlain unconformably by the mesozoic sediments. The paleozoic succession dips at a low angle to the east and is disturbed by several major tension faults which trend northwest to southeast. The most important of these runs from Mudawara through Qa Disi to Quweira. There faults do not have a great vertical displacement but have caused block tilting adjacent to the fracture zone. There are in addition a number of north-south trending faults, the largest of which runs through Quweira and has a vertical displacement of several hundred meters. The sediments show a well developed pattern of joints which trend approximately north to south and east to west. The joint frequency is greatest in the finer grained sediments in the upper part of the succession.

The mesozoic sediments are present only in the northern edge of the basin and dip northeastward at a low angle.

Hydrology. The basin has an annual rainfall of less than 100 millimeters. No perennial runoff occurs. The present drainage system has natured into two separate surface water basins, but it is thought that these constitute a single hydrogeological catchment. The Qa Disi surface water basin is closer, and all runoff drains toward the playa of Qa Disi. The upper wadi Utum basin has an outlet into wadi Utum, but surface runoff leaves the basin only under conditions of intensive rainfall.

Table 1

Stratigraphic Unit (Sandstone Aquifer Project)	Stratigraphic Unit (German Geol. Mission)	Lithology	Age	Thickness (in meters)	Aquifer characteristics
Upper Kurnub Sandstone	Multicolored standstone	Fine-grained sandstones, clayey sandstones and clays	L. Cretaceous	15	Poor
Lower Kurnub Sandstone	White sandstone	Medium to fine grained sandstone	L. Cretaceous	50	Fair
	Conularia sandstone	Fine-grained sandstone, mudstone and shales	M. USilurian	140	Poor
Khreim Formation	Sabellarefex sandstone	Fine-grained sandstone, mudstone and shales	L. Silurian	110	Poor
	Graptolite sandstone	Fine-grained sandstone, mudstone and shales	U. Ordivician	90	Poor
	Bedded brown sandstone	Fine to coarse grained sandstone	M. Ordivician	250	Good
Dis Formation	Massive white sandstone	Medium to coarse grained sandstone	L. Ordivician	130-350	Good
	Massive brown sandstone	Medium to coarse grained sandstone	L. Cambrian	190-350	Good
Um Salab Formation	Bedded arkosic sandstone	Arkosic sandstone	L. Cambrian	50-60	Poor
Basement Complex		Granite and diabese	Precambrian	——	Poor

It has been recorded that the water which reaches the playas following floods disappears more rapidly than would appear possible by open surface evaporation. It is considered that water drains into the ground through the sandy silts of the playas and through the large fracture lines which cross some of the larger playas. This assumption is partially confirmed by the fact that the playas are not saline, which indicates that natural leaching occurs.

To assess the volume of indirect recharge to the groundwater basin, a surface water study program has been drawn up. This is an integral part of a water balance study. A hydrological network has been established to measure precipitation flood runoff and evaporation on a daily basis. If possible, a rainfall runoff relationship will be established and this will be related to past records to obtain a long-term assessment of the recharge.

Hydro-geology. Present knowledge of groundwater conditions in the area is limited to the data collected from eight wells. The location of the wells is shown on the accompanying map and the pertinent data is summarized in Table 2.

The limits of the groundwater basin have not been defined, but it is thought that they coincide fairly closely with the combined limits of the upper wadi Utum and Qa Disi surface water basins, an area of about 3,500 square kilometers. Well data indicate that there is a gradient from Qa khreim (S4) to Quweira 1, a distance of approximately fifty kilometers, with a mean rate of fall of two and a half meters per kilometer. There is also a southerly gradient of about three meters per kilometer over a distance of five kilometers from Quweira 2 (S5) to Quweira 1. The water level elevation at Mudawara, approximately thirty-six kilometers east-southeast of Qakhreim, is 720 meters, twenty meters lower than at S4. This indicates that there is groundwater divided between Qa khreim and Mudawara which is thought to separate the wadi Utum and Tabuk groundwater basins. It is believed that the divide between the wadi Utum groundwater basin and the East Jordan artesian basin will coincide fairly closely with the escarpment which runs east-west through Ras Al-Nagb.

Table 2

Location	Sandstone Project Number	Total depth (in meters)	Saturated thickness aquifer-cut (in meters)	S.W.L. (in meters)	Water Table elevation (in meters)	Tested yield (m^3/h)	Specific capacity ($m^3/h/m$)	Salinity (ppm)	Remarks
Quweira 1	—	227	74	153	620	17	3.8	756	C.W.A. desert well
Quweira 2	S5	350	193	157	635	—	—	568	To be deepened to basement
Ram	—	130	48	82	716	12	.8	265	C.W.A. desert well
Qa Disi	S2	350	267	73	729	100	10	220	To be deepened to basement
Sahl Essawan	S3	163	51	85	740	83	5.8	256	To be deepened
Qakhreim	S4	198	30	96	744	53	1.2	218	To be deepened
Mudawara	—	106	—	6.4	720	24	.6	675	Railway Company Well

In the southwest of the basin the crystalline rocks are at the surface and it is considered that these will form a fairly effective barrier against groundwater movement. It seems probable that nearly all the water which leaves the basin as sub-surface flows down via wadi Utum. It is known that there is a considerable sub-surface flow down the wadi Utum throughout the dry season and this must be maintained by groundwater drainage from the wadi Utum groundwater basin.

The effective grain size of the sandstones is small and the effective porosity is probably low. But this would appear to be compensated for by the great thickness of saturated section. It seems probable that a large portion of the permeability is provided by the jointing system. Adjacent to faults, fractures resulting from the disturbance provide very high secondary permeability. However, the estimates of transmissibility calculated from wells sited on faults cannot be applied without caution to a regional study of groundwater movement in the basin.

Additional boreholes are required to determine the configuration of the water table in the basin, the transmissibility and storage capacity of the sandstone aquifer, the quality of the groundwater, and to estimate the rate of groundwater movement into the wadi Utum gorge.

Surface Water Projects

"Water spreading," as the term is used here, means the utilization of a controlled volume of runoff for irrigation. This type of water spreading involves the diversion and control of rapid moving flood waters and distributing these waters at a non-erosive velocity over a specified area. This must be accomplished without the aid of an operator, unless the system is designed to provide for partial manual operation. There are many variations in the detailed plans of specific irrigation systems, but the general plan applicable to all installations consists essentially of a structure to divert a portion of the flood water from a natural drainage channel to an area where the water is spread uniformly and slowly to provide additional soil moisture.

As lands ordinarily irrigated with flood waters have low value and as the frequency of flooding is quite variable, it is obvious that the initial construction cost should be kept in balance with the benefits that might reasonably be expected over a period of years. The structures required for proper operation should be simply designed and of sturdy construction, making maximum use of materials available on the site. Many systems will be built at relatively remote locations; consequently, the operator will not have the opportunity to make frequent inspections or always be on hand at the time flood water may be available.

Water supply. The quantity of flow that may be expected to run off a small drainage area during the average year is dependent on such a great variety of inter-related factors that it is difficult to prepare any table or formula that would have universal application. Generally a greater degree of conservatism should be used in estimating the annual runoff for water spreading than is used in the construction of an ordinary dam or stock water supplies.

Climate, soil type, topography, vegetation and land use all have an important bearing on the volume of runoff. A careful analysis of all these factors coupled with good judgment and a proper understanding of the peculiarities of the area is necessary to make reliable estimates. A conservative guide for determining the balance that should be established between the drainage area and the area irrigated may be stated as follows:

(1) In rainfall belts ranging from thirty to thirty-five centimeters, provide 2700 donums of drainage area for every forty donums proposed for irrigation.

(2) In rainfall belts ranging from forty to fifty centimeters, provide 2500 donums of drainage area for every sixty donums proposed for irrigation.

Duration of flow. The quantity and duration of flow from an area must be determined in order that the land will be properly irrigated during each period of substantial flow. It is generally considered that at least fifteen centimeters depth of water is required to successfully provide one irrigation. The duration of flow is dependent largely on the slope of the main drainage channel, the shape of the drainage area, soil type, vegetation, topography and all other factors that affect flood flow. The floods in large rivers usually rise slowly, endure for a considerable period and slowly recede, while in small streams and dry runs the rise is rapid, the duration short and the recession rapid. When no surface or sub-surface storage exists on a drainage area, and when there is adequate channel capacity so there is no overflow and consequently no valley storage at flood stage, the time of concentration, when considering small be assumed to be approximately equal. Thus, the duration of flow is approximately equal to twice the time of concentration, when considering small areas. Observations that have been made on existing installations indicate that the duration of flow for drainage areas having relatively undulating topography and a main channel of low gradient is roughly equivalent to one hour for every 1600 meters of main channel. This figure might generally be used in instances where more detailed data are lacking. The duration of flow can best be determined by actual observation of a definite drainage or by a comparison with similar areas where flow conditions are known.

Diversion of flood water. There are several methods of diverting water from natural drainage channels into the supply canal of a water-spreading system. The type of construction used is largely dependent on the topography at the point of diversion.

The most satisfactory method is to excavate the supply canal to a point where the water can be diverted at base grade. No structures are required in the channel, the flood capacity of the stream channel is not affected in any way, and as a consequence, maintenance is kept at a minimum. While in some instances diversion of water at base grade involves considerable excavation, this type of construction has so many inherent advantages that it should be adapted in every possible situation. It is advisable to start the ditch at an elevation of about thirty centimeters below that of the natural channel to divert the maximum of water at low flows. It may be practical at some locations where the channel is relatively wide to construct a low wing dam of rock or concrete to divert the flow into the supply ditch. Such dams should never be over thirty to forty centimeters high and should have the ability to withstand continuous overtopping.

At certain locations it is necessary to construct a dam across the channel to raise the water to the elevation of the supply canal. All the general principles of dam construction should be observed, including provisions for by-passing the flood water. Earth dams can be built where the topography is such that a good natural or excavated spillway can be provided. The principles involved in earth dam construction must be observed, and when earth dam construction is used it may be possible to place the inlet to the supply canal at an elevation below the crest of the spillway and thus provide for storage that may be utilized at periods other than when runoff occurs.

Control structures. The flow in the supply ditch must be controlled within reasonable limits to prevent damage to the system during periods of flood. The control structures should be located near the upper end of the ditch at a point where it will not be endangered by excessive bank erosion occurring in the main channel. An inspection of the section of the stream will reveal the degree of erosion that may be expected to occur over a period of years. It may be advisable to do some protective work to stabilize the stream channel a short distance upstream and downstream from the diversion. Proper location of the diversion will minimize the hazards of bank erosion.

The structure should be installed as close to the point of diversion as possible to avoid silting upstream due to the difference in velocity of flow. The structure should be substantially built and provided with gates to control the flow. There are periods when the gates must be kept closed to remove the possibility of flooding harvested crops. The structure should be built high enough to prevent overtopping during peak flood flows and should have adequate cutoffs, as it may be subject to considerable pressure under conditions of full head when the gates are closed. Ordinarily when a direct diversion is made to base grade, the gate structure is made large enough so that there will be only a small loss of head through the structure; consequently, there is little increase in velocity through the gate and little or no provision need be made to control erosion in the channel immediately below the structure. Where velocity through the gate structure is high, riprap should be placed for a short distance downstream from the structure to prevent erosion of the ditch channel and banks.

Sliding gates should be designed to permit movement during full head conditions by the power available. It is good economy to divide the opening into a number of small sections so that the gate can be easily operated by one or two men when mechanical hoists are not used.

Irrigation requirements. Water-spreading systems are particularly adapted to alfalfa or hay land because of the resistance these crops offer to erosion. Unless the topography is ideal, irrigation of cultivated crops by flood water is not satisfactory. Care must be taken that water does not stand on the area long enough to kill the crop. It is often necessary to make provisions for draining or releasing the surplus water after a few days. All the discussion here is confined to irrigation of lands in semi or erosion-resistant crops.

The soil of an area should always be studied to determine whether or not it has the fertility needed to grow the desired crops. The alkali content of soil and of the area from which the drainage comes should be analyzed. to determine whether or not leaching of undesirable salts will occur to a harmful degree.

Water spreading by means of dikes is not generally adaptable to lands having a greater average slope than one to one and a half percent. Lands on slopes greater than this require too close spacing of contour dikes, and further, produce velocities that cause erosion unless the area irrigated has a good sod-forming grass cover.

Modified syrup pan method. The plan of permitting the total flow to pass over all the area under irrigation has been universally used because it has the advantage of simplicity. Two variations of the diking layout are shown in Figure 1. The supply canal is run along the upper side of the area at right angles to the direction of slope, the water discharging through several small openings or around the end, depending on the method used. The plan shown in layout No. 1 is only adapted to low flows. When large quantities of water are discharged in such a system, the dikes are apt to overtop, thus entailing high maintenance charge. This system can be used successfully if the distance between trail dikes is kept within approximately 100 meters. For the average field, such a requirement would involve too much movement of earth to be practical.

Where the volume of water to be handled exceeds 600 to 800 cubic meters per hour, layout No. 2 functions much more satisfactorily. The only difference between this system and that previously discussed is that the water is discharged through several properly spaced openings. There is practically no limit to the width of area that can be covered, provided the openings are properly spaced. Only two trail dikes are required to confine the water on each side of the field. The maximum depth of water governed by the dike spacing and height should not exceed fifteen centimeters under average conditions. The free board should not be less than fifteen centimeters. The total dike height should not generally exceed forty-five centimeters.

Spreader dikes. Spreading systems, consisting of dikes and turnouts, are of two general types:

(a) Fully diked ponding systems

(b) Wild flooding systems

The ponding type is particularly applicable to gentle slopes, not over two percent and preferably under one percent on soils of low infiltration capacity. It consists of a series of dikes so constructed that the water moves slowly from one dike to the next, covering the area between with a sheet of water.

The wild flooding type of spreading consists of releasing water at numerous points through the main or upper dikes or directly from the conveyance dike and allowing it to flow directly down the slope, with secondary dikes necessary to keep the flow evenly spread over the area.

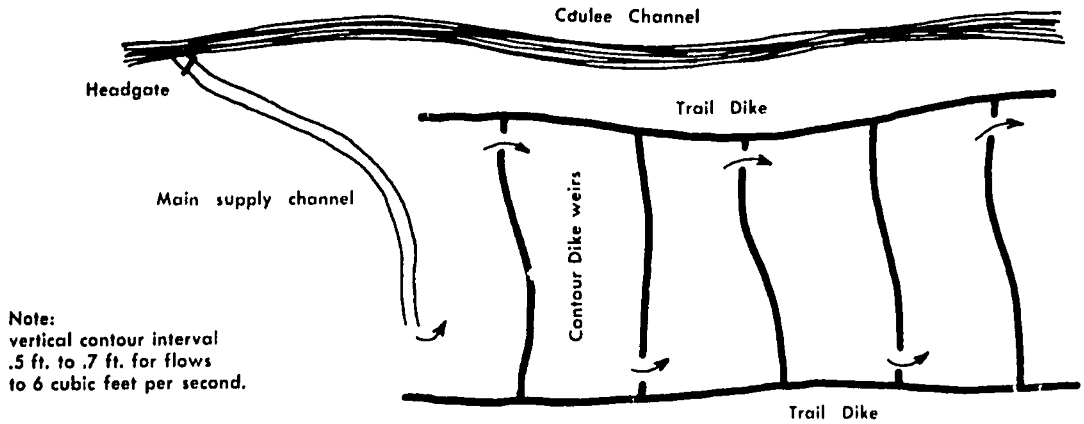
Sometimes a complete diversion is feasible with a fluctuating water supply, but experience has shown that unless adequate hydraulic data are available it is necessary to limit the flow at the diversion point in event of excessive flood flows.

Conveyance dikes or ditches transport the water from the diversion point on a natural water course to the spreading areas. This may be some distance, in which case the dikes are actually ditches or canals. They may be built with earth taken from above or below the dike alignment, but they rarely have a bank on the upper side. If the ground on which they are constructed has a little slope, a strip of twenty to 150 meters will be covered with water and irrigated when the system is in operation.

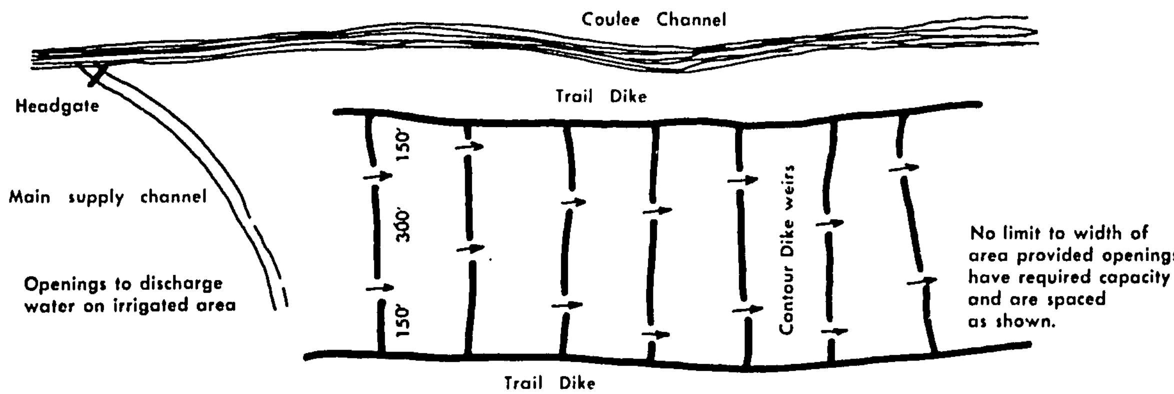
Conveyance dike channels may have no grade or they may have grades producing velocities as high as the material through which they are built will permit without serious erosion. When the floor of the channel or land above the dike is level, the water surface falls as it moves along the dike. In this case the top of the dike should have a gradual slope in the direction of flow. Dikes with level channels are seldom over 1000 meters in length and even this may not be economical construction. A dike two meters high and two meters wide at the top, with an upstream slope of three to one and a lower slope of one and one-half to one, contains three times as much earth as one with the same top width and side slopes but only one meter high and one meter wide. Therefore, conveyance dikes should normally be built with a channel grade sufficient to provide the desired velocity of water, usually from fifty to eighty liters per second, and the dike will be of uniform height, with forty-five to sixty centimeters freeboard.

When water is directed through several open-

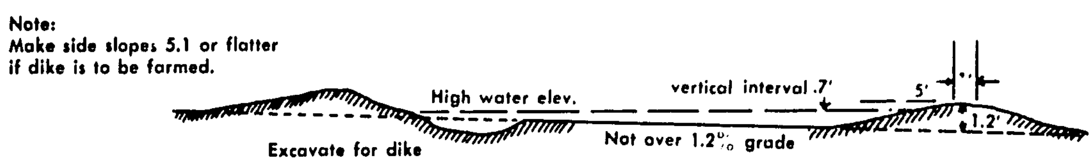
FIGURE 1



Layout No. 1 Adaptable to Slopes up to 1.2%



Layout No. 2 Adaptable to Slopes up to 1.2%



Section Through Dikes

TYPICAL WATER SPREADING LAYOUT
SYRUP PAN SYSTEM
Feb. 1966 M.D.

ings in a section of the dike, a level channel and level top may be justified in order to have an equalizing basin which will discharge equal volumes of water through all openings. When dikes convey water with considerable suspended sediment, high velocities are necessary to avoid deposition in the channel and to carry the sediment out on the land.

Ponding Systems

Level dike channels are necessary in the ponding system of spreading in order to obtain sufficient surface grade to back the water over the area between the dikes. The backup will not be uniform along the entire length of the dike, due to the surface fall of the water. But this is taken care of by building the dikes from the downstream side, leaving broad, shallow borrowpits. Part of the water, as it passes from the area above one dike to the area below, flows into the borrowpit, which serves the same as a bor r irrigation ditch. The lower edge of the borrowpit is level and water flows out of it slowly in a thin sheet onto the area below. Thus the entire area between dikes receives some moisture.

Erosion is most likely to occur at the spillway. The fall through the spillway creates high velocities, which are likely to erode the curved end portions of the dikes and also the floor of the spillway. This part of the layout is one of the most difficult to design.

To overcome this difficulty, the following points should be borne in mind:

(1) Make spillways wide. Water is much less erosive in a broad, shallow sheet.

(2) Study the contour map and make the distance between dikes as long as possible. Keep gradients low.

(3) If there is any choice, make turns where the vegetation is best. There will be less chance of erosion.

(4) Do not make the turning radius too small.

(5) Make the curved portions of the dike particularly strong.

(6) To stabilize curved banks, vegetation should be established on them as soon as possible. Rip-rapping with rock is also very effective.

Operation, Improvement, and Maintenance of the System

It is difficult to design a water-spreading system free of flaws when first constructed. The flow of water is seldom the same in any two storms. Nevertheless, the system must handle these variable flows by one automatic plan. Incomplete and inaccurate basic data are frequently a further handicap.

Usually the first flow of water through the system will reveal the flaws in design. If the designer can be on hand to watch the water flow through the system he will be able to recognize the defects of this plan much more quickly than if he has to study the effects of the flow after it has passed. Followinr are some of the defects that may appear afte the system receives a flow of water:

(1) Too great a concentration of water hitting certain sections of a dike with too high velocity. This may cause the water to overtop the dike or to break through. The solution of this problem may require reduction of the inflow at the head of the system. It may require the relocation or widening of a spillway from the dike above. The difficulty might be solved by a diversion dike or ditch above to increase the spread of the water. Possibly the dike may have to be raised in height or reinforced.

(2) Dry areas not receiving water. Often a short ditch leading water to the dry spot will solve the problem, or a dike may be required to divert water to the dry area. A pipe may have to be put through a dike to let water come through to the dry spot. Sometimes partial dike or spillway relocation is necessary. The designer should not expect to irrigate all of the spreader area in each run. If sixty-five to eighty-five percent of the area can be given a good wetting in the average water run, a successful design has been attained.

(3) Too much or too little water coming through the openings in flood spreaders. This fault can be corrected by reducing or increasing the size of the opening.

(4) Too rapid a concentration of flowing water in the system. This flow may require more small plugs in natural drainage ways, in old road ruts and trails, in low spots, in the borrowpits, etc., to turn out the water frequently and keep it in a sheet.

Maintenance of water-spreading systems should be given prompt and careful attention to avoid much heavier costs later. Some of the more common maintenance problems are as follows:

(1) Gullying at the spillways. Slight gullying at the spillway is frequent and nothing to cause grave concern. If the gullies spread or entrench quickly it may be necessary to make the spillway wider by tearing down some of the dike at the spillway end in order to give water more spread space. More openings or pipes may have to be put through the dike in order to cut down the amount of water going to the spillway.

(2) In straight channels paralleling dikes, obstructions such as rocks, drift, shrubs, or earth projections, may deflect the current against the loose dike fill, causing the dike to wash or cave. Remove such obstructions to permit free flow.

(3) Gullying in the return or excess water channel. It is well to note the tail or excess water area, particularly after a big flow. If head cuts are developing, direct the water to a more favorable location if possible. At least keep it in a thin sheet where it moves over areas likely to erode. It is sometimes impossible to avoid some erosion for a few years while an artificially sloped and vegetated area develops an adequate cover which will take the flow without eroding. Maintenance of the excess channel may require protection from grazing by fencing.

DEVELOPMENT OF SMALL IRRIGATION PROJECTS AND CAVAK IRRIGATION PROJECT IN TURKEY

by

Yalcin Saidoglu*

Introduction

Maximum crop production can be achieved only by irrigation because Turkey has an arid and semi-arid climate. The large water resources are limited in number. Many small water resources will favorably affect the national economy if they are properly developed.

Description of Small Water Resources

It is generally difficult to classify the water resources into two groups, small and large. However, in Turkey, from the practical point of view, the water resources which have a discharge less than 500 liters per second are called "small water resources."

Aims of Small Water Resources Development Projects

(1) To develop small surface water resources such as tributaries in upper watersheds and small creeks of the coastal plains.

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(2) To develop groundwater resources.

(3) To irrigate lands adjacent to large surface water resources by diversion or pumping, until the large irrigation systems are completed.

(4) To provide livestock water or to irrigate the small land plots by accumulating the winter runoff behind a dam or in a pond in the upper watershed creeks which have insignificant base flow and are unsuitable for construction of large reservoirs.

Characteristics of Small Water Resources

(1) Technical and economical characteristics:

(a) Small water resource development projects do not require a long survey and planning period and detailed investigations.

(b) Their development is inexpensive and the benefits are realized in a short time.

(c) The cost-benefit ratio is high in small water resource development projects; thus repayment of costs is possible in a short time.

(d) They are not a great burden for the state, as their operation is easy and their maintenance is undertaken by farmers.

(e) Generally, they do not require expropriation and right-of-ways.

(2) Social characteristics:

(a) The development of small water resources helps the people living in upper watersheds to benefit from water resources which must serve the nation-wide population.

(b) It helps prevent the unemployment and the migration of people from villages to cities through developing farm irrigation, not only in areas which have large plains and big irrigation systems, but also in villages which have small land parcels. In fact, three-fourths of the villages are hilly and consist of small holdings in Turkey. These should be agriculturally and economically developed on a regional basis.

(c) Unlike a reservoir of large capacity, it does not require the transfer of villages and other inhabited places.

Small Water Resource Development Projects: Their Implementation, Operation, Financing, and Farmers' Participation

TOPRAKSU General Directorate is authorized by law to plan and design projects for supplying irrigation water to lands with a water requirement up to 500 liters per second.

On the other hand, DSI (State Hydraulic Works) is responsible for supplying irrigation water to lands with a water requirement over 500 liters per second.

The small irrigation projects are generally financed by the state. However, farmers share the costs through material and labor, and participate in the costs of expropriation and right-of-way. Thus, the amount of state investment decreases and farmers are becoming much more interested in the project implementation. After construction the system is operated by farmers.

Actual Example: Cavak Irrigation Project

Description of Project Area

Location. The project area is in southern Turkey, about eight kilometers north of Mersin city, in the Efrenk creek watershed. This watershed consists of approximately 50,000 hectares. The project activity is in sub-watershed No. 1.

Climate. Winter is moderate and rainy and summer is hot and dry, in the project area. The average annual rainfall is 615.3 millimeters. The average of maximum temperatures in the main six-month growing period is 40°C. The minimum temperature in the past ten years was —5.4°C. The growing season is 255 to 300 days.

Average monthly temperatures and rainfall are as follows:

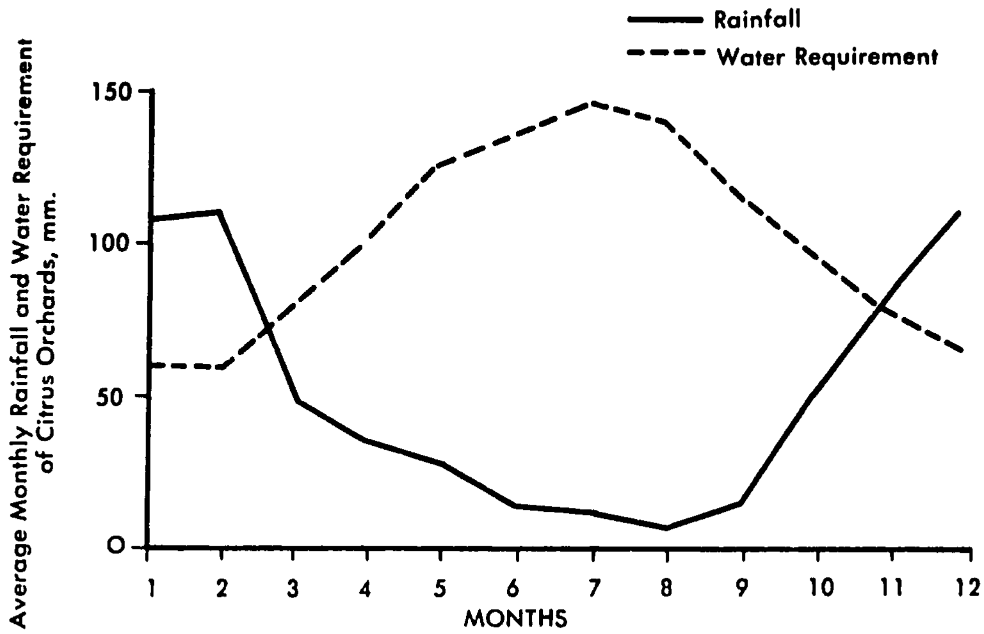
Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
Rainfall in mm	106.9	110.1	48.9	34.8	26.2	13.3	8.4	5.4	13.5	51.0	83.4	113.1	615.3
Average Temperature C°	9.1	10.0	12.6	17.1	21.4	25.0	27.6	27.9	25.1	20.0	15.9	11.3	

Topography. Generally, the topography of the project area is undulating, with slopes of five to thirty-five percent.

Soils. The soils within the project area can be classified into three groups:

(1) Red-brown soils of granular structure from calcerous rocks reaching one-half to one meter depth and with a slope of six to thirty percent.

(2) Yellowish brown, deep clay soils located on clay and sandstones. These soils have low permeability, a low infiltration rate, and are erodible and generally have a slope of four to forty percent. Soil conservation measures should be taken on such soils.



Graph No. 1

(3) Alluvial soils accumulated along the Efrenk creek. Their profiles are deep. They have medium permeability and slopes reaching one to four percent.

Water resources. The water source of the project area is Efrenk creek, which has a maximum water discharge of sixty cubic meters per second in December and a minimum discharge of 0.400 cubic meters per second in September.

Average annual rainfall and consumptive use of water for orchards are shown in graph No. 1:

Project Formulation

The objective of the small water resource development project is to supply irrigation water to Cavak Village lands on the right and left banks of Efrenk creek and to solve other agricultural production problems.

Water requirement for irrigation in the project area has been estimated according to the Blaney-Criddle method. The project has been designed to irrigate 5,500 decares of land by considering the discharge of Efrenk creek.

It is anticipated that citrus will be grown on the total project area. So, the net water requirement will reach a maximum of 146.6 millimeters in July, with a net rate of flow for the total area of 0.311 cubic meters per second.

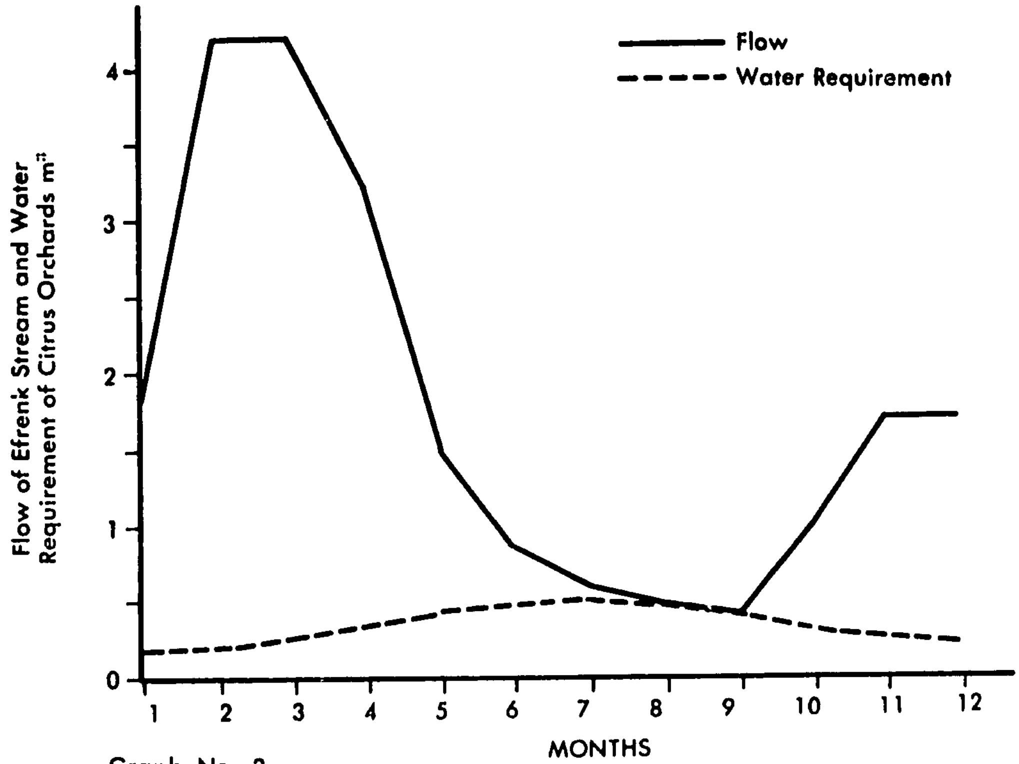
Overall efficiency for distribution and application of water was estimated to be sixty percent because the project area was small and canals would be lined. So the physical structures have been planned to provide 518 liters per second of water, which is the gross water requirement for the project area in July.

The monthly discharge of Efrenk creek and the gross monthly water requirement of citrus are shown in graph No. 2. It can be seen from this graph that the water requirement for the project area is less than the discharge of Efrenk creek.

The project was planned to irrigate by gravity:

(a) 2350 decares of citrus plantation formerly established in the project area and which has been irrigated by pumping.

(b) 3150 decares of land which has never been irrigated in the past.



Graph No. 2

It is essential to take conservation measures for soil erosion in the project area, and it is of primary importance to construct bench and canal terraces before the actual irrigation, considering the soil characteristics, slope of the land and runoff.

For irrigation of the terraced land, priority has been given to the completion of tertiary canals which have drops on each terrace line.

Cooperation was planned with the related authorities in solving the other problems of the project area.

Long-Term Plan

In the project area, soil conservation measures and construction of the physical structures have been planned so as to accomplish the necessary works in four years.

Project Facts

Physical structures and estimated project cost. A diversion dam of twenty meters width and 1.60 meters height was built to get water from Efrenk creek to the project area, on the right bank, a conveyance canal of 1120 meters length and a siphon of 120 meters length conveying the water to the left bank, have been constructed. On the left bank a main canal of 4500 meters length, a gallery of 380 meters length two reinforced concrete flumes of ten meters spans, twenty-four flood crossings of various sizes, and a farm pond of 35,000 cubic meters capacity have been constructed. On the right bank, a main canal of 6900 meters length, a tunnel of 389 meters length, a siphon of thirteen meters length, and eleven various sized culverts have been constructed. In addition, field irrigation canals of 8200 meters have been completed.

The soil conservation structures, bench terraces on 1673 decares, and canal terraces on 104 decares, have been completed.

Farmers have participated in the project financing by sharing material transportation and excavation cost related to the physical structures. Besides, some farmers have assisted in the realization of the project by taking soil conservation measures in their own lands.

The state and farmer investments related to the project are as follows:

(1) State investment:

a – For irrigation structures ....TL. 951.474
b – For soil conservation measures TL. 862.368

(2) Farmer investment:

a – For irrigation structures ....TL. 191.700
b – For soil conservation measures TL. 61.700
Total........................TL. 2067.242

Effect of the project on crop rotation. Since completion of the project, citrus has replaced grain and other field crops.

Economic analysis. Gravity irrigation is now being applied on 2350 decares of land which was formerly irrigated by pumping. Irrigation water has been provided for an additional 3150 decares of new land. The economic analysis has been based on the benefits from irrigation for only the 3150 decares of land which had never been irrigated before. Since there is no reliable data for the pumping irrigation expenses, the benefits secured from the application of the gravity irrigation on the lands formerly irrigated by pumping are not considered in the estimate of benefits.

The areas where the structures are completed and the investments made on the project area from 1962 to 1965 are as follows:

Year	Investment	Areas where structures are completed
1962	TL. 297,056	788 decares
1963	TL. 873,620	788 decares
1964	TL. 420,870	787 decares
1965	TL. 475,687	787 decares
Total	TL. 2,067,242	3,150 decares

Annual cost, which includes interest and amortization of the investment and operation and maintenance costs, is 590,197 TL. Annual benefit, based on the fact that citrus will yield after six years, is 2,233,755 TL.

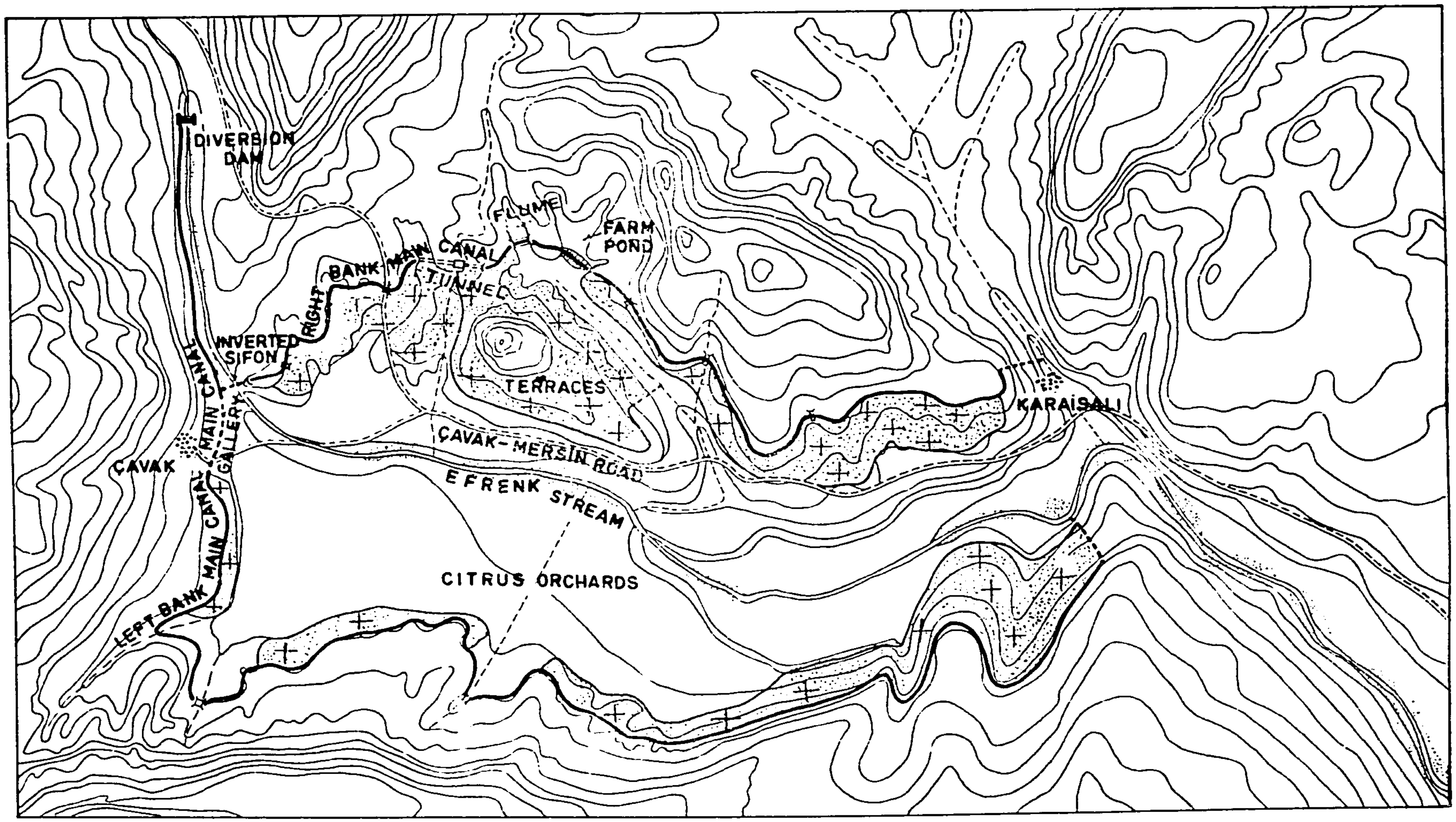
The cost-benefit ratio for the project has been estimated at 3.78.

Implementation

An attempt has been made to solve the problems of the project through cooperation by the related authorities, and the project has been affected by such collaboration.

Mersin TOPRAKSU Regional Directorate has executed the services related to water conveyance to the project area, water use and distribution, soil conservation measures and training of the farmers for modern irrigation techniques. Road and bridge construction in the village has been fulfilled by Mersin Public Works Directorate. Mersin Extension Service has provided improved citrus stocks and trained the farmers on plantation and plant protection techniques.

ÇAVAK IRRIGATION AND SOIL CONSERVATION MAP



SCALE 1 : 25.000

PUMPING OPERATION OF DRAINAGE WELLS IN THE UNITED ARAB REPUBLIC

by

Dr. Mahmoud A. Abu Zeid *

Introduction

In an increasing number of situations, it has been found that a properly designed and constructed drainage well system is an essential requirement for maintaining satisfactory production on agricultural lands. Design, location, and operation of these drainage wells should be based on sound engineering criteria.

In this paper the problem of pumping operations of these drainage wells has been investigated analytically, and system performance is related to control of the groundwater table. The effects of different patterns of cyclic operations of the pumps on lowering the water table and on the economics of drainage problems are also discussed.

A study of pumping operation problems requires the collection of some field data which include the fluctuations of the water table in the area under study and the influence of local irrigation on these fluctuations. The period during which the water table is higher than desired should be calculated. During this period continuous pumping or other patterns are required.

Continuous pumping, even with the use of water pumped for irrigation, is not necessarily the most economical approach. The reduction of the operating period may be a more economical procedure due to the minimum depreciation and use of equipment.

The period of pumping may be reduced considerably by using a cyclic pattern of operation (on-and-off-period), which would necessitate use of the non-steady state solutions. These solutions are valid because lowering the water table following an irrigation should be done in a sufficiently short time so that economic damage will not occur to crops. If the portion of each cycle during which the pump is operating is not very long, the decreasing discharge methods of solutions would appear to be the best to apply (1,2). Otherwise, if the periods of pumping are long and

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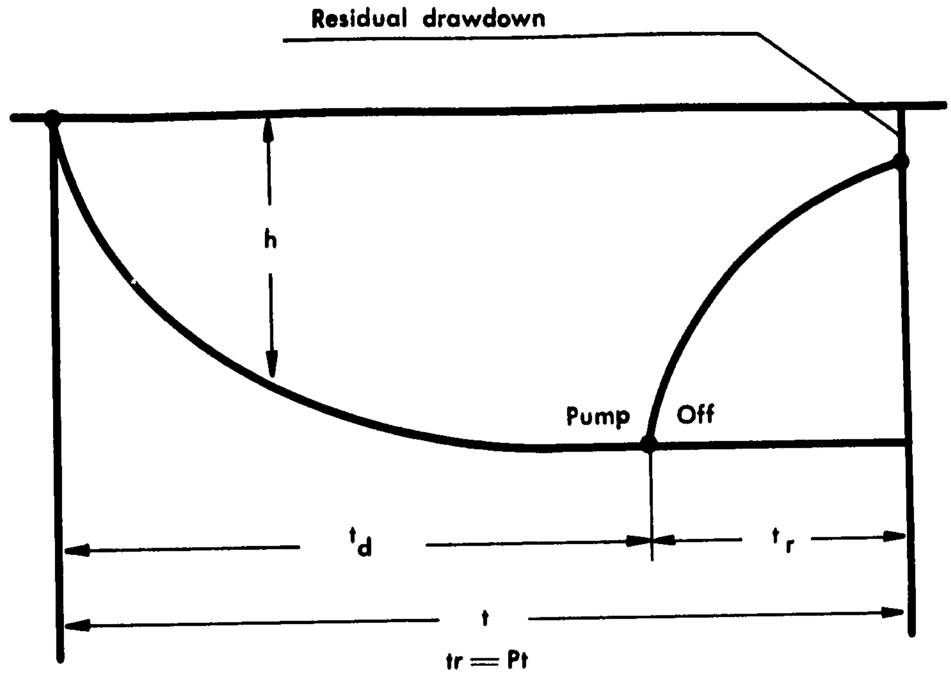


Figure 1. A Pumping Cycle.

the variation in the discharge is not large, the Theis recovery formula may be used.

"t_d" —"t_r" or "P_t" of "t".

Statement of the Problem

It is necessary to design an economical cyclic pattern of pumping to operate drainage wells. This pumping schedule should keep the water table below a certain level during the high water table season of the year.

In the following analysis, it will be assumed that "n" is the number of cycles needed to keep the water table always below a certain value; the portion of each cycle period, "t," during which the pump is operating, is denoted by "t_d," and when the pump is shut off equals to a portion "t_r" or "P_t" of "t" (Fig. 1).

The theoretical analysis that will be carried in this paper is only made for one well, due to the mathematical complications which arise upon using multiple wells in non-steady state solutions (3) to investigate the effect of cyclic operations.

Proposed Solutions for Cyclic Pumping Operations

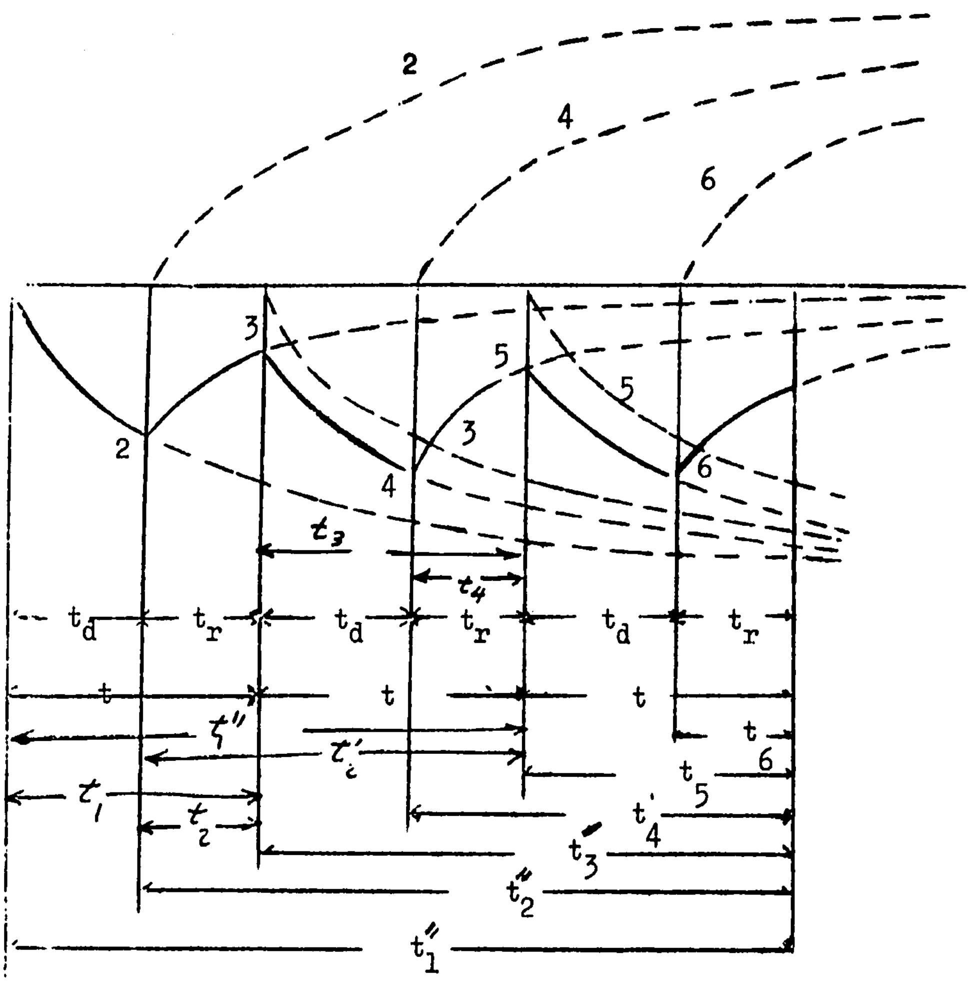
There is more than one factor involved in such a problem and it would be difficult to develop a general solution without assuming certain cyclic patterns. However, the effects of some of these factors are discussed below.

(1) *The portion* "t_r" *of each cycle* ($t_r = P_t$). This part, at which the pumps are shut off, always defines the residual drawdown at the end of each cycle. The residual drawdown may be defined as the difference between the observed water level in the well and the non-pumping water level extrapolated from the observed trend prior to the pumping level.

Keeping "t," and the pumping period, "t_d," constant for all the cycles, a continuous increase in the residual drawdown will result at the end of each cycle. Also, for a certain number of equal cycles the residual drawdown increases by decreasing "t_r" (Fig. 2).

(2) *Number of cycles.* If this number is

Figure 2



increased, for a certain pattern, the residual drawdown increases too.

(3) *Period length of each cycle.* This period does not affect the drawdown for a certain "P." The residual drawdown will be the same at the end of "n" cycles if "t" is equal to one day or one month. Upon the examination of the recovery formula (4), it can be concluded that the absolute value of time has no significant effect on the drawdown, the only important factor being the number of cycles independent of their length.

Therefore the factor "P" and the number of cycles required depend on:

(a) The residual drawdown that is reached after the first cycle, and how it compares with the required residual drawdown.

(b) The minimum drawdown that must be maintained until the end of the pumping season.

Hence the first step in any solution should be the choice of a certain "P" that gives at the end of the first cycle a residual drawdown close to the minimum required value. Then to keep the drawdown within a slight change at the end of the following cycles, either a minimum number of cycles is to be chosen or "P" is to be changed for each cycle. The change in "P" may be accomplished by keeping the pumping period the same for all cycles and increasing the length of the shutoff period. However, there is an advantage in using more cycles with smaller durations: this enables the use of an increasing "P," which may reduce the operating period. If the residual drawdown at the end of the first cycle is not enough to start with, a smaller "P" can be tried and followed by higher values.

The residual drawdown of any period after pumping stops can be calculated from the Theis recovery formula (4). Considering Fig. 2, which shows the drawdown and recovery curves for three cycles, the following residual drawdowns were calculated. The analyses were made on the assumption that the effect of stopping any pump on the water levels can be arrived at by adding a recharge well having the same characteristics. Therefore the residual drawdown, according to Theis formula, at the end of the first cycle equals:

$$(R\ D)_1 = C \ln \frac{t_1}{t_2}$$

where "C" is a constant, "t_1" and "t_2" are as defined in Fig. 2. Also

$$(R\ D)_2 = C \ln \frac{t'_1\, t_3}{t'_2\, t_4}$$

$$(R\ D)_3 = C \ln \frac{t''_1\, t'_3\, t_5}{t''_2\, t'_4\, t_6}$$

To obtain the same drawdown at the end of all cycles, the following condition should be satisfied:

$$\frac{t_1}{t_2} = \frac{t'_1\, t_3}{t'_2\, t_4} = \frac{t''_1\, t'_3\, t_5}{t''_2\, t'_4\, t_6} = \text{.....(1)}$$

If the pumping period for each cycle, "t_d," is the same, and it is necessary to keep the residual drawdown at the end of the first and second cycles the same, the following conditions should be met:

$$\frac{t_d + t_{rl}}{t_{rl}} = \frac{(2t_d + t_{rl} + t_{r2})(t_d + t_{r2})}{(t_{rl} + t_{r2} + t_d)(t_{r2})},$$

or

$$t_{r2} = \frac{t_{rl}\,(t_{rl} + 2t_d)}{(t_{r2} - t_{rl} + t_d)} \text{ ....(2)}$$

if $t_d = t_{rl}$ therefore,

$$t_{r2} = \sqrt{3}\ t_d \text{ ....(3)}$$

To keep the same residual drawdown at the end of the third cycle the following conditions should be met:

$$t_{r3} = 2.21\ t_d \text{ ....(4)}$$

Generally if $t_{rl} = c\, t_d$, then

$$t_{r2} = t_d\, \frac{(c\text{-}1 \pm \sqrt{(5c+1)(c+1)}}{2} \text{ ....(5)}$$

and t_{r3} is, the solution of the quadratic equation:

$$Y^3 + Y^2\, \phi_1(c) + Y\, \phi_3(c) + \phi_3(c) = 0$$

where

$$\phi_1(c) = 6 + 4c + f(c) - 2c^2,$$

$$\phi_2(c) = 11 + 3.5\ f(c) + 13c + 2c\, f(c) + 2c^2 + 0.5c^2 f(c) + 0.25\, c^2 (f(c))^2,$$

$$\phi_3(c) = 2.5\ f(c) + 0.5(f(c))^2 + 6 + 8c + 2.5\ c\, f(c) + 0.5c\, (f(c))^2 + 2c^2,$$

and

$$f(c) = \frac{X(c\text{-}1) \pm \sqrt{(5c+1)(c+1)}}{2}$$

The previous equations for "t_{r3}" show the complications involved in proceeding for more than three cycles. *However, if the cycle period "t" is constant and "P" changes,* the conditions for having the same drawdown at the end of any number of cycles will be much simpler, as follows:

For the end of the second cycle.

$$\frac{t}{P_1 t} = \frac{2t. \quad t}{(t + P_1 t)\ (P_2 t)}$$

or
$$P_2 = \frac{2\ P_1}{(1 + P_1)} \quad \text{.........................(6)}$$

Also for the following cycles one finds that,

$$P_3 = \frac{3x \quad 2P_1}{(2+P_1)(1+P_2)} \quad \text{.........(7)}$$

$$P_4 = \frac{4x3 \times 2 \times 1\ P_1}{(3+P_1)(2+P_2)(1+P_3)} \quad \text{...........(8)}$$

....

....

....

and
$$P_n = \frac{n!\ P_1}{[(n\text{-}1)+P_1]\ [(n\text{-}2)+P_2]\ [(n\text{-}3)+P_3]\ \cdots\ [1+P_{n\text{-}1}]} \quad \text{.............(9)}$$

If "P_1" is known, any "P" can be calculated easily from equation 9.

Also, the "P_1," which gives a certain residual drawdown, can be calculated as follows:

$$(R.D.)_1 = s = \frac{264}{T}\ Q\ \log \frac{t}{t P_1} \quad \text{.........(10)}$$

or
$$P_1 = e^{-\frac{sT}{114.6Q}} \quad \text{......................(11)}$$

"P_1" depends on the drawdown to be mentioned, the co-efficient of transmissibility, and the pumping rate.

Examples

(1) If P = 0.5, the following P's will be as follows:

$P_2 = 0.666$ $P_3 = 0.720$ $P_4 = 0.748$

$P_5 = 0.765$ $P_6 = 0.777$ $P_7 = 0.787$

$P_8 = 0.795$ $P_9 = .800$ $P_{10} = 0.806$

(2) Compare pumping and shutoff periods at the end of the first three cycles to produce constant drawdowns of the values 2.2 feet, 2 feet, and 0.9 feet for the following two cases: (a) If pumping period is the same for all cycles, recovery and length of cycles are different; (b) if "t" is the same for all cycles and "P" is changing.

Table 1 shows the results obtained for example 2.

Table 1

Comparison of Results for Example 2, assuming that total length of the three cycles is the same for both cases (3t)

	CASE A					CASE B				
S ft	t_{r1}	t_{r2}	t_{r3}	Total on Period	Total off Period	P_1	P_2	P_3	Total on Period	Total off Period
2.2	t_d	$1.73t_d$	$2.21t_d$	$3.0t_d$	$4.94t_d$	0.5	0.666	0.72	$2.94t_d$	$5.0t_d$
Corresponding P	0.5	0.634	0.688							
2.0	$1.11t_d$	1.914	$2.44t_d$	$3.0t_d$	$5.468t_d$	0.527	0.69	0.742	$2.944t_d$	$5.524t_d$
	0.527	0.657	0.709							
0.9	$3t_d$	$5t_d$	$6.215t_d$	$3.0t_d$	$14.215t_d$	0.75	0.857	0.881	$2.949t_d$	$14.268t_d$
	0.57	0.833	0.861							

Summary

Economics of drainage wells operation problem depend mainly on periods of pumping and non-pumping. These periods, in turn, depend on the amount of drawdown required and how fast this lowering is desired.

In this study, factors involved in such cyclic operation schedules have been discussed and some theoretical analyses made for methods to design these operation schedules. The computations become very complicated when groups of drainage wells with interfering effect are considered.

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CHAPTER IX

Technical Factors

WATER SUPPLY OF SHIRAZ VALLEY AND ITS COMPARISON TO WATER REQUIREMENT OF CROPS

by

B. Bahrani, PhD, M. B. Shooshtarian and M. J. Haeri*

Abstract

Shiraz Valley is located in the southern part of Iran and is potentially one of the best agricultural regions of the country. In this study the annual water capacity of the valley is calculated from the water measurement data of all water sources and is compared with water rerquirements of crops determined by the methods of Blaney-Criddle and Lowry-Johnson. The results showed that the estimated water capacity for the 1965 year was approximately three times as much as the water requirement calculated by the Blaney-Criddle method, and two times as much as that calculated by the Lowry-Johnson method.

Thus, the results indicate an inefficient use of water during the process of conveyance and farm water application. If a good irrigation system with a reasonable efficiency is maintained, it is estimated that the total cultivated land areas of the valley could be increased by fifty percent.

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Introduction

The study of crop water requirements and its comparison to water supply is one of the most important problems of arid and semi-arid regions, for it is in these regions that water is the foundation of agriculture, and any development in agriculture must start with water development. Water development has two aspects: one is to increase the present water available by means of storage and diversion dams, establish tunnels and canals, and develop underground resources. The other is to decrease water losses from reservoirs and canals and thus increase irrigation efficiency.

In several cases it is observed that the available water of a given region is greater than the maximum and average crop water requirement, due to inefficient use of water in irrigation. It is for this reason that before any attempt is made at irrigation development of any region, study of its water supply should be made to determine whether there is a surplus or a deficit of water in the region. In the case of surplus, recommendations should be made to use water more efficiently, and for deficits, attempts for water resource development would become necessary.

The objective of this study is to determine the water supply of Shiraz Valley, compare it to water needs for crops under cultivation, and thus make recommendations for irrigation development.

Location, Weather and Agricultural Conditions

Shiraz Valley surrounds the historic city of Shiraz. It is located on the 29°,36′ north latitude and 32°,52′ east longitude from Greenwich, and has an average altitude of 1600 meters.

The average annual rainfall is 298 millimeters and the average annual maximum and minimum temperatures are thirty-six and three degrees centigrade respectively†.

The valley has an elliptical shape whose longer side lies from northwest to southeast, and is surrounded by mountains on all sides. These have an average altitude of 2500 meters. There are eighty-nine villages in the valley. Total arable land is 30,000 hectares, of which only 10,000 hectares are being annually cultivated. The rest, with the exception of some small dry farming, is under one-year and two-year fallow. Also in its southeastern part there are some small portions of saline soils that can be reclaimed by drainage and leaching. The main crops in this valley are wheat, barley, sugar beets, alfalfa, pulse, cotton, rice, melons, vegetables and orchards.

Sources of water for the valley include small streams, springs, ghanats and groundwater pumping. Ghanats are a historic method of making use of groundwater and are very common all over Iran. They were made several hundred years ago and have a maximum and minimum discharge rate of 200 and ten liters per second respectively. The use of groundwater by means of pumping was started nearly fifty years ago, and at present there are 250 deep and semi-deep wells in Shiraz Valley. The depth of these wells varies from ten to twenty meters for the semi-deep, and eighty to 200 meters for the deep ones. The power for most of the pumping plants is from diesel engines and the water discharge rate varies from three to 100 liters per second. In the southeastern part of the valley there are a few artesian wells. They give an average discharge of twenty liters per second.

† Taken from weather data of College of Agriculture's weather station (eight years for rainfall and thirteen years for temperature data).

Water Measurements

It should be mentioned here that to get an accurate result from water resource studies, measurement of water must be made periodically at various seasons for several years. But in some cases and for some practical purposes, one measurement of water made during the growing season may give a satisfactory estimate of the water supply. In this study all water measurements were made during the months of June, July and August, 1965. In Shiraz Valley, where spring starts in the beginning of March, these three months are not considered the flooding period but probably the average period so far as the amount of water is concerned.

Water measurements have been made by the following methods: for pumps the volumetric and the carpenter's square method, and for streams, weirs, parshall flumes, current meter and float methods. Discussion of the technique of these methods of measurement is not included here, since most of these are conventional methods of discharge measurement and are thoroughly described in Israelsen's irrigation textbook (2).

Area under Cultivation

Fortunately, due to the fact that a land reform project has been started in Iran recently, data of the area of cultivated lands of Shiraz Valley are available and were used for this study. But in a few cases actual measurement of the land was made. The cultivated area of the valley for each crop, together with their length of growing season, is shown in Table 1.

Water Budget Calculations

For calculation of water supply the conventional irrigation equation

$$Qt = ad$$

is used, where "Q" is the discharge rate in cubic meters per second, "t" is time in seconds, "a" is cultivated area in meters squared and "d" is water depth in meters. It should be mentioned here that in case of pumping plants the total annual operational time was considered as "t" in the equation (1). For streams the time "t" was taken to be only ten months of the year, because, on the average, during two months of the year this water is not being used for irrigation purposes and is lost by runoff. Taking all of these things into consideration, the water capacity of ten regions of Shiraz Valley is calculated in terms of inches of water and is shown in Table 2. According to this table the total water capacity (including 11.7 inches of rainfall) for 10,000 hectares of cultivated lands is calculated to be 97.9 inches.

Water Requirements of Crops

Water requirements of crops was determined by two methods, namely, Blaney-Criddle and Lowry-Johnson. According to studies done in Iran (4) and in other parts of the world (1,2) the Blaney-Criddle method gives best results in arid and semi-arid regions. In this method water requirement of crops is calculated according to this equation

$$U = K \frac{pt}{100}$$

where "U" is the water requirement in inches during the growing season (2), "K" is a reduction factor for various crops, "p" is the monthly percentage of daylight hours, which is related to the latitude of the location, and "t" is the monthly average air temperature in F°. Using the average temperature data of eight years and taking "p" and "K" factors from appropriate tables (2), the water requirement of nine main crops is calculated and is shown in Table 3.

The Lowry-Johnson method, according to Israelsen and Hansen (2) is especially adapted for agricultural valleys as a whole, and does not consider the individual crop. This method calculates the water requirement by equation

$$U = 0.8 + 1.56 \times 10^{-4} F \tag{3}$$

where "U" is water use in feet and "F" is the so-called "effective heat" in degree-days, which is the sum of all daily maximum temperatures in F° without considering those days whose maximum temperature is less than 32 F°.

The water requirement of Shiraz Valley calculated by the Lowry-Johnson method, using average weather data of eight years, is shown in Table 3. The data on the length of growing season for various crops of the valley listed in Table 1 are used for calculation of water requirement by the two methods. For further explanation about description of the experiment refer to Reference No. 3.

Results

The calculated annual water capacity for ten regions of Shiraz Valley is shown in Table 2. This table indicates that the total annual water capacity for the valley is 212.62 millions of cubic meters, which is equivalent to 97.9 inches of water for 10,000 hectares of cultivated lands. This figure includes the average annual rainfall.

Water requirement for nine main crops of the valley was calculated from equations 2 and 3 as shown in Table 3. In Tables 4 and 5 the water requirement data are adjusted for the areas of individual crops by considering a weight factor (percent area for each crop). In Table 4 the total water requirement of crop by the Blaney-Criddle method and in Table 5 that by the Lowry-Johnson method is calculated to be 31.23 and 45.72 inches respectively.

Discussions and Conclusions

Before comparing the results of the water capacity and water requirement calculations, the following facts should be kept in mind: First, as mentioned before, all water measurements were made during the summer season, which is not considered the flooding period for the valley but is the peak period of water need for the crops. Second, measurements were made as near to the farm as possible, so the figures do not include the seepage and evaporation losses from canals outside of the farm. Third, since the Blaney-Criddle method of calculating water requirement is based on the average monthly temperature, and that of Lowry-Johnson is based on the monthly maximum temperature, it can be postulated that the former estimates the average and the latter estimates the maximum water requirement for the valley. Considering the above points, the following conclusions can be drawn:

(1) The water capacity of Shiraz Valley is more than three times as much as the average and two times as much as the maximum water need of the crops of the present cultivated area of the valley.

(2) Therefore, it can be said that a great part of the water, which should otherwise be used to irrigate more lands and grow more crops, is being lost annually.

(3) The water losses are said to be due mostly to the low application efficiency of irrigation.

(4) Considering the fact that in a good irrigation system the total efficiency can be raised to 70 percent, it can be concluded that with the present water capacity of Shiraz Valley it is possible to increase the cultivated area by at least fifty percent, meaning that 5000 hectares more land could be brought under irrigation.

Table 1

Total land area and the length of growing season for nine main crops of Shiraz Valley

Crop	Area, Hectares	Growing Season, Months
Grain	3,890	8
Pulse	585	4
Melons	1,010	4
Vegetables	191	9
Orchards	2,390	10
Sugar beet	355	10
Rice	604	7
Cotton	710	7
Alfalfa	255	12

Table 2

Annual water capacity for ten regions of Shiraz Valley

Region Number	Total annual water million cubic meters	Area Hectares	Average water deposit inches	Water deposit plus rainfall inches
1	16.36	835	76.7	88.4
2	38.19	2142	70.0	81.7
3	19.79	866	89.7	101.4
4	11.43	689	64.9	76.6
5	26.89	583	181.1	192.8
6	6.98	359	76.3	88.0
7	45.66	1826	98.0	109.7
8	14.92	613	95.6	107.3
9	18.51	1268	57.0	68.7
10	13.89	801	68.1	79.8

Annual water equals 85.2 inches.
Average annual rainfall equals 11.7 inches
Total equals 97.9 inches

Table 3

Water requirements of nine main crops of Shiraz Valley calculated by Blaney-Criddle and Lowry-Johnson methods

Crop	B-C inches	L-J inches
Grain	28.13	41.0
Pulse	17.91	30.0
Melons	22.27	31.2
Vegetables	38.50	51.6
Orchards	34.97	59.9
Sugar beet	40.80	57.6
Rice	45.16	44.4
Cotton	32.70	45.6
Alfalfa	55.00	61.2

Table 4

Adjustment of water requirement data of Blaney-Criddle method for the area weight factor

Crop	U, inches	Area percent	Ux percent
Grains	28.13	39.0	1097.07
Pulse	17.19	6.0	107.46
Melons	22.27	10.0	222.70
Vegetables	38.50	2.0	77.00
Orchards	34.97	24.0	839.28
Sugar beet	40.80	3.5	142.80
Rice	45.16	6.0	270.96
Cotton	32.70	7.0	228.90
Alfalfa	55.00	2.5	137.50
			3123

Average water use equals 3123.24 divided by 100 equals 31.23 inches.

Table 5

Adjustment of water requirement data of Lowry-Johnson method for the area weight factor

Crop	U, inches	Area percent	Ux percent
Grain	41.0	39.0	1599.0
Pulse	30.0	6.0	180.0
Melons	31.2	10.0	312.0
Vegetables	51.6	2.0	103.0
Orchards	59.9	24.0	1437.6
Sugar beet	57.6	3.5	201.6
Rice	44.4	6.0	266.4
Cotton	45.6	7.0	319.2
Alfalfa	61.2	2.5	153.0
			4572

Average water use equals 4572 inches divided by 100 equals 45.72 inches.

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CROPPING PATTERNS AND IRRIGATION PRACTICES

by

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The irrigation practices of a tract have a direct bearing on the cropping patterns. In an irrigated region, the depth of the water table determines the cropping pattern in more than one way. If it is so high that the land becomes waterlogged, the anaerobic conditions created make the growth of common crops impossible. On the other hand, if the root zone depth of soil is free from waterlogging but the water table is within the capillary fringe and the quality of water is good, the groundwater supplies part of the water requirements, thus minimizing the irrigation requirements.

The fluctuations in the depth of water table during the year can also affect the cropping pattern if for a part of the year it remains within the root zone depth. In that case during such period only those crops can be grown which have a shallower root system or those that can stand an excess of water.

With reference to the depth of water table, cropping patterns will depend on the provision or absence of an efficient drainage system which can drain the required depth of soil for good growth. With a rising water table, in the absence of drainage the ordinary crops gradually go out of the cropping pattern and ultimately, when the water table comes to the surface and the area gets submerged under water, then even crops such as rice, which can stand excess moisture, cannot be raised. The rise of water table in the Indus Plain, after the inception of the various canal systems in the absence of effective drainage, has had a marked effect on cropping patterns. In the perennial canal colonies of ex-Punjab, the kharif (summer) acreage under cotton has gone down fifty-six to thirty-three percent. In areas where the water table has risen within five feet depth, cotton has practically gone out and now occupies only three percent of the kharif (summer) acreage. It forms only twenty-eight percent of kharif acreage in areas with water table in the range of five to ten feet. In areas with water table ten to fifteen feet deep, the percentage is about five percent less, compared with the area of water table more than fifteen feet deep. In the Sind Plain, the instance of Dadu Division is typical. Cotton formed forty-four percent of the kharif acreage in 1937-38, after which there

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was a rapid decline. It now comprises only two percent of the kharif acreage. Similarly, other water-sensitive crops, such as maize, gram, oil seeds, etc., have gone out of the cropping pattern.

There has been a corresponding increase in the acreage under rice. In the area having water table within five feet, sixty percent of kharif acreage is under rice. It goes down to twenty-four percent for areas in the five to ten foot range, fourteen percent of those of ten to fifteen feet water table depth, and only eleven percent in areas with water table deeper than fifteen feet.

The cropping patterns and irrigation practices will also change as the good land becomes salinized and as saline land is reclaimed from salinity. Secondary salinization and formation of sodium soil can be checked by appropriate irrigation and drainage practices. Even if the farmer is willing to follow these practices, the provision of water resources for correct irrigation is not in his control. The drainage installation cannot be provided by him inasmuch as the disposal works cannot be provided for one holding. The drainage system is designed for a hydrologic unit and this work must be undertaken by collective or public investment and effort.

When sufficient water is not available for the amelioration of land affected by salinity or alkalinity or both, some economic return is possible by the production of salt-tolerant crops. It is, however, only a transition period between productive and unproductive land because the affected land soon becomes unfit for producing any crop. Varieties of the same crop differ in salt tolerance. For example, cotton is one of the salt-tolerant crops in the United States, but none of the varieties grown in the Indus Plain are considered as salt-tolerant. When adequate water supply is available the crops are selected for their ameliorative value which may be due to the high irrigation application required or some physical or chemical benefit to the soil.

When the irrigation and drainage facilities have been provided by collective or public effort then the farmer has to follow the scientific irrigation practices, the correct water depth for irrigation and the crop rotations which can ensure salinity control.

The primary objective of a scientific cropping pattern is the sustained and maximum production from the lands. It has to fit into the economic outlook of the country in terms of raw material for food and fiber. Such a cropping pattern should fulfill the following conditions:

(a) It should fit the textural features of the soil and help maintain soil fertility.

(b) It should ensure protection of land from salinization and provide desalinization of land affected.

(c) It should ensure the most efficient utilization of the water supply available for irrigation.

(d) It must be feasible with the farmer's resources of water and finances for capital input and labor.

(e) It should give to the farmer the highest possible net income.

The three major variables to determine the cropping patterns which influence the irrigation practices are:

(1) Soil texture
(2) Soil salinity/alkalinity and depth of water table
(3) Water allowance

The impact of (1) and (2) has already been discussed above. As regards water allowance, a reference to this has been made in detail in the West Pakistan Country Report. Where usable groundwater is available, it is being or will be developed for raising the existing water allowance. Surveys have shown that the major part of the land area of the northern plain has usable groundwater. In the Salinity Control and Reclamation Project I (SCARP I) on area of 1.2 million acres in Central Rechna Doab, the water resources have already been developed by the installation of tubewells and the operation has already started. A similar project, SCARP II, on a 2.2 million-acre area of Chaj Doab, is also being undertaken. SCARP III, on a 1.3 million-acre area in Lower Thal and SCARP IV, on two million acres in

Upper Rechna Doab, are also in initial stages of execution or planning. Others will follow. All the available groundwater resources will be tapped within the next two decades or so.

Over this transitional period of twenty to twenty-five years, there will be expanding areas of adequate water allowance from surface and groundwater resources, and reducing areas with the low allowance of only the canal water supplies. At the end of this period all areas where usable groundwater is available will have adequate water supply for irrigation.

The position with regard to the areas which have saline groundwater is not so encouraging. It is possible that with the development of groundwater in the adjoining sweet groundwater areas, part of the canal water supplies may be spared for saline groundwater areas. By the development of surface storage works on the river system, it is also planned to further develop the river water resource. It is feared, however, that not all areas of salty groundwater will be able to get existing irrigation water supply supplemented from these sources.

Improvements in the cropping patterns should be considered from the point of view of sustained use of land. Cropping patterns and irrigation practices that would result in salinization of the soil would be hazardous. Maximum crop cover on the land during the year is required to retard the phenomenon of evaporation from the soil surface, which causes upward movement of salts. Maximum crop cover means the highest possible cropping intensity, which would also bring the highest gross returns to the farmer. For improvements in the existing cropping pattern and irrigation practices, it is necessary that the 'five firsts' of agriculture be employed for maximum crop returns, viz., improved seed, fertilizers, implements, plant protection and credit facilities.

From the foregoing discussion, it appears that factors other than water supply are important in themselves, but the actual intensities and patterns of cropping are determined by availability of water for irrigation. The possibilities of improvements in cropping patterns are, therefore, discussed separately for areas of adequate water supply and areas of inadequate water supply.

Adequate Water Supply

The development of groundwater for supplementing the surface water supplies in the Indus Plain is in the initial stages. The only areas which have adequate water supply at the present stage are:

(1) The SCARP I area of 1.2 million acres in Central Rechna Doab, where about 2000 tubewells have been in operation since 1963. These tubewells have been installed for maintaining the water table at a safe depth as well as for providing usable groundwater for irrigation to supplement the existing canal water supply. The allowance of irrigation water (including canal and tubewell supplies) provided for the SCARP I area is one cubic foot per second for 150 acres.

(2) In other areas, farmers in the Punjab Doabs have installed their own tubewells for additional water supply. More than 30,000 such tubewells have already been installed. The majority of these have been installed in the canal irrigated areas. The actual water allowance of canal plus the tubewell supply or only tubewell supply, as the case may be, generally varies with the size of holding.

SCARP Areas

Crop rotation and cropping patterns followed under different soil conditions in the SCARP I area have already been given in the Fifth Seminar. To determine a suitable cropping pattern on available water supply, an area can be divided into categories such as the following:

(a) Heavy soils with less than twenty percent salt patches

(b) Heavy soils with more than twenty percent salt patches

(c) Light soils with less than twenty percent salt patches

(d) Light soils with more than twenty percent salt patches

The following cropping patterns are recommended for these main types of soil, with allowance of one cubic second for 150 acres.

Cropping Pattern for Type (a)

Kharif (summer)	Percentage of Cultivable Area
Rice	32 acres
Cotton	16 acres
Sugar cane	8 acres
Maize	8 acres
Fodder	16 acres
Total	80 acres

Rabi (winter)	Percentage of Cultivable Area
Wheat	40 acres
Gram	16 acres
Oil seed crops	8 acres
Senji in cotton	16 acres
Berseem	8 acres
Total	88 acres

Cropping Pattern for Type (b)

Kharif (summer)	Percentage of Cultivable Area
Rice	48 acres
Fodder	12 acres
Maize	8 acres
Sugar cane	8 acres
Cotton	16 acres
Total	92 acres

Rabi (winter)	Percentage of Cultivable Area
Wheat	32 acres
Gram	16 acres
Berseem	16 acres
Senji in cotton	8 acres
Oil seed crops	8 acres
Total	80 acres

Cropping Pattern for Type (c)

Kharif (summer)	Percentage of Cultivable Area
Mash	32 acres
Cotton	16 acres
Bajra	24 acres
Jowar	8 acres
Fodder	16 acres
Total	96 acres

Rabi (winter)	Percentage of Cultivable Area
Wheat	48 acres
Gram	24 acres
Berseem	16 acres
Oil seed crops	8 acres
Total	96 acres

Cropping Pattern for Type (d)

Same as for Type (c) above with preliminary leaching.

The details of feasibility of these cropping patterns have been studied.

Water Supply

Based on the soil surveys data for the SCARP I area in Rechna Doab, the average water requirements of a twelve and a half-acre holding exceed the water supply in the months of June, July, August, and September by six, seven, eight and fifteen-acre inches: thirty-six-acre inches in all. The average monsoon precipitation of ten inches during the months of July, August and September will take care of the shortages in these months. The only shortage will be six-acre inches in June. This means one irrigation to two acres which can be offset against the surplus in the preceding month of May. As the proportion of different soils will not be the same in other project areas as in SCARP I, it is clear that a uniform water allowance of one cubic foot per second for 150 acres may not be applicable. In some areas, a higher water allowance than this will be required, and in others a lower one.

Doubts have been expressed that the high intensities of these cropping patterns are practicable or likely to be attained. These doubts are based on the investigations conducted on private tubewells. In a survey by the Board of Economic Enquiry, the average cropping intensity on tubewells in Gujranwala District was 162 percent. In ten of forty-six individual tubewells, the cropping intensity was more than 200 percent. In another survey by the Pakistan Institution of Development Economics, the overall intensity for 111 tubewells to Gujranwala District was 146 percent, which means that a large number had intensities higher than 146.

In another survey of tubewells in seven districts by Harza International, the average cropping intensities for different sizes of holdings were:

Size	Cropping Intensities Summer	Winter	Total
7- 25 acres	85	108	193
25- 49 acres	66	68	134
50- 99 acres	62	65	127
100-200 acres	62	57	119

In SCARP I, planned by WAPDA, the cost-benefit ratio is worked out on the basis of the cropping patterns recommended in the foregoing. The intensity so far attained in this project area is only 127. In time, it is expected to go up. The proposed target should be vigorously pursued. SCARP II visualizes intensities of 100 percent, 120 percent and 140 percent in the saline groundwater area of Lower Jhelum Canal, the good groundwater area of Lower Jhelum Canal, and the Upper Jhelum Canal area respectively. In SCARP III, the cropping intensity proposed for stage 2 is 120 percent. In SCARP IV, the intensity propsed is 150 percent. It will be seen that different intensities have been arrived at for different SCARPS. This means that the water allowance varies from project to project. The question of whether a uniform allowance of water is feasible and whether the intensity proposed in the case of SCARP I can be aimed at in other SCARPS needs a thorough examination.

With the canal water supply, the designed cropping intensity is generally in the ratio of 1:2 or 2:3 in kharif (summer) and rabi (winter). The recent tubewell surveys show that on private tubewells, the kharif intensity is actually higher than the rabi intensity, as the farmer prefers to increase the area under cash crops of sugar cane, cotton, rice and maize, which are all kharif crops. The WAPDA Master Plan (first phase) assumes the kharif and rabi intensities of sixty percent and eighty percent. This is not likely to prove correct. In this respect, the four types of cropping patterns recommended earlier are more realistic.

Non-Saline Areas

The four cropping patterns discussed in the foregoing were originally proposed for seriously or fairly extensively affected areas such as the scheme areas of SCARP I. There are areas in the Punjab Doabs where damage is less extensive than in these areas. The question might be raised whether in such areas the proportion of a high water using crop such as rice should be the same. The same question will arise for the project areas after the damaged soils have been ameliorated, i.e., when all the affected areas have been reclaimed. There is no doubt that the inclusion of such a crop in the rotations ensures the control of salinity. For protection of the land from re-deterioration, it is necessary to include such a crop because it will take a long time before the cultivator gets used to high irrigation applications to crops other than rice. The other crops do not thrive in areas where rice is the principal kharif crop. However, if it is not the dominant crop then the other crops can do very well. In the cropping pattern type (a), the proportion of rice is forty percent of the cropped land. Provided higher applications to other crops can be ensured by extension work, the following cropping pattern may be adopted:

Kharif	Percent of Cultivable Area	Rabi	Percent of Cultivable Area
Rice	12	Wheat	40
Cotton	24	Gram	16
Sugar cane	12	Oil seed crop....	8
Maize	16	Senji in Cotton..	16
Fodder	16	Berseem	8
Total	80	Total	88

Non-SCARP Areas

The cropping pattern discussed in the foregoing is for the water allowance of one cusec for 150 acres. There are other water supply conditions to which these will not be applicable. On private tubewells installed by the Zamindars, in canal-irrigated areas as well as outside the canal commands, the water allowance varies from farm to farm and place to place. Even without tubewells high water allowance of one cusec for forty-five acres is provided for three to six years for reclamation.

Since the water table depth of any area has a great bearing in evolving the cropping pattern for that area, this factor contributes greatly in determining the irrigation requirements of crops and the total water required, which ultimately reflects on the water supply factor for different zones. The cropping for each supply factor has been so arranged as to satisfy the water requirement of the crops under each supply factor. If for some reason the irrigation requirement in the month of peak need is still not fulfilled, from the water available—from the rainfall or moisture reserve—then the sowing time of crops could be adjusted to fit the supply available.

Inadequate Water Allowance

Projects for development of groundwater resources to supplement the canal water supply are being planned to be completed within the next twenty years or so. So all areas will continue to receive the existing quantity of canal water until each of these is taken up under the SCARPS. There will, however, be some areas for which the provision of increased water supply cannot be visualized in the foreseeable future because the groundwater is saline and cannot be used for irrigation. Neither is there a possibility of additional supplies being transferred from adjoining areas. The replacement plan will not permit deliveries of additional supplies of river water. An example of this is the areas on the left bank of the Sutlej.

Each canal system is designed for a certain water allowance and a certain intensity of cropping. In each crop season, the designed intensity allows only a certain percentage of the area to be cropped. The rest of the area has to remain fallow. The low water allowance for the cropped acreage and for the uncropped acreage would result in a negative moisture balance in the soil, resulting in salinization of land.

The *actual* intensity of cropping differs from the *designed* intensity due to a number of reasons: The water supplies in the canals depend upon the river supplies, which vary from year to year. In years of low river supplies the full designed supply is not available in the canals. Some of the canals have to depend not only on the rivers from which they divert but on the supplies in the other rivers as well, because the waters are transferred from one river to another by link canals provided for making full use of river supplies of the Indus and its tributaries. With the transfer of water supplies of the three eastern rivers to India, replacement works are being built for feeding the areas irrigated by these rivers in Pakistan. After the treaty comes into operation, the water supply position in the West Pakistan canals will be even less satisfactory than under the present conditions.

Water supply conditions also vary in different reaches of canals and distributaries. The distributaries and outlets in the head reaches over-draw, while those in the tail reaches suffer. However, it is not possible to recommend cropping patterns for such undeterminate variables. A cropping pattern can be suggested only for the designed water allowance and cropping intensity. In practice the actual cropping pattern will be varied by the farmer from place to place with the water supply actually delivered to him.

The tendency of the cultivator is generally to crop the maximum possible area with the available water supply. If, however, there is scarcity of water at the sowing period of a crop, then the area under that crop reduces although the water supply conditions may improve subsequently, during the growing period. Similarly, if the water supply conditions are unsatisfactory near the maturing period, the crop yield is poor and in the following year, although the water supply may be adequate during the sowing period, the farmer hesitates to put the maximum area under the crop. There may be cases in which inefficient and backward type of cultivators predominate and cultivate less land than that which should be cultivated with the given quantity of water.

To get a picture of the existing cropping and irrigation practices, data were collected for various canals in the central region for one year, 1961-62. Table 1 shows the actual intensity of cropping on perennial and non-perennial canals separately during that year, compared to the designed intensity of each canal. A study of these data shows that, with few exceptions, the actual cropping intensities are generally much higher than the designed. On perennial canals the only exceptions are the Gujranwala Division of the Upper Chenab Canal, the Bahawal Canal and the Fordwah Canal. In two of these three cases, the difference between the authorized and actual intensities is negligible; on Fordwah Canal the actual intensity was six percent lower than the designed. On all other canals, the actual intensity was higher than the designed by even up to 100 percent.

Similar intensities are shown on the non-perennial canals with only three exceptions: in Balloki Division of the Lower Bari Doab Canal the actual kharif intensity was about thirty-five percent, compared to about sixty-seven percent designed. On the Eastern Sadiqia Canal, it was twenty-four percent, compared to thirty-five percent. On Fordwah Canal it was about the same as designed. On all other canals the actual intensity ranged between 100 and 150 percent of the designed. No rabi cropping is designed on these non-perennial canals, but in actual practice the rabi intensity is of the same order as the kharif intensity.

The designed intensities are based on the designed water allowance on each canal and must vary with the actual water supply conditions. It is apparent, however, that the available water supply is spread over a much larger area than that for which it can supply the requirements of crops. For instance, with a water allowance of three cusecs per 1000 acres and a designed intensity of seventy-five percent, with a kharif-rabi ratio of one to two each cropped acre would get an irrigation amount of three feet, the fields cropped twice during the year getting six feet. As the cropping intensity rises the irrigation amount would be reduced, resulting in a water deficiency for plant growth as well as in soil salinization.

As long as the existing water allowance is not raised, the only practicable relief possible is by keeping the cropping intensity as near the designed as possible. With this step, the irrigation applications would be higher than the existing applications and the irrigated land would have a lower salinity hazard. At the same time, the crop yields would increase. The total crop output from the reduced area would in no case be less than that from a larger area given less adequate irrigation.

On a short-term outlook, the government will lose in revenue from water rates. But on a long-term basis, this would not be the case, as the rate at which the land is going out of production due to salinization, as well as the incidence of remission on account of crop failure, will be reduced.

The actual cropping patterns for the year 1961-62 are shown in Table 1. With respect to the four major crops of sugar cane, rice, cotton and wheat, the picture of cropping patterns on perennial and non-perennial canals in different divisions is summarized in Table 2. The only alternative is that on perennial canals the cropped area should be reduced to the designed intensity, while the proportion of different crops in the total cropped area need not be changed.

The condition in respect to non-perennial canals is different. On most of these rice is the major crop grown. The farmer had taken to rice cultivation because these areas were getting waterlogged and other crops did not do well. A single crop economy is much more hazardous than mixed cropping. A calamity or crop pest can ruin the economic conditions in the area. Also, the water requirements of the rice crop are much higher than those of most other crops. If the farmer could grow these other crops, the crop acreages as well as the farmer's income would be much higher. Drainage is the prerequisite for a change-over from rice to other crops. During the interim period when the existing water supply conditions must continue, an improvement in the cropping pattern can be achieved if field drainage can be provided. Where sweet groundwater is available the farmers are already getting interested in installing their own tubewells, with the help of which they are able to raise irrigated crops in summer and in winter. Encouragement is being given by the government by extending credit facilities. In sweet groundwater areas having non-perennial irrigation from canals, further encouragement and financial help are necessary.

In non-perennial areas having brackish groundwater, the farmer can do little or nothing by way of drainage by pumping, while open drainage can only be provided by government effort.

Intensive extension work is necessary to educate the cultivators to make the correct use of the available water supply by cropping the area for which the available water supply is adequate.

(A) Cropping Patterns for a Holding of Twelve and One Half Acres with Watertable Five to Ten Feet under Adequate Drainage.

(1) For saline soil with perennial supply.
Water allowance: One cusec for fifty acres.
Cropping intensity: 200 percent.

(a)	Rice	11.5 acres (First two years)	Berseem	4.5 acres
	Kh. Fodder	1.0 acre	Gram	8.0 acres
(b)	Rice	11.5 acres (Third year)	Gram	2.5 acres
			Wheat	8.0 acres
	Kh. Fodder	1.0 acre	Berseem	1.0 acre

(2) For saline soil with non-perennial supply.
Water allowance: One cusec for fifty acres.
Cropping intensity: 200 percent.

Rice	11.5 acres	Gram	11.5 acres
Kh. Fodder	1.0 acre	Berseem	1.0 acre

(3) For good land* with water table five to ten feet.
Water allowance: One cusec for 150 acres.
Cropping intensity: 200 percent.

Sugar cane	3.0 acres	Wheat	5.5 acres
Cotton	5.0 acres	Gram	1.5 acres
Maize	2.5 acres	Berseem and Senji	3.5 acres
Kh. Fodder	1.0 acre	Vegetable and Tobacco	2.0 acres
Rice	1.0 acre	Total	12.5 acres
Total	12.5 acres		

* Good land: Non-saline, non-alkali soils.

(B) Cropping Patterns for Good Land for a Holding of Twelve and a Half Acres: Water Table Beyond Ten Feet.

(1) For good areas of rice cultivation zones.
Water allowance: One cusec for seventy-five acres.
Cropping intensity: 250 percent.

Perennial

(a)	Rice	6.0 acres (Short period variety)		
(b)	Rice	6.0 acres (After Rice at (a))	Berseem (2 acres for fodder and 4 acres for fodder and green manuring.)	6 acres
	(Janter green: manuring) — Rice	5.5 acres	Wheat	6.5 acres
	Kh. Fodder	1.0 acre		

Non-Perennial Canal Supply Plus Water Supply from Other Sources.

(a)	Rice	6.0 acres (Short period variety)		
(b)	Rice	6.0 acres (After Rice at (a))	Gram	6.0 acres
			Wheat	5.5 acres
	(Jantar green: manuring) -- Rice	5.5 acres	Rabi Fodder	1.0 acre
	Kh. Fodder	1.0 acre		

(2) For good area.
Water allowance: One cusec for 100 acres.
Cropping intensity: 290 percent.
This will suit best where ample fertilizer facilities are available.

(a)		(b)	
Potatoes (Spring crop)	11.5 acres	Tobacco	11.5 acres
Fodder	1.0 acre	Fodder	1.0 acre
Maize	11.5 acres	Maize	11.5 acres
Potatoes (Autumn crop)	11.5 acres	Potatoes	11.5 acres
Fodder	1.0 acre	Fodder	1.0 acre

(3) For good areas.
Water allowance: One cusec for 200 acres.
Cropping intensity: 175 percent.

Sugar cane	2.0 acres	Wheat	7.5 acres
Cotton	2.5 acres	Berseem and Senji	2.5 acres
Maize	4.0 acres	Gram	1.5 acres
Fodder	1.0 acre	Methra	1.0 acre
Total	9.5 acres	Total	12.5 acres

(4) For good areas.
Water allowance: One cusec for 225 acres.
Cropping intensity: 150 percent.

Sugar cane	2.0 acres	Wheat	5.5 acres
Cotton	2.0 acres	Berseem and Senji	2.5 acres
Maize	3.0 acres	Gram	1.5 acres
Fodder	1.0 acre	Methra	1.0 acre
Total	8.0 acres	Total	10.5 acres

(5) For good areas.
Water allowance: One cusec for 250 acres.
Cropping intensity: 130 percent.

Sugar cane	2.0 acres	Wheat	5.0 acres
Cotton	2.0 acres	Berseem and Senji	2.5 acres
Maize	3.0 acres	Gram	1.0 acre
Fodder	0.5 acre	Methra	0.5 acre
Total	7.5 acres	Total	9.0 acres

Table 1

Cropping Patterns on Various Canals, 1961-62. Actual Cropping 1961-62 — Percent of C.C. Area

Perennial Canals

Name of Division	Kharif									Rabi								Grand Total
	Suger Cane	Rice	Cotton	Maize	Chari	Bajra	Other Crops	Rauni	Total	Wheat	Bar-ley	Gram	Mixed Crop	Oil Seed	Other Crops	Rauni	Total	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Lower Bari Doab Canal Circle																		
Balloki Division	11.0	6.1	11.5	7.0	5.1	2.1	11.5	0.6	54.9	30.9	0.7	3.7		5.2	2.7	0.3	43.5	98.4
Khanewal Division	4.9	1.6	23.9	6.2	5.9	3.1	9.8	1.1	56.5	28.7	2.3	2.8		12.2	14.5	0.3	60.8	117.3
Montgomery Division	8.3	5.2	16.7	9.0	5.5	2.5	11.1	0.5	58.8	31.7	0.8	4.3		8.2	16.9	0.2	62.1	120.9
Lower Chenab Canal East Circle																		
Burala Division	7.9	2.4	13.5	8.1	10.5	1.3	8.6	0.4	52.7	26.4	0.1	2.0	0.8	12.1	19.3	0.2	60.9	113.6
Lower Gugera Division	12.0	1.4	7.4	7.2	8.3	0.2	9.0	0.3	45.8	21.5	0.2	1.8		19.6	18.2	0.1	61.4	107.2
Upper Gugera Division	8.6	9.7	11.3	7.0	7.9	1.6	2.4	0.4	48.9	18.6	0.4	0.3	2.8	12.7	14.7	0.3	19.8	98.7
Lower Chenab Canal West Circle																		
Khanki Division	2.6	13.7	7.2	1.3	11.1		1.4	1.7	39.0	32.6	0.4	1.8		2.4	19.5	0.7	57.4	96.4
Hafizabad Division	13.5	3.0	6.4	7.7	9.0	3.2	5.9	0.8	49.5	29.5	0.1	1.2		3.0	30.0	0.2	64.0	113.5
Lyallpur Division	12.3	2.6	11.1	9.0	9.4	2.4	3.2	0.5	50.5	26.0	0.7	3.0	1.9	15.6	14.6	0.2	62.0	112.5
Jhang Division	9.4	1.2	13.2	6.1	9.6	3.6	3.0	0.9	47.0	3.3	0.4	2.4	38.9	3.7	13.5	0.2	62.4	109.4
Upper Chenab Canal Circle																		
Gujranwala Division	2.6	17.8	1.4	1.3	5.1	0.6	1.1	1.7	31.6	11.0	0.8		1.4	6.7	9.5	0.7	30.1	61.7
Sheikhupura Division	3.1	20.5	2.6	2.7	6.3	0.9	1.9	1.1	39.1	20.8	0.1	0.5	1.6	1.4	14.0	0.7	39.1	78.2
Lower Jhelum Canal																		
Kirana Division	5.4	1.5	19.1	6.9	4.8	8.0	5.7	1.6	53.0	31.7	0.5	0.7		1.9	19.0	0.4	54.2	107.2
Rasul Division	4.0	1.4	21.5	4.3	3.5	11.5	10.8	1.4	58.4	29.4	0.2	0.4		1.1	26.1	0.4	57.6	116.0
Sargodha Division	1.6	1.7	14.5	1.1	8.1	4.0	2.7	2.1	35.8	26.6	0.6	0.6		1.1	13.5	0.7	43.1	78.9
Upper Jhelum Canal																		
Gujrat Division	4.8	10.9	11.2	3.7	2.6	9.9	10.3	0.6	54.0	27.2	0.3	0.8		2.6	17.4	0.4	48.7	102.7
Central Bari Doab Canal																		
Lahore Division	7.0	4.4	12.8	4.3	15.4	4.4	5.7	0.2	54.2	17.4	2.2	2.7	8.4	6.9	10.0	0.3	47.9	102.1

(continued)

Table 1 (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Pakpattan Canal																		
Western Bar Division	3.6	0.5	23.7	1.0	7.1	2.5	3.0	1.5	42.9	29.8	0.1	1.4		6.8	7.7	0.7	46.5	89.4
Eastern Bar Division	5.5	2.4	23.3	2.6	7.0	2.3	3.6	1.1	47.8	36.1	0.6	0.6	0.3	5.9	9.5	0.3	53.3	101.1
Eastern Sadiqia Canal																		
Sadiqia Division	6.2	0.1	15.8	0.7			22.7	0.9	46.4	7.9	0.1	1.6	8.0	3.8	19.2	0.2	40.8	87.2
Hakra Division	6.1	0.5	14.3	0.8	4.8	1.8	18.1	1.0	47.4	3.8	0.1	2.4	14.6	4.0	18.7	0.3	43.9	91.3
Bahawal Canal																		
Baghdad-ul-Jadid Division	6.8	1.8	2.8	2.7		1.1	22.9	1.6	39.7	9.7		1.1	14.2	6.8	6.7	0.7	39.2	78.9
Abbasia Canal																		
Ahmadpur Division	13.2	0.1	6.7	1.4	0.4	3.2	18.6	1.2	44.8	14.3		5.8	6.5	4.1	9.4	0.9	41.0	85.8
Panjnad Circle																		
Rahimyarkhan Division	10.2	0.1	17.0	1.9	0.1	1.1	16.1	1.2	47.7	28.3	0.1	1.4	0.2	3.9	13.2	1.1	48.2	95.9
Khanpur Division	9.3	0.2	16.4	1.2	7.8	1.6	5.9	1.0	43.4	25.7		0.5	2.2	5.7	10.6	1.0	45.7	89.1
Fordwah Canal																		
Fordwah Division	13.5	1.3	12.2	0.8		1.8	9.8	0.4	39.8	15.0	0.2	1.1	15.9	1.7	5.0	0.1	39.0	78.8
Haveli Canal																		
Multan Division	3.5	3.0	25.1	2.2	14.0	0.3	7.3	3.0	58.4	42.0	0.9	0.9		4.6	18.4	0.8	67.6	126.0
Shujabad Division	1.4	0.5	26.9	2.2	15.8	0.3	5.0	3.2	55.3	42.1	0.3	0.2		5.0	15.0	1.0	63.6	118.9
Trimmu Division	5.7	4.6	17.6	1.7	6.3	1.4	4.6	2.4	44.3	26.1	0.4	2.4	0.1	3.9	4.2	0.5	37.6	81.9

Non-Perennial Canals

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Lower Bari Doab Canal Circle																		
Balloki Division	1.8	7.6	15.6	1.8	4.5	0.6	2.8		34.7	7.4		8.9		0.1	12.4	0.2	29.0	63.7
Khanewal Division			1.9	0.4	0.5	0.2	85.7		88.7	1.6	0.2			0.4	67.7		69.9	158.6
Lower Chenab Canal West Circle																		
Khanki Division	0.9	31.4	0.6	0.1	4.3		4.3	0.1	41.7	12.4	0.1	0.2		0.2	18.8	0.6	32.3	74.0

(continued)

Table 1 (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Upper Chenab Canal Circle																		
Marala Division	1.3	22.0	1.2	0.2	3.9		1.5		30.1	11.1	0.3	0.6	9.6	0.7	3.1	0.3	27.7	57.8
Gujranwala Division	0.7	32.5	0.5	0.3	3.7	0.4	0.9		39.0	11.8	0.2	0.6	1.5	3.5	15.4	0.8	33.8	72.8
Sheikhupura Division	0.7	24.3	0.6	0.9	4.5				31.0	37.5		1.5	1.1		5.2	0.4	45.7	76.7
Lower Jhelum Canal																		
Shahpur Division	2.2	3.9	18.3	2.3	10.3	1.1	6.6	0.9	45.6	26.3	0.1	2.2		0.1	17.3	1.1	47.1	92.7
Dipalpur Canal Circle																		
														Wad Wattar 7.0				
Kasur, Khanwah and Suleimanki Divisions	3.0	12.5	4.2	0.8	7.0	2.4	1.0	0.3	31.2	11.0	0.5	0.9	3.3	0.2	3.5	0.5	26.9	58.1
Pakpattan Canal																		
Suleimanki Division	0.7	19.5	6.7	0.6	7.4		0.8	0.3	36.0	13.3	0.6	3.2	2.6	0.3	26.8	1.1	47.9	83.9
Khanwah Division	1.5	5.0	18.0	0.6	14.1	2.0	1.0	0.6	42.8	19.6	0.5	6.1	2.4	2.3	9.0	1.7	41.6	84.4
Eastern Sadiqia Canal																		
Sadiqia Division	1.3	4.2	4.9	0.3			13.6		24.3	0.4	0.6	1.7	0.3		14.9	0.2	18.1	42.4
Mailsi Canal																		
Islam Division	0.7	0.6	21.2	0.3	17.3	2.7	4.2	0.5	47.5	31.7	0.4	3.4		5.4	6.9	1.2	49.0	96.5
Lodhran Division	0.5	0.1	17.7	0.3	16.2	5.4	1.8	0.4	42.4	24.1	0.3	3.4		5.6	4.3	1.7	39.4	81.8
Bahawal Canal																		
Baghdad-ul-Jadid Division	2.1	2.3	10.3	0.2		1.2	24.2		40.3	30.1		6.3	1.2	4.3	4.5	1.1	47.5	87.8
Ahmadpur Division	1.2	0.2	7.4	0.3	5.3	8.2	18.9		41.5	29.1		8.5		7.0	6.0	2.0	52.6	94.1
Panjnad Circle																		
Rahimyarkhan and Dallas Divisions	4.9	3.8	22.7	1.6	0.5	2.5	14.4	0.1	50.5	23.6		2.8		2.8	7.5	3.2	41.9	92.4
Qaim Canal																		
Baghdad-ul-Jadid Division	2.1	7.6	13.0	0.2		2.8	14.2		39.9	27.9	0.1	12.7	2.3	3.5	6.4	0.9	53.8	93.7
Fordwah Canal																		
Fordwah Division	1.2	6.1	7.5	0.5	0.5	1.3	17.1	0.2	34.4	12.9	0.3	2.8	10.6	0.6	9.4	0.3	36.9	71.3
Haveli Canal																		
Shujabad Division	1.5	1.2	18.6	2.1	16.1	2.7	9.3	1.9	53.4	30.1	0.6	1.0		1.7	17.5	1.4	52.3	105.7
Trimmu Division	4.0	5.3	10.3	1.5	7.7	2.3	11.4	0.9	43.4	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	43.4

Table 2

Area under Major Crops on Various Lands in 1961-62
(Percent of C.C.A.)

P e r e n n i a l

Name of Division	Sugar Cane	Rice	Cotton	Wheat
Ahmadpur	16.6	Less than 4	8-12	12-16
Fordwah	13.5	Less than 4	12-16	12-16
Hafizabad	12-14	Less than 4	4-8	28-32
Lyallpur	12-14	Less than 4	8-12	24-28
Balloki	10-12	4-6	8-12	28-32
Lower Gugera	10-12	Less than 4	4-8	24-28
Montgomery	8-10	4-6	16-20	28-32
Upper Gugera	8-10		8-12	16-20
Jhang	8-10	Less than 4	12-16	Less than 4
Rahimyarkhan	8-10	Less than 4	16-20	28-32
Khanpur	8-10	Less than 4	16-20	24-28
Burala	6-8	Less than 4	12-16	24-28
Lahore	6-8	4-6	12-16	24-28
Sadiqia	6-8	Less than 4	12-16	8-12
Hakra	6-8	Less than 4	12-16	Less than 4
Baghdad-ul-Jadid	6-8	Less than 4	2-4	8-12
Khanewal	4-6	Less than 4	20-24	28-32
Rasul	4-6	Less than 4	20-24	28-32
Kirana	4-6	Less than 4	16-20	28-32
Gujrat	4-6	10-12	12-16	32-36
Eastern Bari	4-6	Less than 4	20-24	———
Gujranwala	0.4-4	16-18	Less than 2	8-12
Sheikhupura	0.4-4	20 maximum	2-4	20-24
Sargodha	0.4-4	Less than 4	16-20	28-32
Khanki	0.4-4	12-14	4-8	32-36

Area under Major Crops on Various Lands in 1961-62
(Percent of C.C.A.)

N o n - P e r e n n i a l

Name of Division	Sugar Cane	Rice	Cotton	Wheat
Ahmadpur	0.4-4	Less than 4	4-8	28-32
Shujabad	0.4-4	Less than 4	24-28	More than 40
Multan	0.4-4	Less than 4	24-28	More than 40
Western Bar	0.4-4	Less than 4	20-24	———
Sulemanki	———	———	4-8	12-16
Gujranwala	Less than 4	32-36	0.4-1.2	———
Khanki	Less than 4	28-32	0.4-1.2	———
Sheikhupura	Less than 4	24-28	0.4-1.2	———
Marala	Less than 4	20-24	0.4-1.2	———
Kasur	Less than 4	12-16	4-8	———
Balloki	Less than 4	8-12	24-28	———
Sulemanki	Less than 4	8-12	8-12	———
Baghdad-ul-Jadid	Less than 4	8-12	8-12	———
Khanewal	Less than 4	4-8	12-16	———
Shahpur	Less than 4	Less than 4	16-20	———
Islam	Less than 4	Less than 4	20-24	———
Lodhran	Less than 4	Less than 4	16-20	———
Baghdad-ul-Jadid	Less than 4	Less than 4	16-20	———
Rahimyarkhan	4.8	Less than 4	20-24	———
Khanpur	4.8	Less than 4	———	———
Dallas	4.8	Less than 4	24-28	———
Shujabad	4.8	———	20-24	———
Fordwah	4.8	———	8-12	———

SOIL MOISTURE AS A FUNCTION OF PLANT GROWTH

by

Ch. Muhammad Hussain*

Introduction

The influence of groundwater moisture on crop production has been studied through experimentation under different irrigation conditions at various research stations, having varying water table depths. The studies so far have given very interesting results. The crop of rice at the site where the water table is within five feet from the ground surface has given as much yield with forty inches irrigation application as obtained by applying sixty inches on areas with a deep water table. This means a saving of twenty-acre inches of water due to the sub-soil water table condition.

Similar observations were made on a cotton crop, sown in a high water table area without any irrigation, subsequent to the one applied for sowing of the crop. The crop was raised only on capillary sub-soil moisture of fresh groundwater.

These studies lead to a consideration for finding suitable water table depths and building of a fresh water reservoir so the capillary soil moisture could be used by plants, which would ultimately reduce the demand of surface irrigation applications.

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The experiments were conducted at the Chakanwali Reclamation Farm having sub-soil water table within five feet of the soil surface, at Moharanwala and Haveli (water table ten feet to fifteen feet), and at Bhallewala (water table twenty feet to twenty-five feet) Experiment Stations. The irrigation applications to the rice crop tried in these experiments were thirty-acre inches, forty, fifty and sixty-acre inches. Both fine and coarse varieties of rice were put to trial at Chakanwali and Bhallewala Reclamation sites and only a course variety was sown at Haveli and Moharanwala Stations, as a fine variety does not do well in these tracts.

To ensure the complete application of the scheduled amounts to all the plots under each treatment, the number of irrigations were kept the same and the depths of each irrigation were fixed for all the trea'ments. In all cases interval of irrigations was kept at seven days.

At Bhallewala site the trial was laid out in thirty-two plots of one-fourth acre each. The plot size at Haveli Farm was also the same, but the total number of plots was sixteen. Three foot-wide buffer strips were provided between the plots to ensure a complete check of irrigation effects.

Observations and Results

The observations were continued on these sites from the summer of 1963 to the summer of 1965. The yield results of rice paddy are given in the following tables:

Table 1

Yield of Rice Paddy Obtained from Chakanwali Reclamation Farm in Maunds per Acre (One Maund Equals Eighty-Two Pounds)

Application Depth	1963		1964				1965				Average			
	Fine Variety	Coarse Variety	Fine Variety		Coarse Variety		Fine Variety		Coarse Variety		Fine Variety		Coarse Variety	
			With Drains	Without Drains	With Drains	Without Drains	With Drains	Without Drains	With Drains	Without Drains	With Drains	Without Drains	With Drains	Without Drains
Thirty Inches	19.12	13.75	22.00	10.10	24.90	18.75	16.75	10.18	20.50	17.00	19.38	10.14	22.70	17.87
Forty Inches	19.87	17.25	23.50	11.50	30.40	24.80	18.00	13.25	27.20	22.75	20.75	12.37	28.80	23.78
Fifty Inches	20.50	12.00	25.37	15.00	27.75	22.25	24.60	21.50	25.48	20.30	24.98	18.25	26.61	21.28
Sixty Inches	21.38	12.50	28.75	20.00	24.37	14.37	27.50	23.50	22.45	18.20	28.12	21.75	23.41	16.28

Table 1 shows that the maximum yield at this station was received from the coarse variety of rice, sown under drainage conditions and supplied with an irrigation depth of forty inches. The yield was 28.80 maunds per acre and was 184 percent more than the lowest yield of 10.14 maunds, obtained from a coarse variety, grown with thirty inches irrigation without any drainage facilities. The results show that under the high water table conditions represented by the Chakanwali site, a coarse variety of rice proves best with a forty-inch irrigation and the crop yields reduce when the depths are greater than forty inches. However, for a fine variety, which matures comparatively late, more than forty-acre inches are needed for meeting the optimum consumptive needs of the crop resulting in maximum production.

At Bhallewala site where the sub-soil water table is fairly deep, the results obtained are shown in Table 2:

Table 2 shows that under deep water table conditions, where the influence of sub-soil moisture is not significant, the best yield of rice can be obtained with a 60-inch irrigation.

The yields of the coarse variety of rice from Moharanwala and Haveli Farms, where the groundwater level is neither too high nor too low, also depict the above trend. The best yields were obtained from the highest amount of irrigation water applied. The yield of rice at both these farms is shown in Table 3:

Table 2

Yield Results of Rice Paddy Grown at Bhallewala Research Station (in Maunds per Acre)

Water Applied (acre inches)	1963 Fine Variety	1964 Fine Variety	1964 Coarse Variety	1965 Fine Variety	1965 Coarse Variety	Average Fine Variety	Average Coarse Variety
Thirty Inches............	12.33	14.64	12.10	6.00	3.68	10.99	7.89
Forty Inches............	13.33	16.50	12.50	6.88	4.76	12.24	8.63
Fifty Inches............	14.66	17.52	15.50	9.38	5.25	13.85	10.37
Sixty Inches............	16.17	20.44	18.60	10.63	6.25	15.74	12.42

Table 3

Yield Results of Rice Paddy Grown at Moharanwala and Haveli Reclamation Farm (in Maunds per Acre)

Amount of Water Applied	Moharanwala Farm 1963	Moharanwala Farm 1964	Haveli Farm 1963	Haveli Farm 1964	Haveli Farm 1965
Thirty-acre inches	8.80	16.10	10.37	12.00	11.75
Forty-acre inches	9.25	23.00	11.52	13.75	14.75
Fifty-acre inches	10.45	26.70	11.80	14.75	16.00
Sixty-acre inches	11.65	33.50	12.13	14.50	16.50

The overall results of this experiment at various sites reveal that depth and quality of the groundwater have a big influence on the irrigation requirements of crops. At Chakanwali Reclamation Farm, where the water table is about two feet during summer, the crop has been successfully matured with a thirty-inch irrigation application, and the best yield was obtained with forty inches as compared to fifty-inch and sixty-inch irrigation applications. Where the water table is twenty-five feet from the soil surface, the heavy irrigation application is needed to get maximum yields. Thus the irrigation requirement of crops will be different in the zones, where water table is beyond the depth of ten feet. As such it is required that for different zones the irrigation requirement of crops should be determined on the actual experimental trials for making the judicious use of the irrigation supply for high irrigation efficiency. In this way the heavy losses of irrigation water can be eliminated and the irrigation applications can be adjusted in such a manner that maximum use of the water supply is made for meeting the consumptive use of the crops and the leaching requirements of the soil.

TECHNICAL FACTORS IN IRRIGATION PRACTICES

by

Korkut Ozal, Tuna Tunaman, Seref Ozgul

Synopsis

The practice of irrigation used to be considered as an art but is being gradually transformed to the domain of a science. Many of the empirical methods and procedures can now be approached more realistically.

Among many factors subjected to such a transformation, the design of system capacities is still being carried on mostly by empirical techniques.

In this paper three approaches to system capacity design are presented:

In the first article, the design of irrigation system capacities is evaluated by a probabilistic model.

In the second, the same subject is seen from the farm practices angle.

Finally, a procedure for the definition of drainage system capacities is presented.

Technical Aspects of Irrigation Practice

With the development of basic technology of irrigation practice, many of the technical factors which used to be evaluated by empirical methods can now be treated by more rational approaches. The evaluation of a factor from such an approach provides a better and clearer understanding of the basic phenomena and consequently a more efficient irrigation practice.

During recent years research and development activities on irrigation practices have been brought into high gear. Various fields have been subjected to intensive and extensive research. Water consumption, moisture movement in both saturated and unsaturated zones, soil physics, salinization and alkalinization processes, etc., are now being studied on a sounder basis.

One of the subjects which has not received adequate attention, however, is the determination of irrigation and drainage system capacities.

The Importance of Capacity Determination in Irrigation Practices

From the engineering point of view, an irrigation system consists of a network of water conduits, either open or closed. Those conduits which convey the water from the source to the point where it will be stored within the soil are called irrigation distributing conduits. Parallel to the distributing conduit network there is another conduit system which serves to collect and dispose the unwanted or excess water. In Figure 1 the schematic layout of an irrigation system is shown.

The conduits of both distribution and collection systems are designed to have ample capacities — neither too much nor too little — to accommodate water control demands of the systems throughout their economic life. Due to lack of knowledge of plant-water and plant-soil-water relations and due to the high number of factors involved, the capacity determination of an irrigation or a drainage system at the present is generally based upon some empirical or semi-empirical methods and on a certain set of assumptions.

Factors that Affect System Capacities

Several factors in one way or another affect the capacities of distribution and collection systems. A proper determination of those capacities therefore requires the evaluation of the pertinent factors.

In general, the following factors deserve consideration:

(1) *Climatic factors*: The climatic characteristics of the area have direct or indirect influence on capacities. The rainfall intensities are the prominent factors so far as drainage system capacities are concerned. The amount and distribution of solar radiation, the wind and effective rain determine the consumptive water use of the plant and consequently the capacities of the systems.

(2) *Plant characteristics*: The physiologic characteristics of plants are another factor affecting system capacities.

(3) *Soil characteristics*: Physical (depth, texture, structure, surface condition, infiltration and moisture retention capacities, etc.) and chemical characteristics of soil have direct bearings on irrigation and drainage system capacities.

(4) *Topography*: The topography governs the general layout and consequently service areas. The slope and surface relief may also have some influence on system capacities.

(5) *System losses*: The conveyance efficiency of the system is also one of the important factors to govern system capacities.

(6) *The method of system operation*: The way in which a distribution or disposal system is operated also has an important bearing on system capacities.

(7) *Economy*: The last and final decision on system capacities is dictated by economy considerations.

In the following chapters three approaches to system design are briefly discussed.

Irrigation System Design By a Probability Model

by

KORKUT OZAL*

The Irrigation Cycle

The cycle in which water is provided to and removed from the soil can be described by the following simplified model:

(1) *The intake*: Water is given to the soil through complete or partial wettening of its surface. The rate by which water enters the soil

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is called the intake or infiltration rate. It is usually governed by such soil characteristics as soil potential hydraulic conductivity and diffusivity. It is the characteristic that governs the duration of water application.

(2) *Moisture retention*: The retention of moisture in the soil may be in various forms. From the irrigation standpoint that part of the retention capacity in unit depth of soil that may be filled by normal irrigation practices and can be emptied by the plants within a suction zone that does not affect their growth is of importance. This is known as the available capacity of soil. It is one of the factors that governs the frequency of water application.

(3) *Moisture extraction*: The pattern and the intensity of moisture removal from the soil by the plants is the last part of the irrigation cycle and the factor that governs the frequency of water application. The depth and distribution of the root system and the suction level to which the plant is allowed to reach defines the readily available moisture capacity of the soil. In other words, this capacity dictates the amount of water to be applied at each water application. On the other hand, the maximum rate of water consumption determines the duration in which this amount is to be applied. This rate, however, is not constant and reaches to its maximum value during the warmest period of the season. The irrigation water application is therefore most frequent during this period.

The Determination of Irrigation Water Demand

(1) *Methods for determining consumptive use.* The water demand of the plants is an important factor in the capacity design of irrigation systems. There have been three different approaches to the determination of water demand: (a) experimental, (b) empirical, (c) theoretical. Ozal (1) provides a discussion of those methods and their relative merits. In general, all of these methods are in one way or another approximations. Those methods that are based on theoretical considerations (such as Penman) are the ones that give the closest agreement with the actual observations. But the data required by them are the most difficult to obtain. Empirical methods (such as Blaney-Criddle or Turc) can be used in conjunction with such data that are usually available. Their accuracy, however, is the lowest.

Another important point in regard to these methods is the introduction of the type of plant into the computation. Some methods contain a crop coefficient in water relations (such as Blaney-Criddle's K), while some others (Penman and Thornthwaite) assume that the type of crop does not have any bearing on water use. A possible explanation for this can be given as follows: In theoretical relations the amount of evapo-transpiration is expressed in terms of solar radiation or temperature. It therefore corresponds to the amount of potential evapo-transpiration. In empirical relations, however, the values correspond to the maximum water use efficiency.

(2) *Timely variations.* The irrigation water demand of plants is not distributed uniformly along the time dimension. It may have seasonal as well as cyclic variations due to the effect of changes in radiation, humidity, wind, effective rain, etc. Those variations can be recognized by the methods mentioned above. The minimum time interval used in the above methods is one month. The demand, however, is not uniform during this period. Depending upon the frequency of water application, a coefficient of non-uniformity is applied. In the following table this factor is given:

Table 1

The non-uniformity factor of water demand (fu)
(to be applied on average monthly values)

Frequency of Water Application (days)	fu
30	1.00
15	1.09
10	1.15
6	1.21
3	1.28
1	1.35

(3) *Economy of water use.* The yield of a plant is a function of the water supply. In Fig. 2,

the general response of the plant is shown. Although point (4) corresponds to the highest possible yield, it can be the most economic point of irrigation. In practice, either water or area might be the limiting factor. Point (3) corresponds to the most economic water application in case of limited area, and point (2) corresponds to the most economic water application in case of limited water supply.

Present Approach to System Design

The present practice in determining system capacities has different bases from country to country, and even from project to project. It is generally impractical to attempt generalization in detail. However, the basic approach to system design does not differ so much. It consists of the following steps:

(a) The determination of water duty

(b) The determination of system capacities

Determination of Water Duty

"Water duty," which in many countries is referred to as "water modulus," is the water requirement of a representative unit area (hectare or acre) during the maximum demand period on a continuous flow basis from the point of main diversion in a collection work. It is usually expressed in liters per second per hectare in the metric system and acres per cusec in the British system. One liter per second per hectare is approximately seventy-one acres per cusec. Water duty is determined by two approaches:

(A) *Synthetic approach.* This approach usually consists of the following steps:

(1) A crop pattern is assumed.

(2) The irrigation water requirements of various crops are determined on a monthly basis by one of the methods mentioned above.

(3) By considering the amount of rain, leaching requirements, and water application efficiencies, the field delivery requirements (FDR) are determined.

(4) The field delivery requirements of various crops are weighted to find the average field delivery requirement. The month which gives the maximum FDR is taken as the basis of capacity.

(5) This value is converted to total delivery requirement (TDR) at the diversion point by taking into account the farm and conveyance losses.

(6) TDR expressed in liters per second per hectare gives the water duty. In Fig. 3 an example for this approach is shown.

(B) *Empirical approach.* In this method the water duty is determined from the previous experience. As stated by Lamba and Murty, "The percentage of cultivable commanded area to be supplied with water is determined by the experience from irrigation systems in the area or in the neighboring areas." Thereafter, the full supply factor FSF at outlet is estimated, based on experience. It is the average acreage to be irrigated by one cusec of outlet capacity. It is also the average water allowance on the basis of commanded cultivable area.

Capacity Design

The design of the capacity is governed by the water delivery system. Three methods are employed: (a) Continuous flow, (b) Rotation, and (c) Demand.

(A) *Continuous flow.* In this method the water available at the diversion is preallocated and distributed to all the canals on a continuous flow basis in accordance with established water rights or in proportion with service areas. No method has so far been proposed to determine canal capacities for this type of water delivery. The capacity may be designed by the following relation:

$$Q = c.q_{max}.A \qquad (1)$$

where "Q" is the capacity, "A" is the service area and "qmax" is the maximum water duty on the basis of available water; "c" is a coefficient of safety and is recommended as

1.05-1.10 for lower reaches of main canal

1.10-1.20 for secondaries

1.20-1.40 for tertiaries

(B) *Rotation.* In this method the irrigation area is divided into groups and each group is served on days in accordance with a prearranged schedule. Tertiaries receive water for definite periods and cannot receive any water in between. The grouping is made among secondaries, among the tertiaries of a secondary, and even among the turnouts below a tertiary. Fig. 4 shows such a grouping for secondaries and tertiaries. The capacity of a canal serving an area can be determined by the following relation:

$$Q = R_S \; R_T R_F \, q_{max} . A_T \qquad (2)$$

Where A_T is the largest farm grouping below the area to be served in one rotation (hectare)

R_S is the number of groups of secondaries

R_T is the number of groups of tertiaries

R_F is the number of groups of farms

qmax is the water duty.

(C) *Demand.* In this method the delivery is made upon the request of the farmers. To reduce the requirement of too high a capacity when too many users ask for water at a time, certain modifications and restrictions are introduced.

The capacity of a canal in such a delivery system is usually determined by empirical relations (such as the one given in Fig. 5). Theoretical relations such as the following one based upon normal probability distribution are also used:

$$Q = q_{max} . \sqrt{A \; (1+k)} \qquad (3)$$

Where "Q," "qmax" and "A" are the same as given above and "1+k" is a flexibility factor, either given by an empirical relation or computed by the following relation:

$$k = u \sqrt{\frac{1}{m} - \frac{1}{n}} \qquad (4)$$

In which (u) is a probability coefficient, (m) is the average number of farms normally in operation, (n) the total number of farms below the point.

Comparison of the above approaches is shown in Fig. 5.

Evaluation of the Present Practice

Before discussing the present practice, the meaning and purpose of the capacity design need to be clearly delineated. The capacity should be designed in such a way that it will meet most unfavorable conditions to be encountered within the design period, so long as an economic justification can be given.

The following points may be raised in regard to the present practice:

(1) *The crop pattern.* The average crop pattern used to determine the water duty cannot be expected to have a uniform distribution throughout the irrigated land. Especially in small areas, the deviation from the mean may be substantial. An average forty percent crop at large may attain as high a value as eighty-four percent by a non-exceedance probability of ninety-six percent. In addition to that, the assumed crop pattern itself may not remain the same throughout the design period. This is again especially true in case of small areas. In short, on the dimensions of time and space, the assumed crop pattern is subject to rather wide deviations from the mean.

(2) *Crop irrigation water requirements.* As pointed out previously, the water requirements of crops have cyclic variations. The design based on average values falls too short for dry years.

(3) *Crop coefficients.* The crop coefficients of many empirical formulas correspond to the best water use efficency. Although it is desirable to irrigate crops at their optimal level, such a goal can seldom be achieved under field conditions, and the water consumption of the plant normally tends to assume its potential value so far as ample supply of water exists. It would be somewhat conservative, therefore, to use the optimum water

use coefficients in capacity design. Experiments by various researchers prove this point.

(4) *Field, farm and conveyance efficiencies.* Field and farm efficiencies given by several investigators reflect the highest possible values obtained under closely controlled test conditions. Needless to say, those efficiencies are seldom achieved under field conditions. Their adoption for design purposes may be too optimistic.

Another point in considering losses is that the conveyance losses in the system should not be treated as a constant value since the capacity allowance for the loss will be reduced progressively toward tertiaries. Losses in the upper parts of the system should not be considered, therefore, in the design of lower reaches.

(5) *System flexibility.* System flexibilities generally are not based upon rational principles. Through the use of a statistical model, however, there is a good possibility of developing a sounder approach for determining system flexibilities.

Development of a More Rational Method

In light of the foregoing discussion the following approach may be adopted as a more rational one:

(A) Water Duty

In regard to water duty main remarks may be made as follows:

(1) *Crop Irrigation Water Requirements*

(a) *Crop pattern.* Different crops will have different water-use efficiencies. Such a differentiation will be obtained under closely controlled conditions. In the fields, however, the water loss by evapo-transpiration is basically governed by energy intake. Consequently, crop requirements on which the capacities are to be based can be determined by considering external factors only.

(b) *Timely variations.* Since the cyclic variation of water requirements has a probablistic nature, a sound approach here will be a risk analysis and selection of such a frequency that the sum of the system cost and associated risk of failure will be at a minimum.

(c) *Areal variation.* As pointed out above, the crop pattern may not be uniform throughout the system. In other words, the water duty should contain the area as a parameter.

(2) *System Losses*

The losses to be introduced to the water duty should relate to those losses that will take place downstream from this point. The losses, therefore, may be expressed as a function of the area to be served. By assuming average conditions and normal sized irrigation projects, the variation of system losses is computed and shown in Fig. 6.

(3) *Irrigation Frequency*

The frequency of irrigation may be any value between the following extremes:

(a) The frequency of irrigation may be equal to the duration of water application. In other words, the water may be delivered on a continuous flow basis. Although such an approach may be desirable in the reduction of system capacities, it may not be so from other standpoints, such as difficulty and excessive losses in handling small amounts of water. Furthermore, such a system may keep irrigators busy most of the time.

(b) On the other hand, the frequency of water application may be limited either by the readily available moisture (RAM) or the maximum intake capacity of the soil, whichever is less.

In practice the frequency of water application is either predetermined (such as in rotation) or is computed by soil and plant characteristics. As a usual case the frequencies are selected to be close to the second limit in order to take all other possible frequencies into account.

(4) *Computation of Water Duty*

(a) *Notations*:

(T) Irrigation frequency (days)

(t) Duration of water application (days)

(a) RAM of the soil (or the moisture applied in one irrigation)
(α) Cropped area (fraction)
(ed) Distribution efficiency
(ef) Combined field efficiency
(fu) Non-uniformity factor of water demand (Table 1)
(qmax) Water duty (liters per second per hectare)
(c) Water consumption of the crop (millimeters per day)
(im) Average intake capacity of the soil (millimeters per day)

(b) *Formulation*:

For a fully cropped hectare the following may be written.

$$qmax = \frac{T.fu.c}{t.ef.ed} \qquad (5)$$

Considering the cropped fraction and approximating (T.fu.c) with (a) and adjusting for the units one obtains:

$$qmax = \frac{a.\ \alpha}{8{,}64.t.ef.ed} \qquad (6)$$

The interesting thing with equation (6) is that the water duty expressed this way does not contain any crop parameter. (When irrigation is based upon a full utilization of the RAM or the amount of moisture renewed at every application.)

In case (t) is determined as to correspond to the intake rate of the soil, equation (6) may be reduced (by introducing im = a/t).

$$qmax = \frac{im}{8{,}64\ ef.\ ed.} \qquad (7)$$

The advantage of expressing water duty this way is apparent. It relates the capacity of the irrigation area to the soil characteristics. So a capacity determined this way suits all kinds of crops that may be cultivated.

(B) System Flexibilities

(1) *Notation*

(p) the probability that a farm demands water at a given time
(q) The probability that a farm does not demand water at a given time
(N) Total number of farms in the whole system
(n) The number of farms below a given point in the system
(m) The average number of farms demanding water at a given time below a given point
(s) The average area that can be irrigated during duration (t) below each farm turnout
(S) The service area below a given point (n.s.)
(xy) The number of farms demanding water at a given time below a given point by a non-exceedance probability of y
(u) The mean of a random distribution
(σ^2) The variance of a random distribution

(2) *The Approach*

The irrigation delivery by demand may be considered as a mathematical model where farms demand water at random, as long as a certain water consumption by plants exists. The behavior of the system therefore may be analyzed on this mathematical model of random phenomena. Seen in this perspective, the number of farms demanding water at an instance below a given point may assume any value between zero and (n), the average being (m = n.p). Although it is probable that all the farms may require water at the same time, this probability is normally too small to be justified by the substantial increase it requires in the capacity. Therefore a certain restriction may be necessary. A restriction by a certain non-exceedance probability may usually suffice. This probability is to be determined by an economic analysis. In case of inadequate data, as a design criteria, ninety to ninety-nine percent value may be taken.

(3) *Development of the Argument*

For a Bernouillian sequence of trials, the probability that the number of successes will be between two given values approximates the normal distribution as the (n) goes to infinity.

$$Pr\left[\mu + a\sigma < X_{\varphi} < \mu + b\sigma\right] = \int_{a}^{b} \frac{1}{2\pi} e^{-\frac{z^2}{2}} \cdot dz \qquad (8)$$

In designing canal capacities "a" is taken as $-\infty$ and "b" determined in such a way as the left side of equation (8) will be equal to the predetermined non-exceedance; "b" values can be taken from the areas under the normal probability curve. For example "b" is 1.281 and 1.645 for ninety percent and ninety-five percent non-exceedance probabilities respectively. So the above equation is reduced to the following:

$$X_{\varphi} = \mu + b\sigma \qquad (9)$$

Putting the values of μ and σ for normal (or binominal) distribution.

$$X_{\varphi} = np + b\sqrt{npq} \qquad (10)$$

by rearranging and replacing "n" with "S/S,P" with "T/t-α" and "q" with "l-p" and introducing crop pattern and qmax from equation "6" one finally obtains the

$$Q = \frac{S \cdot \alpha \cdot a}{8{,}64 \cdot e_f \cdot e_d}\left(1 + b\sqrt{\frac{s(T - t\alpha)}{S \cdot t \cdot \alpha}}\right) \qquad (11)$$

The above equation may be also written in the following form.

$$Q = \frac{S \cdot \alpha \cdot c}{8{,}64 \cdot e_f \cdot e_d}\left(1 + b\sqrt{\frac{s(T - t\alpha)}{S \cdot t \cdot \alpha}}\right) \qquad (11.a)$$

(C) Discussion and Conclusion

(1) *The Dimensions of the Parameters*

The relations developed above "11" "11.a" have dimensional homogenity. The term within the bracket is dimensionless. The dimension of the terms outside the bracket is

$$L^2 \cdot \frac{L}{T} - L^3/T$$

which is discharge dimensions.

The terms will have the following magnitudes:

S,s = ha
T,t = days
C (mm)/days)
a (mm)

(2) *Included Factors*

The above expression is the general form of the capacity. All the relevant factors are included in one way or other.

Factors	***Represented***
Cropping	α c (or C)
Soil	(a) and (t)
System losses	(ef) and (ed)
Method of system operation	(t) and (T)
Areal characteristics	(S) and (s)
Economy and safety	(b)

(3) *Agreement with Actual Data*

The equations "11.11a" are tested in a simplified form with the empirical values given in Fig. 5. The result is shown in Fig. 7. As shown by this figure, the fit is remarkably good.

(4) *The Range of Validity*

The equations "11.11a" are valid for large values of S/s where binominal distribution is approximated by normal. By a convergence test it was concluded that the validity of the above equations is down to fifty hectares, which is the average tertiary area. So one may conclude that the relation is valid for all the irrigation systems, including tertiaries. Any value below this should be computed by binominal distribution. For continuous delivery, writing t = T one obtains the following relation:

(11.c)

$$Q = \frac{S \cdot \alpha \cdot c}{8{,}64\ e_f \cdot e_d}\left(1 + b\sqrt{\frac{s(1-\alpha)}{S \cdot \alpha}}\right)$$

(5) *Conclusion*

The method proposed here provides a more rational approach to capacity design. The important thing here is the determination of "b": which should be based on economy considerations. Other parameters such as "a,T" and "t" are to be determined by soil and system operation principles.

In Fig. 8 a chart to determine the capacity is given.

References

(1) *The Principles and Methods of Capacity Determination of Irrigation Distribution System*: K. Ozal, Ankara, 1965.

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(3) *Economic Water Duty*: M. Ram, 1957.

(4) *Criteria for Irrigation Systems*: USBR, 1955.

(5) *Le Calcul des debits dans les canalisations d'irrigations*: R. Clement, 1956.

(6) *Determination of Command Area of Outlets Based on Supply Time Available and Development of Cropping System*: S. S. Lamba and A. N. Murthy, 5th NESA, 1964.

(7) *Theory of Probability*: M. E. Munroe, 1951.

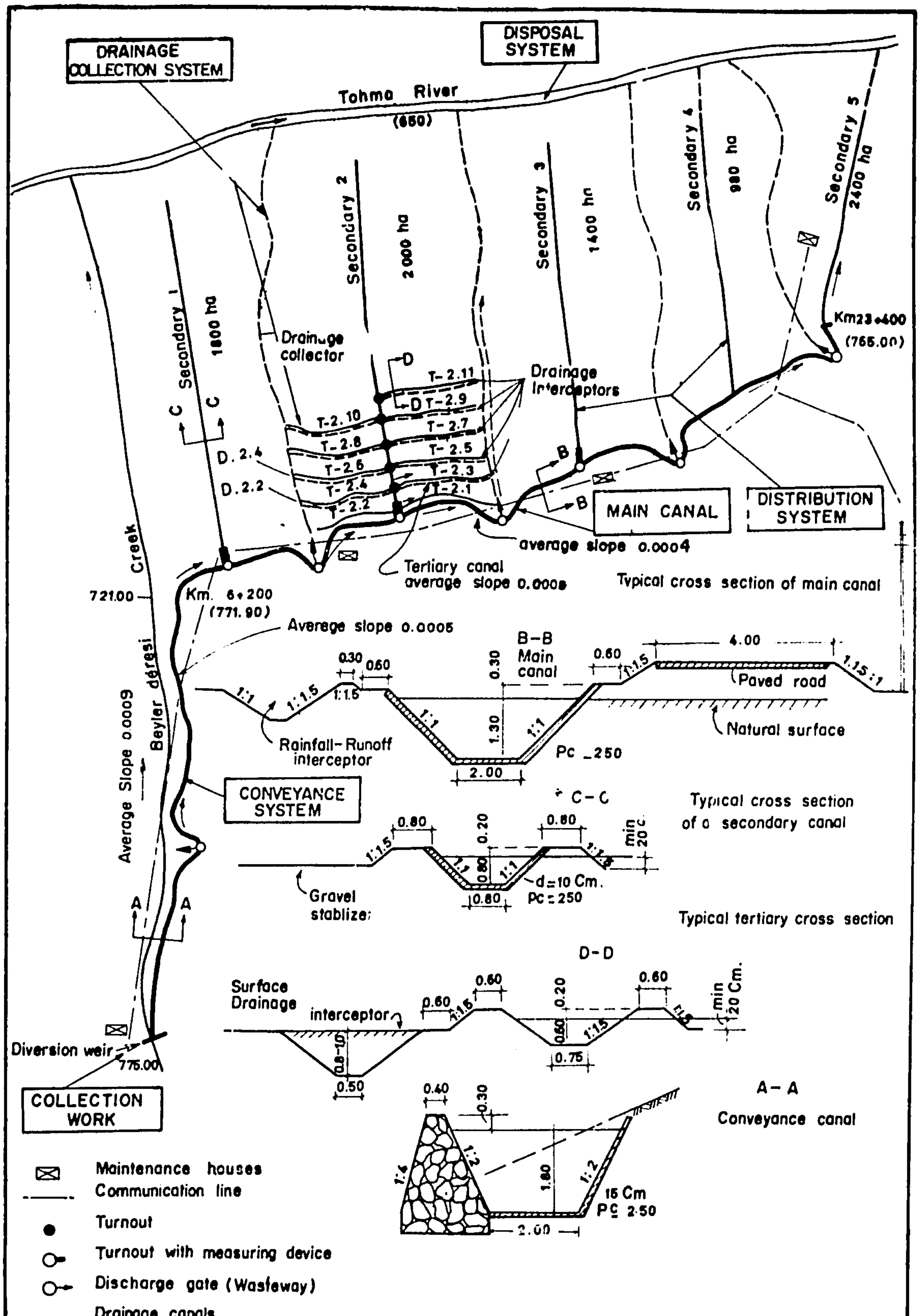
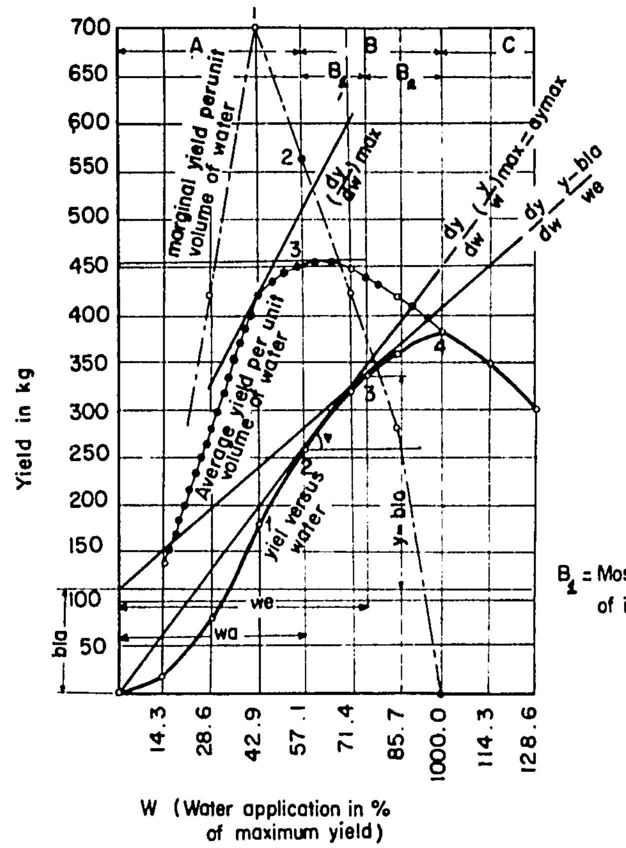


FIG I.A· schematic IRRIGATION LAYOUT



B_1 = Most economic range of irrigation

(1) Point where the marginal yield per unit volume of water is maximum.

(2) Point where the average yield per unit volume of water is maximum.

(3) Point where the net income per unit area is maximum (Water is not a limiting factor)

(4) Point where the yield of the plant per unit area beccmes maximum.

Y = Benefit per ünit area $\frac{b}{a}$ = Production cost per unit area

$Y - \frac{b}{a}$ = net yield per unit area

Wa = Economic water application in case of limited water supply

We = Economic water application in caso of limited area

Fig 2 Marginal analysis of economic water duty (After Ram)

Months	t C°	Blaney criddle 1,8 t	1,8t+32	(P/36°)	f	k values Alfalfa	Cotton	Wheat	Monthly Cons. Uses (mm) Alfalfa	Cotton	Wheat
	1	2	3	4	5	6	7	8	9	10	11
M	15	27	59	8,35	4,93	0,60		0,82	75		103
A	19	34,2	66,2	8,85	5,85	0,80		1,22	115		182
M	23	41,4	73,4	9,81	7,20	0,90		0,94	165		172
J	29	52,2	84,2	9,83	8,26	0,96	0,20	0,19	202	43	40
J	34	61,2	93,2	9,99	9,30	1,10	0,50	-	250	118	
A	33	59,4	91,4	9,40	8,58	0,96	0,80	-	209	174	
S	26	46,8	78,8	8,36	6,58	0,92	1,10	-	154	184	
O	18	32,4	64,2	7,90	5,07	0,58	0,70	-	75	92	
N	14	25,2	57,2	7,02	4,02	0,50	0,40	-	51	41	
							TOTAL		13[illegible]0	652	497

Rainfall (mm) Total	Eff	Crop Irrigation Water Requirement (mm) Alfalfa	Cotton	Wheat	FDR (for various farm losses) (1) Alfalfa 35% farm losses mm	lt/sec	Cotton 30% farm losses mm	lt/sec	Wheat 40% farm losses mm	lt/sec
12	13	14	15	16	17		18		19	
50	46	29		57	45	0,177			95	0,37
75	67	52		115	80	0,34			192	0,76
60	55	110		117	172	0,66			195	0,77
20	19	182	23	20	280	1,07	33	0,13	33	0,13
10	10	250	108		384	1,46	152	0,60		
3	3	206	171		317	1,17	230	0,91		
8	8	146	176		225	0,89	251	0,99		
25	24	51	68		78	0,38	97	0,38		
40	37	14	4		21	0,08	6	0,24		
29[illegible]	269	1040	550	309	1602		769		515	

FDR Weighted (mm) Alfalfa 0,20	Cot. 0,5	Wheat 0,2	Total mm	lt/sec	TDR Total mm	lt/sec ha
20	21	22	23		24	25
9		19	28	0,11	43	0,17
16		38	54	0,21	83	0,32
34		39	73	0,29	112	0,45
56	17	7	80	0,30	123	0,46
77	76		153	0,62	240	0,95
63	115		178	0,70	274	1,08
45	126		171	0,67	263	1,03
16	49		65	0,26	100	0,40
4	3		7	0,03	11	0,05
320	386	103	809		1249	

Notes :

(1) Leaching requirement is considered to be within deep percolation losses.

(2) It should be kcpt in mind that 20% ∝∝, cotton 50 %, 20 % Wheat and 10 % Fallow is an average distribution so far as the whole area concerned So a capacity corresponding to 1.08 lt/sec/ha will suffice. However such distribution becomes highly distorted as the service areas becomes smaller and the chances are great that a tertiary area of 30 hectares may be covered by one type of crop (such as 80 % Alfalfa). In such a case the average value of 1.08 lt/sec / ha wont suffice and a higher value such as $\frac{1,46 \times 0,8}{0,80} = 1,46$ lt/sec /ha may be needed.

Fig. 3 Determination of average water duty by synthetic approach.

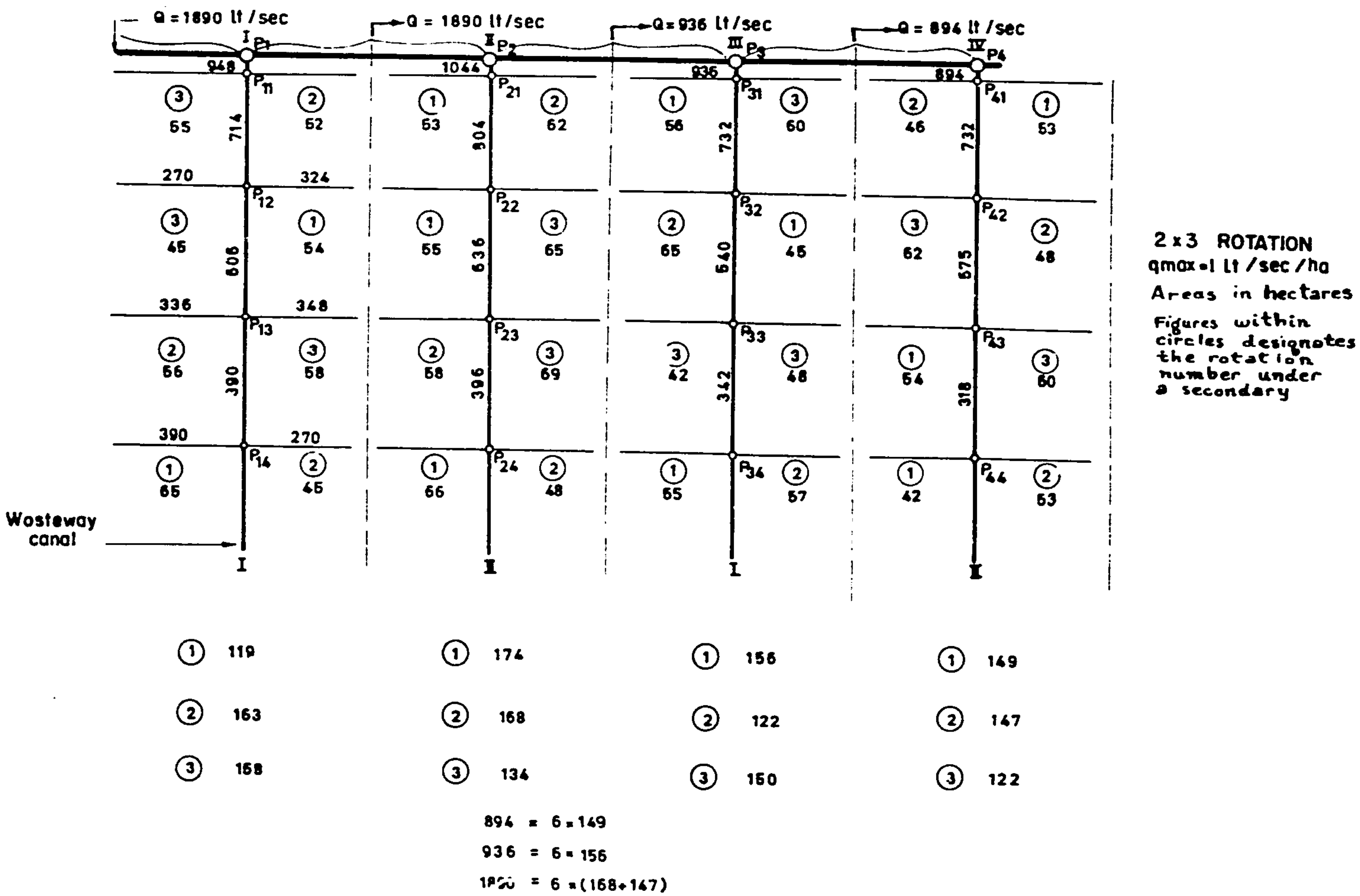


FIG. 4 COMPUTATION OF CANAL CAPACITIES BY ROTATION

$R_T = 3$
$R_s = 2$

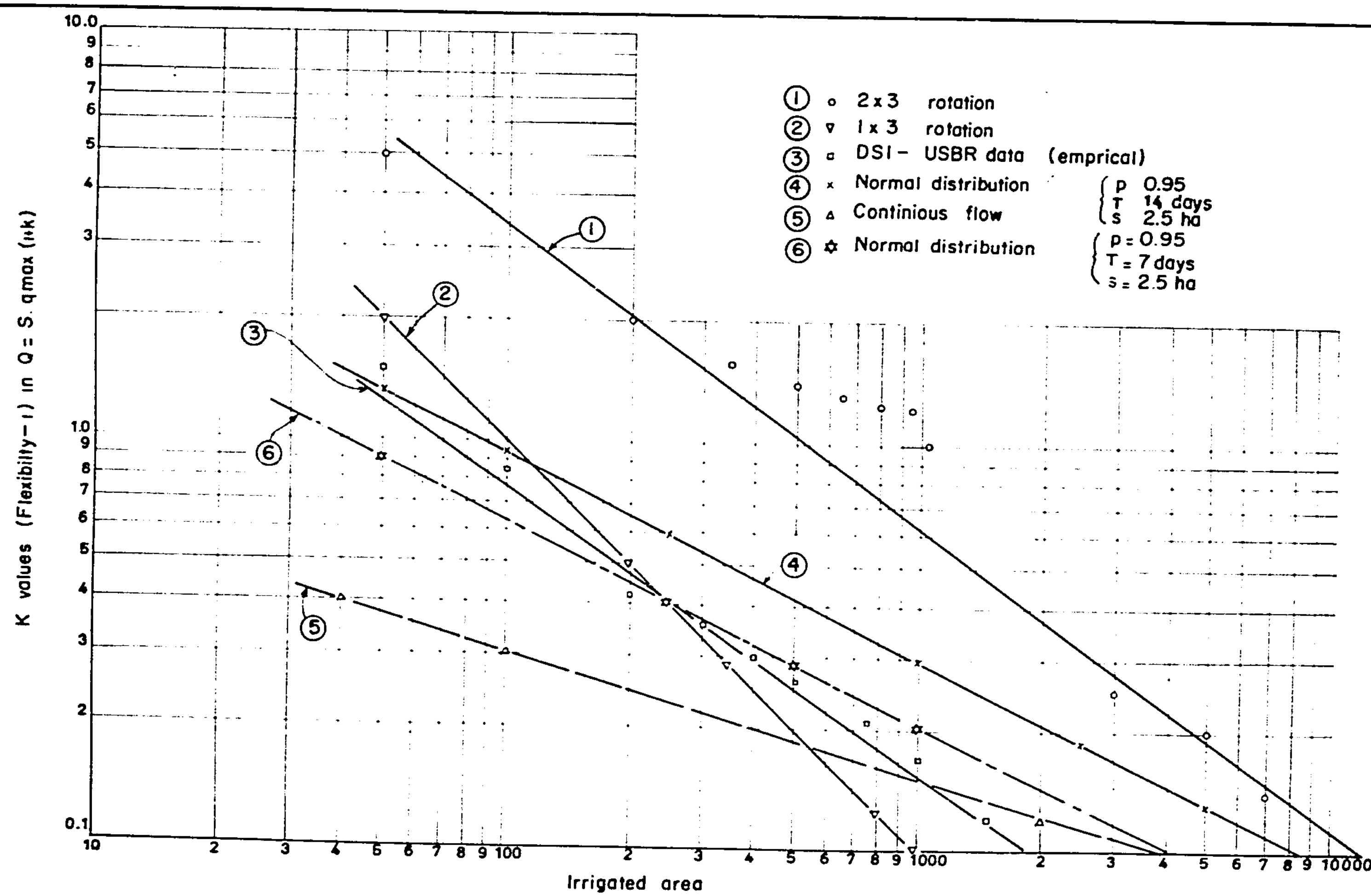


Fig 5 The comparison of various methods of system design

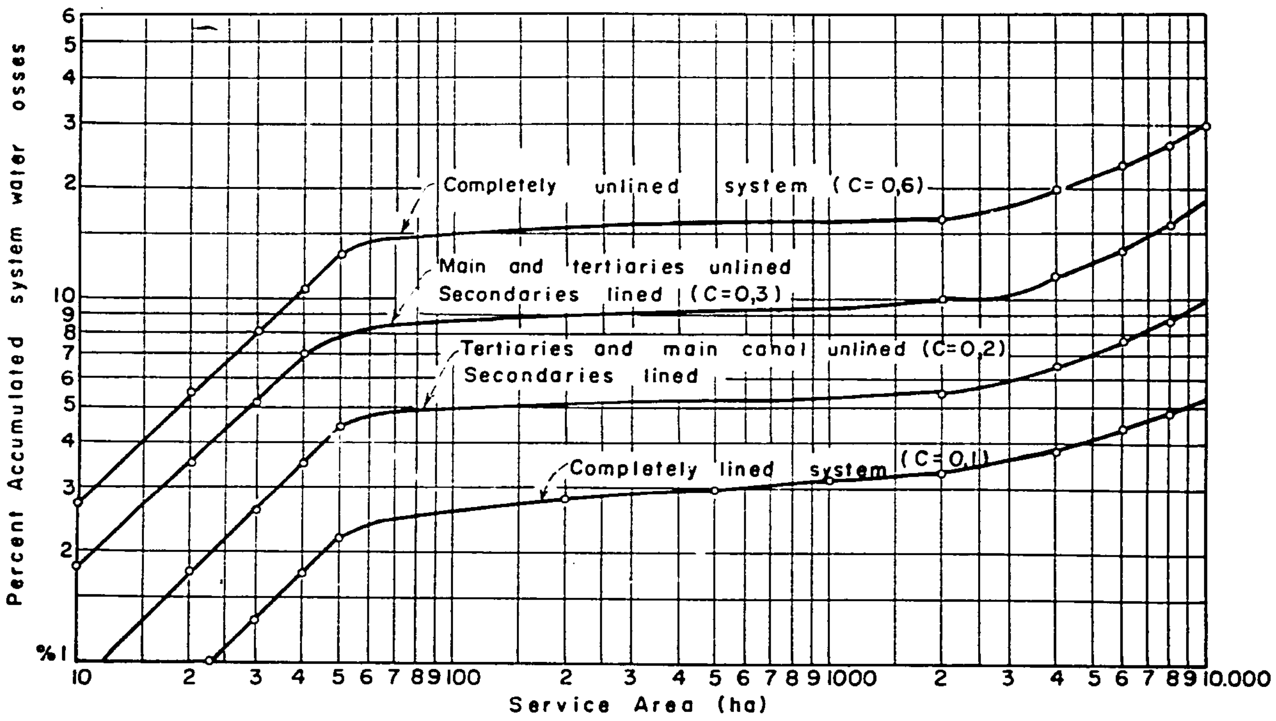


Fig. 6 Accumulated Irrigation system water losses
(Losses in Transmission are not included)
(For normal proportioned irrigation systems)

Tertiary area = 50. ha
Tertiary length = 2 km
Secondary area = 2000 ha
Secondary length = 5 km

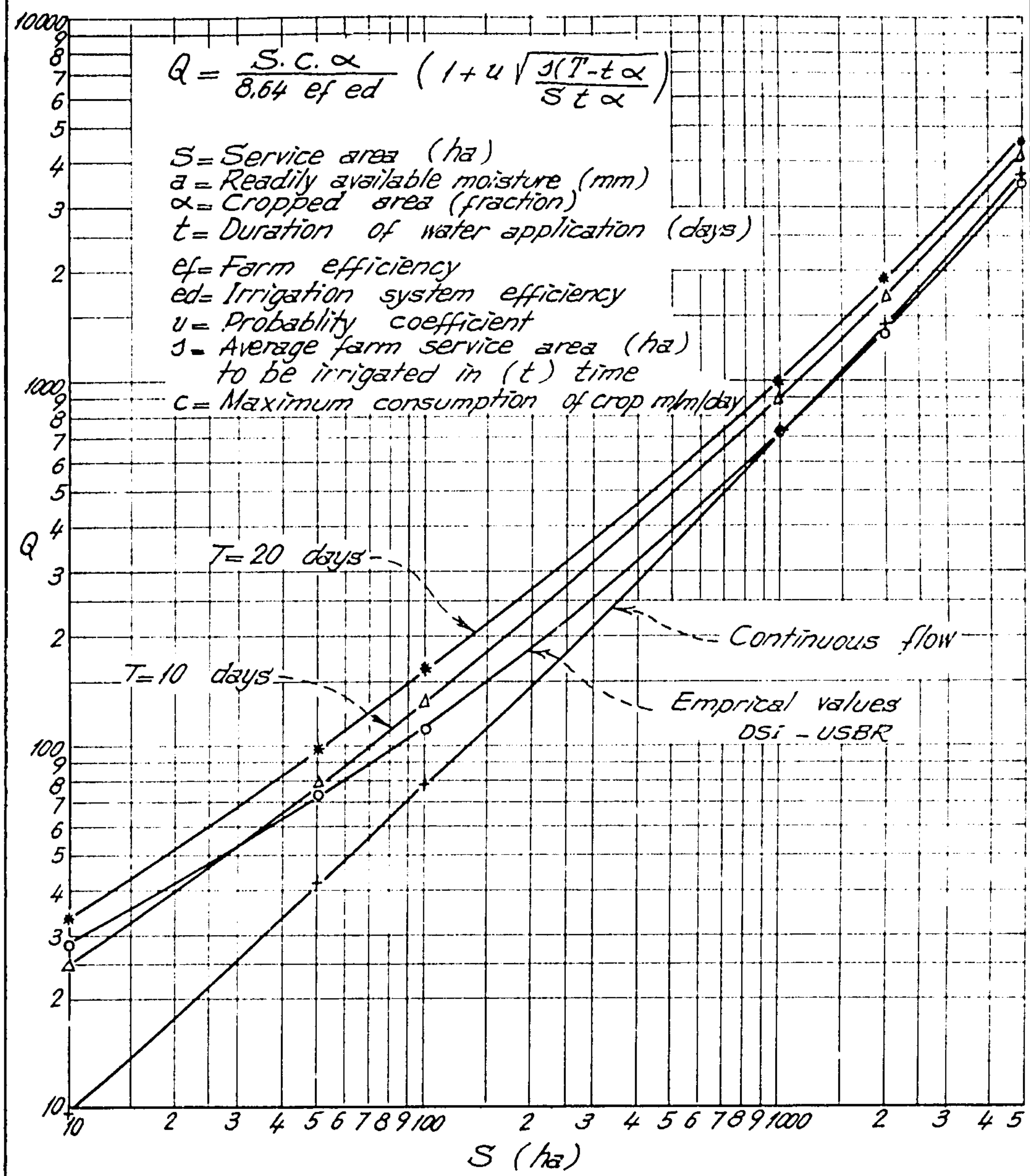


Fig. 7 Q vs S relation for the comparison of Eq (11) with emprical data

a = 100 mm
α = 70 %
t = 1 days
ef = 65 %
ed = From Fig. 6
u = 1,645 (%5 exceedance)
ȷ = 2,5 ha
c = 5 mm/day

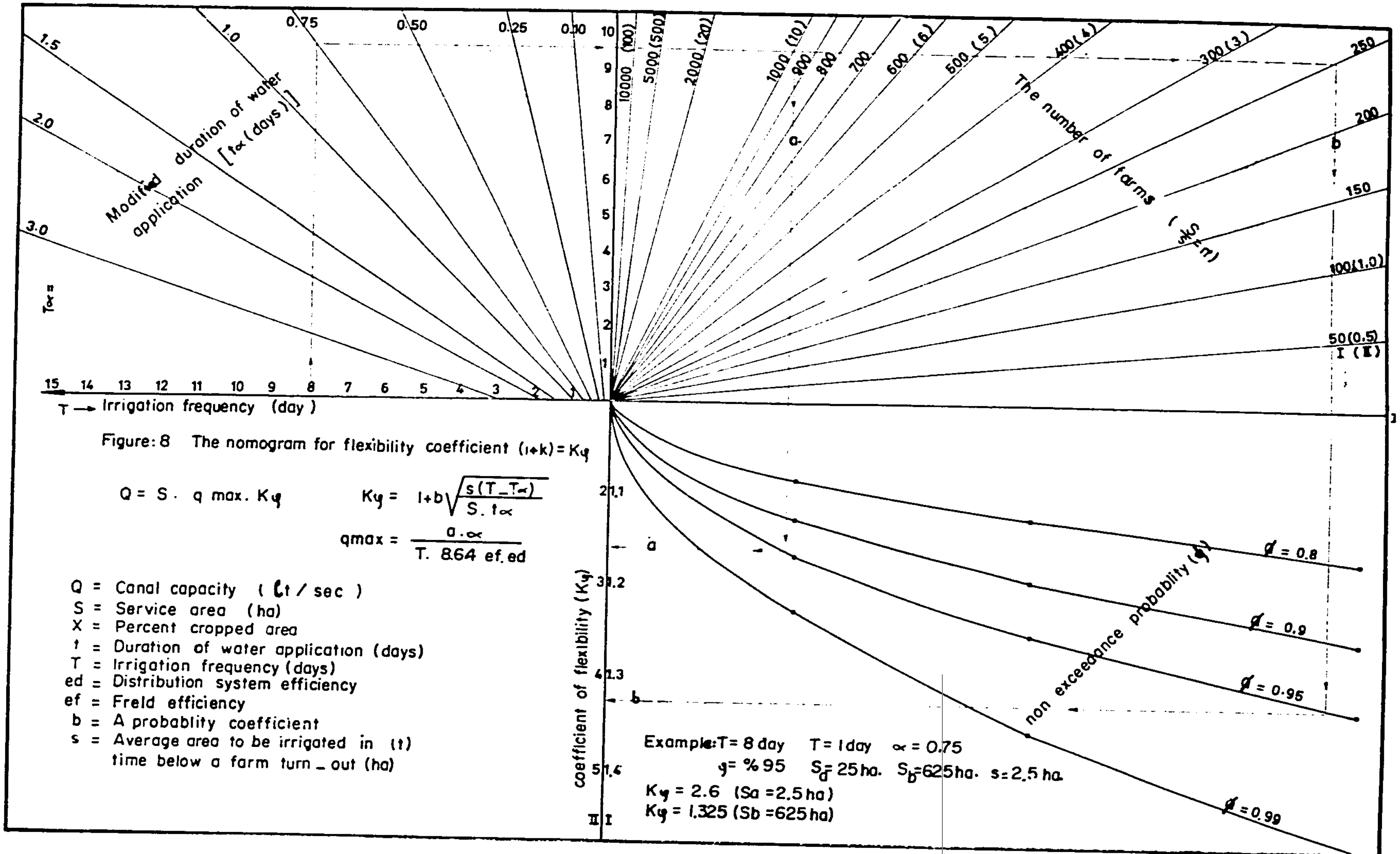


Figure: 8 The nomogram for flexibility coefficient $(1+k) = K_\varphi$

$$Q = S \cdot q\,max. \, K_\varphi \qquad K_\varphi = 1 + b\sqrt{\frac{s(T - T_\alpha)}{S \cdot t_\alpha}}$$

$$q_{max} = \frac{a \cdot \alpha}{T \cdot 8.64 \, ef.ed}$$

Q = Canal capacity (lt / sec)
S = Service area (ha)
X = Percent cropped area
t = Duration of water application (days)
T = Irrigation frequency (days)
ed = Distribution system efficiency
ef = Freld efficiency
b = A probablity coefficient
s = Average area to be irrigated in (t) time below a farm turn _ out (ha)

Determination of Irrigation System Capacities by Farm Practices Approach

by

TUNA TUNAMAN*

General

In the following paragraphs an attempt is made to determine irrigation system capacities from a different approach. As the final goal of a well designed delivery system is to irrigate the crops in the field, this approach takes farm practices at field level as a starting point. Considering the factors that affect irrigation, canal capacity determination may be made by starting from the field canal and going up to the larger canal capacities which serve larger areas, including many fields. From this point of view the characteristics of irrigation at the field level will influence the capacity requirement of the upper canal system. In development of the method the following assumptions are made:

(a) In the determination of a canal capacity for a single field, the crop which has the highest water consumption in the vicinity will be considered.

(b) The canal capacity which is serving a group of fields will be determined according to a crop pattern.

(c) There will be no water waste during the highest rate of water consumption period.

Within these assumptions the capacity should satisfy the following requirements:

(1) To supply the required water for the plants in the peak water-use period.

(2) To be adapted to the cropping pattern in the irrigated area.

(3) To be adapted to the irrigation practices.

(4) It should have a flexibility to suit any water delivery system.

(5) It should not require any other data than the conventional type.

(6) It should have simplicity.

Under these objectives the method is presented as follows:

Determination of System Capacities

The formula for determination of system capacities is:

$$Q = \frac{a\,\frac{t}{s}}{86.4}\left(1+\frac{S}{\frac{s}{t}T}\right)$$

Where: (Q) Is the capacity

(a) Is the depth of water to be applied at each irrigation within the peak water-use period.

(s) Is the area that can be irrigated by one irrigator (in days)'

(S) Is the total area to be irrigated by the canal

(t) Is the duration of time to irrigate definite area (s) by one irrigator

(T) Is the irrigation interval in days

If the considered canal is serving a single field (a) will be the depth of water in each irrigation for a single crop, having the highest water consumption and suitable for that particular soil, climate and economic conditions. (a) can be expressed either in inch or in millimeter.

If the required canal is serving a group of fields, then one has to determine the economic cropping pattern for the whole area and consider the different available soil moistures to figure out the water application depth in each irrigation.

It can be seen that for one particular field, only crop and soil factors need be determined, while in larger areas different soil and cropping factors should be converted to a single factor as

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soil and crop. In the following paragraphs determination of (a) in larger areas is presented step by step and determination of (a) for single units will be included.

Determination of Amount of Water to be Applied at Each Irrigation

(1) The available soil moisture is determined for each group of soil in the service area. This can be done by taking soil samples from each soil group and running a laboratory test to find the available moisture capacity. In case the laboratory data are not available Table 1 and Fig. 1-3 can be used for this purpose.

(2) After figuring out the available soil moisture for each soil group the weighted average of available moisture and related areas for each soil group gives the representing value of available moisture for that particular area.

(3) Effective root zone depths are found for each crop. The weighted average of effective root zone depth and its percentage of growing areas gives average effective root zone depth for the area.

(4) Since the available moisture and effective root zone depths are known, the product of these two values yields the required depth of water to restore the soil moisture, from a value very close to the wilting point, to field capacity.

(5) Consumption of total available moisture is subject to severe drought damage for the crops and is not desired. Instead, irrigation after the consumption of some percentage of available moisture is necessary.

The percentage of available moisture to be consumed depends primarily on the kind of crop and type of soil. For optimum yield, it is desirable to know the optimum moisture percentage to be kept in the soil. Its calculation calls for vast experimental data. Lacking such information, it is generally assumed that irrigation is needed after fifty percent of the available moisture is depleted. This criterion can be generalized for irrigation practices.

In step (4) available soil moisture was found. The half of this moisture expressed in depth gives required (a) water application depth and can be expressed either in inch or in millimeter.

Determination of Irrigation Interval

In the above formula the irrigation interval is designated by (T). Dividing (a) by the daily water consumptive use (c) of the area gives the irrigation interval (T). Therefore, one needs to know consumptive use of water for the particular area.

The following steps show the procedure:

(1) Water consumptive use curves are drawn for each crop. For this purpose any method can be used, as Penman, Blaney-Criddle or Thornthwaite.

(2) The superimposition of these curves gives a peak consumptive use rate period. Within that period one finds the monthly consumptive use of each crop.

(3) The weighted average of consumptive use of different crops and their related areas gives monthly peak consumptive use rate for an area.

(4) Dividing monthly consumptive use rate by thirty days gives the average daily consumptive use rate (c). This value is to be corrected by a non-uniformity coefficient. (An example is provided in the previous article of this paper.)

(5) By dividing available soil moisture by the daily consumptive use rate the irrigation interval (T) is calculated.

Time and Area to be Irrigated

In the capacity equation (s) designates the unit area concept. This is primarily related to the irrigation technique, cultural level of farmers, soil topography, water delivery system, water application system, and other factors. (S) is an area which can be irrigated within unit time (t) by one farmer, considering the above factors.

Unit time (t) may be a day, half a day, or, taking into account Saturday and Sunday, may be a fraction of a day. Unit area may be designated with any unit such as decare or acre.

Table 1

Representative Physical Properties of Soils

Soil Texture	Infiltration[1] and Permeability Inches/hour I_f	Total Pore Space percent N	Apparent Specific Gravity As	Field Capacity percent FC	Permanent Wilting percent PW	Total Available Moisture[2]: Dry Weight percent $P_w = FC - PW$	Volume percent $P_v = P_w A_s$	Inches per Foot $d = \frac{P_w}{100} A_s D$
Sandy	2	38	1.65	9	4	5	8	1.0
	(1-10)	(32-42)	(1.55-1.80)	(6-12)	(2-6)	(4-6)	(6-10)	(0.8-1.2)
Sandy Loam	1	43	1.50	14	6	8	12	1.4
	(0.5-3)	(40-47)	(1.40-1.60)	(10-18)	(4-8)	(6-10)	(9-15)	(1.1-1.8)
Loam	0.5	47	1.40	22	10	12	17	2.0
	(0.3-0.8)	(43-49)	(1.35-1.50)	(18-26)	(8-12)	(10-14)	(14-20)	(1.7-2.3)
Clay Loam	0.3	49	1.35	27	13	14	19	2.3
	(0.1-0.6)	(47-51)	(1.30-1.40)	(23-31)	(11-15)	(12-16)	(16-22)	(2.0-2.6)
Silty Clay	0.1	51	1.30	31	15	16	21	2.5
	(0.01-0.2)	(49-53)	(1.25-1.35)	(27-35)	(13-17)	(14-18)	(18-23)	(2.2-2.[illegible])
Clay	0.2	53	1.25	35	17	18	23	2.7
	(0.05-0.4)	(51-55)	(1.20-1.30)	(31-39)	(15-19)	(16-20)	(20-25)	(2.4-3.0)

Note: Normal ranges are shown in parentheses.

[1] Intake rates vary greatly with soil structure and structural stability, even beyond the normal ranges shown above.
[2] Readily available moisture is approximately seventy-five percent of the total available moisture.

It can be seen that the (s) unit area is not easily determined as it was in finding water application depth and irrigation interval. It has considerable flexibility, and yet this flexibility enables one to apply the method to various irrigation techniques and distribution systems.

The Application of Equation

After all the elements are determined, they are put in the equation and the result gives the net discharge of the canal.

The net discharge of the canal will be in liters per second, if the (s) and (S) are decare and (a) is millimeter in the formula. If the measuring units are acre and inch for (s), (S) and (a), with the conversion factor (0.0417), the discharge is termed in cubic feet per second.

The net canal capacity does not include some losses which should be taken into account in every irrigation system, such as surface runoff, deep percolation, canal conveyance, and other losses. After determining the net canal capacity, these losses should be added to find the gross or actual capacity. These losses can be classified into two groups: irrigation efficiency and canal losses. Losses of these kinds can be determined by various methods. Table 2 gives some standards for this purpose.

Table 2

Item	General soil type		
	Open	Medium	Heavy
	Porous	Loam	Clay
	%	%	%
Farm lateral loss................	15	10	5
Surface runoff loss	5	10	25
Deep percolation loss	35	15	10
Field irrigation efficiency ..	60	75	65
Farm irrigation efficiency..	45	65	60

Discussion and Conclusion

The formula presented has a dimensional homogenity: (s) and (S) are termed in L^2, (T) comes from consumptive use and its dimension is

$$L \quad \frac{L}{T} = T$$

and (a) is L putting them in the equation.

$$\frac{L \cdot \frac{L^2}{T}}{86.4} \left(1 + \frac{L^2}{\frac{L^2}{T} . T} \right) = \frac{L^3}{T}$$

is the dimension of discharge.

The Unit Area

Considering the many factors mentioned above, a unit area may vary from country to country and from place to place. In an irrigation project there may be a few large farms in which an irrigator can irrigate substantial acreages in a unit time (t). In those areas where the fragmentation of farms is common, this type of farm does not necessarily represent the present irrigation technique in that vicinity. The design of canal capacities to serve this type of farm is considered individually.

In the determination of canal capacities, it is necessary to consider the different irrigation technique serving a group of small farms and also large farms. Irrigation efficiency and technique can be improved to some extent even in the countries where the literacy of the farmers is not at the desired level. Yet it is hard to expect to increase the efficiency of manpower on the farm land where the laborer literacy has been a problem for a long period.

To design a delivery system with the unit area substantially large will make the project costly. On the other hand to make the unit area very small will result in low efficiency in the project. Under present conditions the unit area to be irrigated by one man in a unit time should be determined, and this determination should reflect the irrigation practices to be applied to the area over the long term. The designer therefore should consider the economic and technical factors in determination of a unit area.

A unit area of between ten and twenty decares a day is a fairly good criteria. If the undertaking covers all aspects in developing irrigation, such as land consolidation, soil and water conservation, the unit area may vary from the above criteria.

The Effect of Service Area

There are two terms in the formula: The first term has fixed values which give the discharge for a unit area to apply the required depth of water in unit time. The second term is a dimensionless coefficient. Since the only variable in that term is the service area, the second term is the dependent variable of service area.

The other fixed values are unit area and irrigation interval. Irrigation interval is dictated by the natural factors and has less flexibility. The influence of the unit area is mostly on the lower branches of delivery system. Its effect on the main system is negligible. A combination of service area, unit area and irrigation interval gives varying flexibility factors for service areas of different size.

The Irrigation Frequency

Irrigation frequency is determined by the water consumption of crops and moisture-holding capacities of soils. This is a fixed value for definite crops and soils. Irrigation should be completed within the predetermined period. However, to extend this period may not cause drought damage to the crops. Since the fifty percent of available moisture is taken to determine the irrigation interval, there will be some margin of safety.

In the application of the formula it can be seen that the canal serving the small farms will irrigate them in a short time, giving the farmer ample time to do the other farm jobs in the irrigation interval period.

As the acreages get larger the irrigation time on the farm also gets nearer to the irrigation interval. In large areas the necessary time to irrigate them will be the irrigation interval, and the flow in the canal will be almost continuous. As the acreages change, the water application system must also change. Considering the close relationship of acreages and water application time in the formula, the method presented can be applied to any delivery system. If the delivery system is based on rotation, then it is necessary to choose (T) as the rotation interval. In that case a suitable crop pattern for that period also should be chosen or the rotation changed to meet the crop pattern.

Conclusion

In the method presented, the capacity determination requirements are basic and can be obtained from conventional type surveys. Basic soil survey data, climate, crop pattern, and irrigation practices of local farmers are items to be considered in the capacity determination of the distribution system.

With the aid of this formula, many linea family functions can be drawn on an incremental base to visualize how the method works. Fig. 3 is such an example prepared for this purpose.

In Fig. 3 curves are almost parallel when the chosen acreages are large enough. Number (1) in the second term of the formula is negligible in such large areas, and capacity divided by the service area gives the water duty.

The unit area concept gives the designer a flexibility to consider other factors in the design of the lower part of a system.

In Fig. 4 the "S" and "Q" relationship, together with the previous article, is given. Blank circles are derived from the method presented.

The irrigation policy, technical and economic factors should be taken into account in capacity determination. Such factors can be considered by the designer taking advantage in the flexibility of the method.

SOIL TRIANGLE OF THE BASIC SOIL TEXTURAL CLASSES

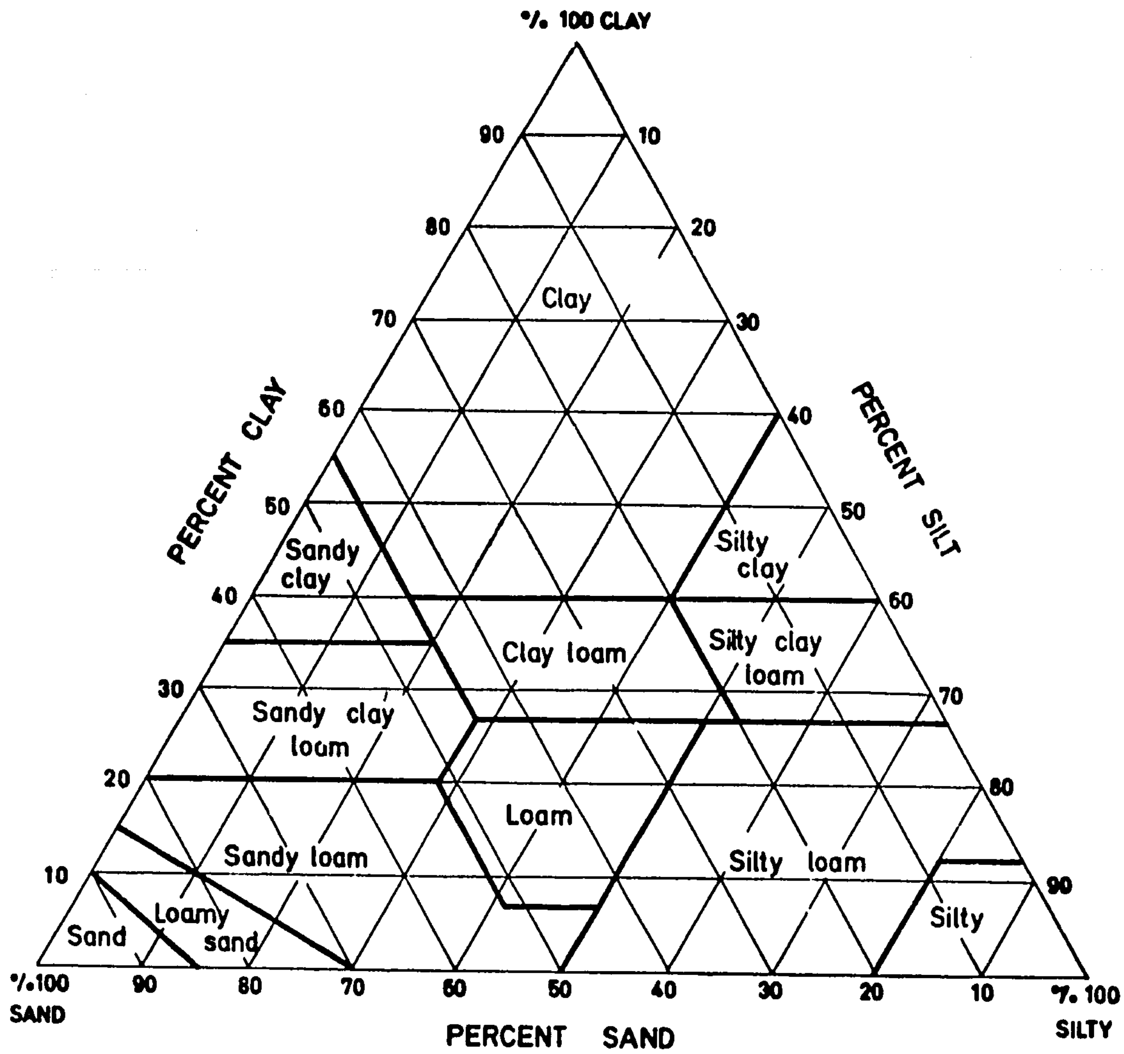

Figure : 1

SOIL TRIANGLE TO DETERMINE AVERAGE SOIL MOISTORE CAPACITY

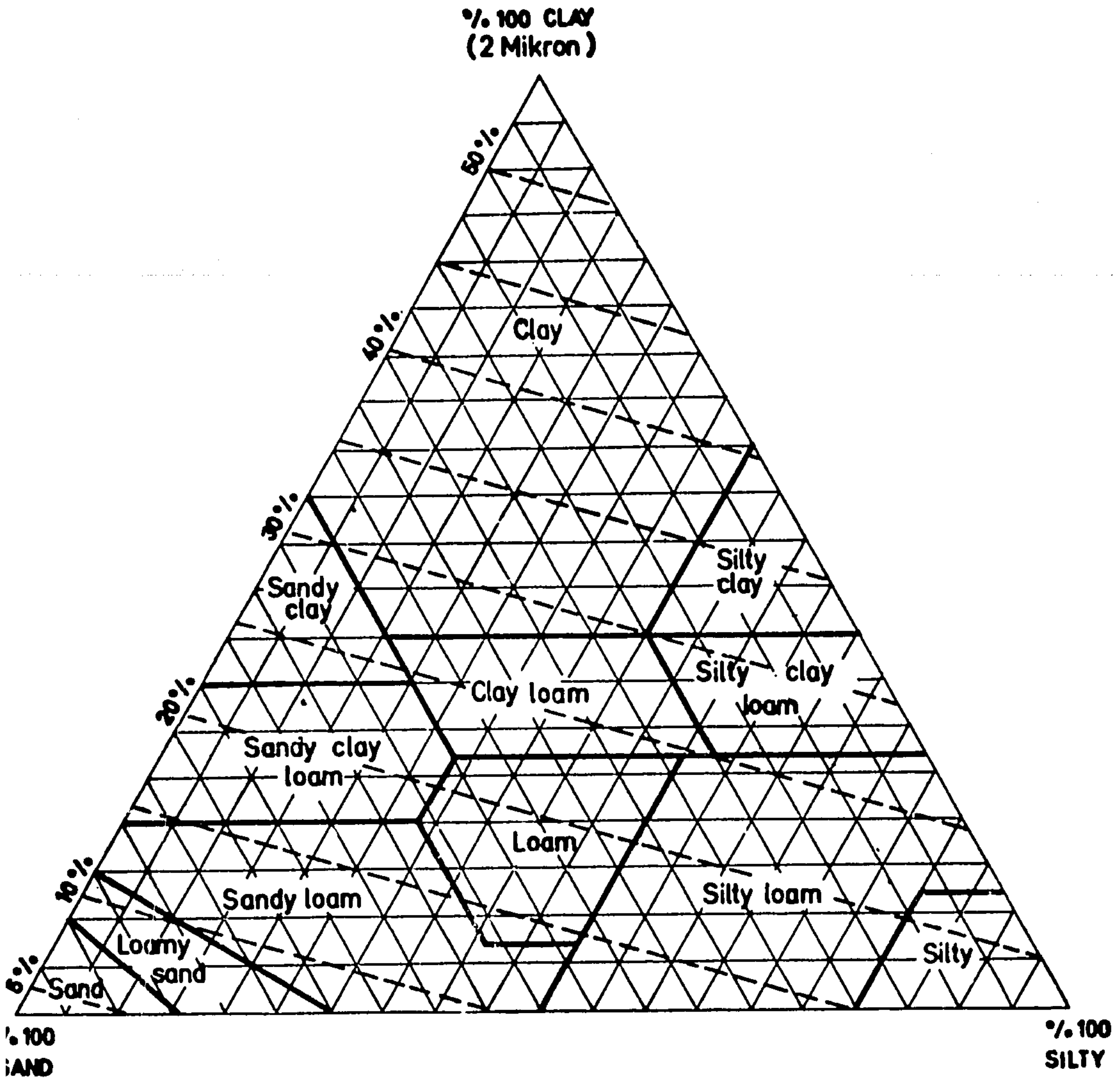

Figure : 2

Curves Showing the effect of Area to the Capacity

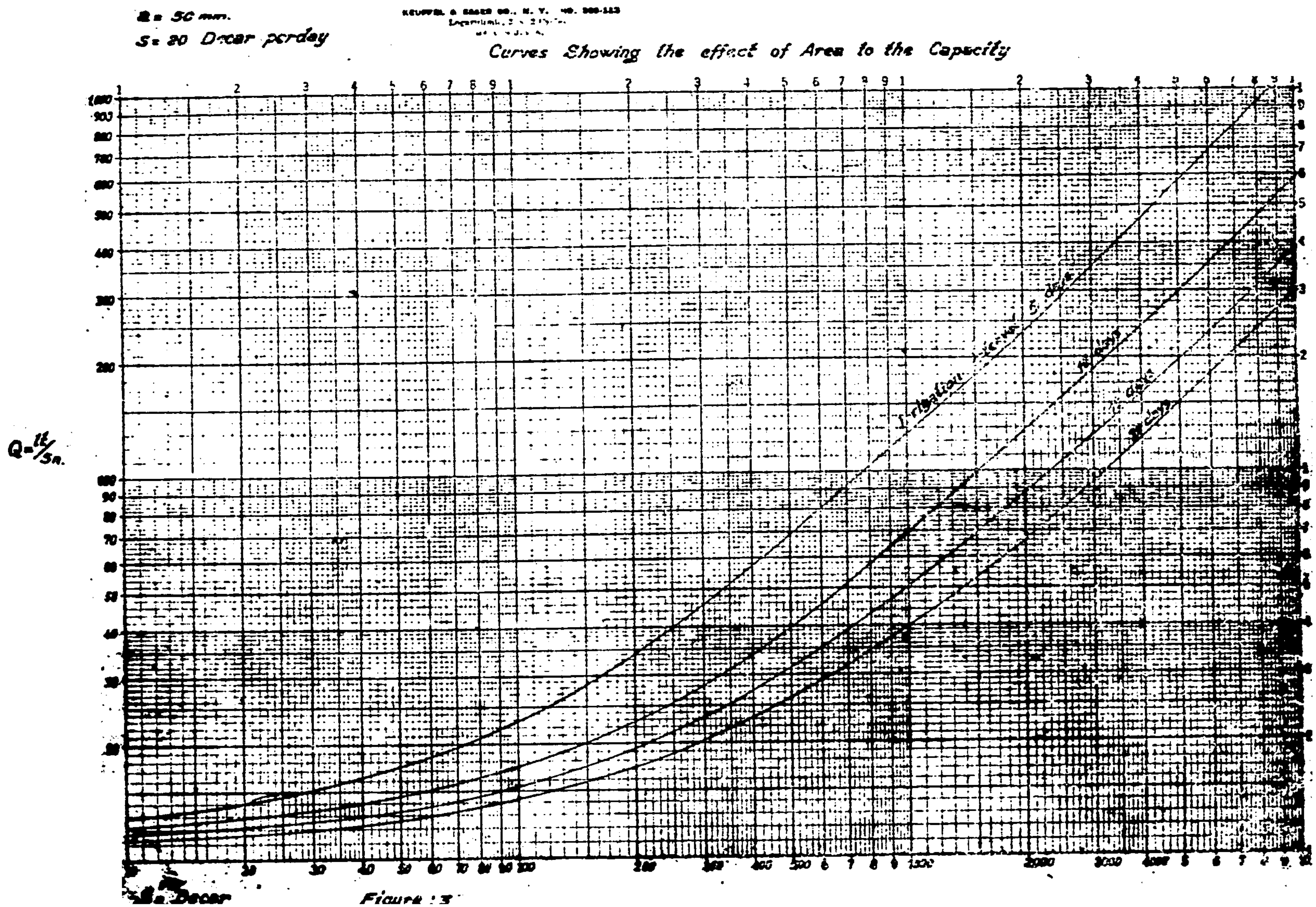

Figure 3

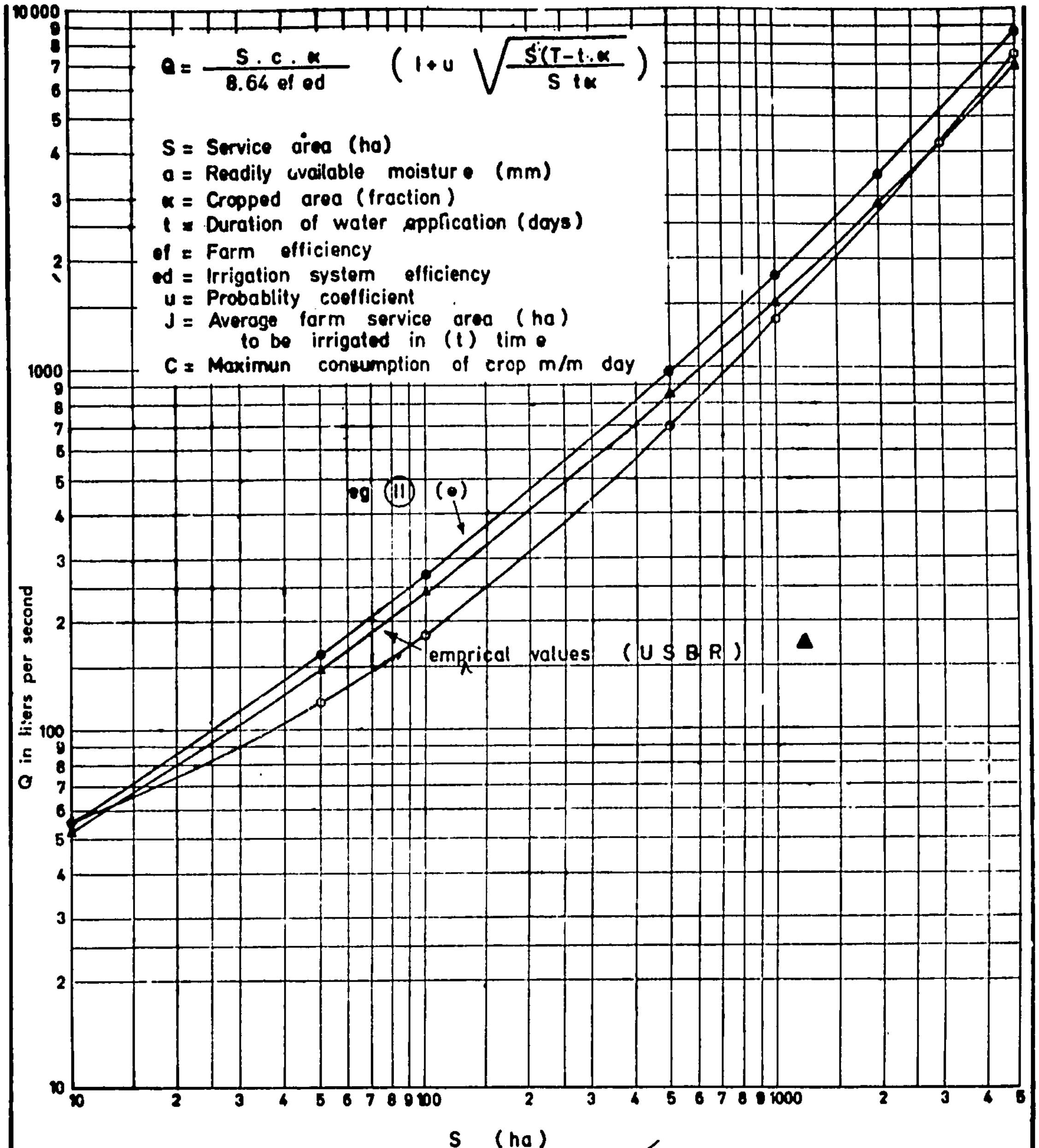

Figure : 4

Q vs S relation for the comparison of different methods with empirical data

a = 100 mm
∝ = 70 %
t = 1 days
ef = 65 %
e = From Fig 6
u = 1645 (% 5 exceedance)
s = 2.5 ha
c = 7 mm / day

Determining Design Capacities of Drainage Systems with Regard to Irrigation

by

SEREF OZGUL*

General

A primary function of a drainage system in agriculture is "the removal of excess water either from rainfall or from irrigation waste and excess salt on the surface and in the root zone of the soil."

In arid regions, as most of the NESA countries are, the first important function of drainage is to maintain the salt balance within the root zone. But in humid regions, maintaining moisture balance in the soil body is more important, and this is also achieved by drainage. In the light of this definition then, the excess water from the agricultural land should be removed in certain periods and should never be permitted to exceed a certain water quantity in the root zone.

The excess water may originate either from surface flows and/or from internal movement of groundwater in the soil body. The sources of excess surface water are irrigation waste water and runoff from precipitation.

The losses from conveyance channels and storage facilities or water moving from the groundwater at higher elevations can also be a source of excess water.

The sources of groundwater in an agricultural area can be grouped as follows:

(1) Deep percolation losses from irrigation and leaching water
(2) Canal or ditch seepage losses from canals within or bordering on the project area
(3) Leakage from surface water bodies at higher elevations
(4) Deep percolation of precipitation
(5) Upward leakage from artesian aquifers
(6) Movement of groundwater into the project area from other irrigated or upland areas outside the project area
(7) Seepage or percolation from irrigation canals, streams, lakes or other bodies of water outside the project area

When the total amount of water coming into the project area from these various sources is offset by the total quantity disposed of through natural processes, then a balance is reached. This occurrence is called a favorable water balance. Studies on determination of the water balance have vital importance in the justification of the drainage requirements and capacities for the various types of drains.

In a project area, the drainage requirement may originate from one or more sources. According to the nature of the sources of excess water, the types of drainage and drains will be different.

In general, if excess water comes from surface flow then a surface drainage is needed. But when groundwater needs to be controlled then sub-surface drainage will be required. As it is understood from this definition, the distinction between surface and sub-surface drains is based upon the location of the water at the time it becomes a drainage problem.

The nomenclature used for technical aspects of drainage, and as used in this paper, is based on the function of the drains. The four types of drains are: relief, interceptor, collector and main.

Relief drains are used to provide a general lowering of the groundwater in those areas where topography of the land surface is nearly level and where groundwater flow is very slight and mostly stagnant. These drains are also oriented parallel to the direction of groundwater. They have draw-down effect equidistant on both sides of the drain.

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Interceptor drains are used to cut off groundwater moving downslope from whatever source. These drains are located in areas where groundwater has considerable gradient. They are perpendicular to the direction of groundwater flow and are effective only to some distance below the drain. Both relief and interceptor drains may be of either open or closed construction.

Collector drains receive flows from sub-surface and surface drains carrying irrigation waste and storm flow. They may be of either the open or closed type.

Main drains are used to convey water from other drains to the disposal point. They receive flow mainly from collector drains and canal wasteways. Sometimes they are called outlet drains.

In addition to these drains there are also special purpose drains. Since these are beyond the scope of this paper, no attempt has been made to include them here.

Factors that Affect the System Capacities

Besides the factors mentioned in the introduction of this paper, the following specific factors are of importance so far as drainage capacities are concerned: upward seepage or artesian flow, sub-surface flow and seepage under special cases such as seepage from the irrigation of higher lying lands or seepage caused by rainfall or snowmelt on high lying areas, and quality of irrigation water for leaching.

Specific factors are not as common as the general factors and are usually difficult to determine. Each case requires individual investigation and should be considered accordingly.

Calculation of Excess Water

According to the explanation given in the preceding paragraphs, excess water and the accretions to the drains may be classified as follows:

(a) Surface runoff from precipitation
(b) Deep percolation from precipitation
(c) Surface runoff from irrigation
(d) Deep percolation from irrigation
(e) Distribution losses
(f) Upward seepage
(g) Sub-surface or groundwater flows

Considering the nature and properties of these factors (a), (b), (c), (d) and (e) will be grouped together and explained under the heading of *Water Balance Computations* and the rest will be explained individually.

(1) *Water Balance Computations*

A method has been developed to calculate surface runoff and deep percolation from precipitation and irrigation and from distribution losses. This method depends mainly on water balance computations and the following assumptions:

(a) The soil profile has a certain amount of water-holding capacity to maintain a rapid crop growth. This capacity is known as readily available moisture and has to be determined prior to computation.

(b) Practically all crops extract moisture mainly from the first 120 centimeters and this depth is enough for most of the irrigated crops.

(c) Irrigation water should be applied after a certain percentage of the readily available moisture has been depleted. Here the extraction is taken as seventy percent.

(d) The irrigation consumptive use is limited by the readily available moisture capacity of the soil.

(e) The crop consumptive use requirement is met by both precipitation and irrigation water.

For convenience in this method of computation a calculation table was prepared to include every step and to include all of the factors.

The computation of the water balance and the determination of excess water by use of this table is illustrated by an example from a project in southern Turkey (Table 1). In this table line (1) gives the potential evapo-transpiration. It can be computed by any empirical, experimental or theoretical method, whichever is available or appropriate. In the example, the Thornthwaite method is used and the results converted to Penman evapo-transpiration by using the equation: Penman-evapo-transpiration = 0.84 (Thornthwaite-evapo-transpiration) + 0.20 (a paper was given on this subject at the Fifth NESA Seminar).

On line (2), the daily and monthly figures of the actual evapo-transpirations are given. It is known from many studies and experiments that the actual evapo-transpiration is less than the potential evapo-transpiration during the period when precipitation is less than potential evapo-transpiration, and when readily available moisture of soil is depleted to a level that the crop requirement cannot be met. For that reason, in the months in which precipitation is higher, the actual evapo-transpiration figures are copied from line (1), and for the remaining summer months figures of line (1) have been multiplied by a factor of 0.85. On line (3), the monthly precipitation figures are shown. This figure must be representative of the normal months as near as possible. Effective precipitation as the portion of the rainfall entering into the soil, line (4), has been found from a chart developed by the U.S. Bureau of Reclamation and corrected for Turkey's conditions. Surface runoff, line (5), is taken as the difference between line (3) and line (4). Precipitation deficit, line (6), is indicated as the excess of actual evapo-transpiration over effective precipitation.

On line (7), readily available moisture of soil and its variations during the year are given. Readily available moisture is determined for the 120 centimeters depth of soil and for the critical depth of the profile. It is necessary to choose a month in which available moisture of soil is completely depleted as the starting time to calculate the amount of readily available moisture which will be stored in the soil. This month in our example was November. Hence under dry conditions prior to November all the moisture in the soil would be completely used due to the deficit of precipitation in the months of July through October.

After determining the beginning of the moisture storage and the amount, the variations of the readily available moisture could be processed for the remaining months. Figures in this line represent the amounts which will be transferred to the next month.

The deep percolation loss from precipitation is given on line (8) and is found by subtracting the actual evapo-transpiration plus replenished soil moisture from the effective precipitation. If the soil moisture has been depleted in the preceding months then there will be no deep percolation. For convenience the unit has been used as millimeters per day on this line.

The net amount of irrigation water requirement, on line (9), is assumed as the same amount of readily available moisture capacity of the soil. In this column also the numbers of the calculated irrigations for each month are shown. In the example, two irrigations were necessary for the month of August.

The farm delivery requirement, line (10), is obtained by dividing the irrigation water-use requirement on line (9) by the assumed farm efficiency. In our example, farm efficiency is assumed as fifty percent.*

Diversion requirement is shown on line (11) and is obtained by dividing the farm delivery requirement in line (10) by the assumed diversion efficiency. Considering the farmer's skill in irrigation, losses from the operation of the irrigation system, etc., as the factors governing the conveyance losses, an appropriate diversion efficiency can be chosen. In our example it was chosen as seventy-five percent.*

On line (12) as a part of the farm irrigation waste an estimated surface runoff is shown. In Turkey, according to the farmers skill, irrigation method used, and the surface conditions of the project lands to be irrigated, it is usually assumed as five to ten percent of line (10). For the calculation of daily runoff the estimated figure has

* For lines (10) and (11) the total requirement will be achieved by two respective diversions as shown in Table 1.

been divided by three. In Turkey, irrigation of one hectare takes about one day, and two days are allowed for general field crops. For this reason a period of three days to remove the surface runoff from irrigation is estimated. The deep percolation from irrigation as the other part of farm waste has been shown on line thirteen. Daily amount of deep percolation can be calculated as follows:

$$\text{Deep Percolation (millimeters per day)} = \frac{\text{Line 10}\left[100-(\text{Surface Runoff Percent} + \text{Farm Efficiency Percent}\right]}{100 \times \text{Irrigation Interval (day)}}$$

Distribution system losses as deep percolation from the main canal, deep percolation from secondary and tertiary canals, and operational wastes are shown on lines (14), (15) and (16) respectively, and totalled on line (17).

Distribution losses are related to diversion efficiency. For that reason they are estimated according to the percentage shown on line (11). To calculate the daily amount of distribution losses it is necessary to know the period in which canals have water. This can be determined by knowing the water delivery system. In Turkey, the demand and rotation systems are used. This example is for demand system where the canals have water almost all the time from beginning of irrigation to the end of the season. Due to the existence of water permanently, this estimated amount is divided by thirty, for the calculation of daily amount as millimeters per day.

In this method of calculation only general factors have been considered to establish a drainage requirement.

(2) *Determination of the Effect of Specific Factors*

For calculation of excess water from specific factors such as upward seepage under artesian pressure, sub-surface flow, etc., the occurrence and areal distribution of the excess water of this nature must be determined.

(3) *Storm Runoff*

Runoff flow from storms with certain frequencies vary according to the soils, vegetal covers, land use, topography, and the hydro-meteorological characteristics of the project areas.

The best method of estimating drainage requirements for storm runoff is the study and comparison of existing drainage structures and the hydro-meteorological records. When there is no possibility to make a study of the kind then some type of analytical method can be used. Under these conditions, in Turkey, either the rational or McMath formula is used. According to some investigators, both formulas give fairly reliable and close results when the "C" factor (coefficient for basin characteristics) is properly selected.

Determination of Drainage System Capacities

(1) *Capacities of Surface Drains*

These should be determined for storm flow only. The reason for this is the fact that the value for storm flow is usually much greater than the value for runoff from normal precipitation and for irrigation waste. In Turkey the storm flow is obtained from one of the following frequencies: five, ten, twenty-five and fifty-year frequency storms. In general, a ten-year frequency is used. When there is need for a conservative design against the damage or where there is a more expensive structure, then flows of lower frequencies are used.

TABLE: I PROJECT WATER BALANCE COMPUTATIONS
SAMPLE PROJECT SİLİFKE

LINE	ALL VALUES IN mm.		MONTHS AND DAYS											
			January 31	Febru. 28	March 31	April 30	May 31	Jun 30	July 31	August 31	Sept. 30	Oct. 31	Nov. 30	Dec. 31
1	Potantial Evapotranspiration		17	19	34	59	102	146	181	173	126	82	42	21
2	Actual Evapotrans-piration	Montly	17	19	34	50	87	124	154	147	107	70	42	31
		Daily				1.7	2.8	4.1	5	4.7	3.6	2.3		
3	Precipitation		135	118	52	25	22	5	0	2	13	49	83	137
4	Effective Precipitation		98	90	47	23	20	4	0	2	12	45	77	99
5	Runoff (Line 3 - Line 4)		37	28	5	2	2	1	0	0	1	4	6	38
6	Precipitation Deficit (Line 2 - Line 4)		0	0	0	27	67	120	154	145	95	25	0	0
7	Readily Available Moisture and Its Variation RAM..............92..mm.		92	92	92	65	90	62	0	39	36	11	46	92
8	Deep Percolation From Precip (mm/day) [Line 4 - (Line 2 + Replenished Mois)]		2.6	2.5	0.4	0	0	0	0	0	0	0	0	0.7
9	The Net Amount of Irrigation Water Use Requirement To Be Applied		0	0	0	0	92	92	92	92x2	92	0	0	0
10	Farm Delivery Requirement [(Line 9 x 1/Field Ir. Efficiency 50%)]		0	0	0	0	184	184	184	184 x2	184	0	0	0
11	Diversion Requirement [(Line 10 x 1/Diversion Efficiency 75%)]		0	0	0	0	245	245	245	245 x2	245	0	0	0
A	Farm Wastes													
12	Runoff (mm / day) (.....10..% of Line 10/3)		0	0	0	0	6	6	6	6	6	0	0	0
13	Deep Percolation (mm/day) Line 10[100-(Runof % + Field I. Eff. %)] / 100 x Irrig. Interval (days)		0	0	0	0	3.2	4.1	4.1	3.9	3.4	0	0	0
B	Distribution Sys. Losses													
14	Deep Percolation From Main Canal (mm/day) (.....15..% of Line 11)/30						1.19	1.23	1.19	1.19	1.23			
15	Deep Percolation From Secondary and Tertiaries (mm / day) (.....5..% of Line 11)/30						0.40	0.41	0.40	0.40	0.41			
16	Operational Wastes (mm / day) (.....5.% of Line 11)/30						0.40	0.41	0.40	0.40	0.41			
17	Total Distribution Losses (Line 14 + 15 + 16) (mm / day)						1.99	2.05	1.99	1.99	2.05			

In computation, the flow is calculated so as to remove the water in about two days and not immediately after the rain. In the example this period was taken as two days for field crops.

(2) *Capacities of Sub-surface Drains*

Capacity calculations of sub-surface drains will change, depending on whether they are of the open or closed type and whether they are interceptor or relief drains.

For the computation of open relief drains the following factors should be taken into account:

(a) Deep percolation from precipitation
(b) Surface runoff from irrigation
(c) Deep percolation from irrigation
(d) Total distribution losses
(e) Upward seepage

For the sub-surface open interceptor drain the factors mentioned above, and also sub-surface groundwater flow from upper parts, should be considered.

For the sub-surface closed relief drains, the factors would be as follows:

(a) Deep percolation from precipitation
(b) Deep percolation from irrigation
(c) Deep percolation from main canal
(d) Deep percolation from secondary and tertiary canals
(e) Upward seepage

For the sub-surface closed interceptor drain, in addition to the foregoing factors, sub-surface flow from upper areas should be added.

(3) *Capacities for Collector Drains*

These drains are generally built as open drains.

If they are open type then in the computations of capacity the following factors should be considered:

(a) Groundwater accretions and irrigation surface wastes in the area
(b) Runoff from storm flow
(c) Quantities delivered to the collector drains by the sub-surface drains

If they are not open type drains, then no surface accretions in the capacity calculations will be included.

(4) *Capacity of Main Drains*

These are the deepest and largest drains. Their capacity is calculated to carry the flows from the collector drains feeding them.

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CHAPTER X

Research

EVALUATING LANDS FOR IRRIGATION COMMANDS

by

Dr. N. G. Dastane and Shri C. S. Saraf*

Summary

Factors affecting the choice of irrigation commands for economic use of water for sustained crop production have been discussed. A simple but comprehensive system is proposed for rating lands for irrigation commands based on five important factors, namely, available water-holding capacity, permeability, depth to water table, soluble salt content, and exchangeable sodium percentage.

Introduction

Heavy costs involved in building irrigation projects and the ever present risk of permanent damage to the soil by mismanagement of water necessitate the consideration of irrigability of the lands and the potentialities of the welfare in the area. The primary motive, therefore, in evaluation of land is to assess its capacity to withstand intensive irrigation without any deterioration and secondly to assess its perpetual productivity per unit of water applied.

Experimental work as well as experience gained in the past three decades in irrigation projects and practices have brought out the relative importance of several factors affecting suitability of soils for irrigation. These factors can be classified as shown in Table 1.

Physical and Chemical Factors

The loamy texture is ideal in irrigation, and deviation on either side lowers the value of the land. The clayey texture hinders leaching and results in poor aeration, while the sandy texture increases water application losses. High values of available water-holding capacity, depth of soil and non-capillary porosity are desirable characteristics from both the irrigation and drainage points of view and therefore, soils possessing such properties are excellent for irrigation. As regards the permeability to water, the moderate values are the best and the extremes on either side are harmful. The deeper the water table the better the land, as it can be drained satisfactorily and

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Table 1

Factors Affecting Choice of Irrigation Commands

Physical	Chemical	Climatological	Miscellaneous	Humanitarian
(1) Texture (2) Permeability (3) Non-capillary porosity (4) Water-table depth (5) Soil depth (6) Topography (7) Water-holding capacity	(1) Soluble salt content (2) Exchangeable sodium percentage (3) pH	(1) Aridity (2) Cropability	(See Narrative Description)	

hazards such as waterlogging, salinity and alkali problems are not involved. A good leveled land is the most suitable for even distribution of water on the surface and in the profile. The steeper the slope, the more the land is wasted in bunds and channels in surface irrigation methods and the development cost is higher. Contour irrigation enables one to reduce such land wastages to some extent. Similarly, development of sprinkler irrigation dispenses with the need of leveling and grading operations and thus reduces the importance of topographic factors.

Higher contents of soluble salts result in salinity problems and those of exchangeable sodium in alkali problems. Hence the values of both these characteristics should be as low as possible for high rating of the land. The pH beyond 9.0 is undesirable on account of alkali hazards. Neither is the pH below 4.5 good, as availability of nutrients to plants becomes a limiting factor.

The limits for the various physical and chemical characteristics are shown in Table 2.

The land has been classified into four classes namely, excellent, good, fair and poor, according to the value of the characteristics. The land in the last class is generally dangerous or uneconomic to bring under irrigation. If water is available at all, special efforts are needed to obtain economic yields of crops.

The texture in column 2 is that of surface soil as well as sub-soil. The available water-holding capacity in column 3 is to be taken into account for the top one-meter layer. In case the soil is, say, only half a meter deep and holds one hundred millimeters of water, the value for the lower half meter will be nil and for rating purposes the total of both the layers will be one hundred millimeters. The steep topography can be handled safely with contour layout systems, selection of optimum plot size, and provision of water control structures. The slopes steeper than ten percent involve higher development costs in surface irrigation methods and hence from an economic point of view, such land is rated as poor. While considering depth to water table in column 5, potentiality of water rise after introduction of irrigation needs to be considered. If the soil is well drained, naturally no dangers of any ill effects are involved.* As regards to permeability and pH, medium values are the best and deviations on both sides are not good. Hence in columns 6 and 10, two ranges have been given in prescribing the limits in the three lower groups.

For assessment of the characters, namely, the permeability, non-capillary porosity, soluble salt content and exchangeable sodium percentage, values of the limiting layer in a root zone are to be taken into account. Thus if the surface soil is permeable and sub-soil impermeable, the latter will be taken into account.

* Potentiality of water rise can be estimated from the factors such as rainfall, irrigation application and efficiency, potential evapotranspiration, inflow and outflow of the area and drainability of soil.

Even though limits for ten characteristics have been given in Table 2, only five are generally adequate for evaluation of the land for irrigation purposes. These are: available water-holding capacity, permeability, depth to water table, soluble salt content and exchangeable sodium percentage. These five characteristics take care of the others indirectly; for example, from the available water-holding capacity, texture and depth of soil can be judged. These five basic characteristics, along with the score for rating, are shown in Table 3.

For every excellent, good, fair and poor class, 3, 2, 1 and 0 marks are suggested respectively. After this marking, the scores of the five characteristics are to be multiplied together to obtain the final score (A x B x C x D x E). On the basis of this score, the following classes are suggested for final rating:

Class	Description	Score
I	Excellent	Above 80
II	Good	50-80
III	Fair	16-49
IV	Poor	2-15
V	Unsuitable	0-1

Thus, a soil having good texture, permeability and low soluble salts and exchangeable sodium percentage, but high water table, will score zero and will go in Class V. Any single limiting factor will thus render the soil unsuitable for irrigation.

Mehta, et al., (1958) have suggested a rating system for the Chambal commanded area into four irrigability classes based on profile characteristics, namely, texture, permeability, capillary porosity, pH, soluble salts and exchangeable sodium. Their rating system is numerical and additive and the total is 100. Their system is satisfactory but suffers from a serious defect in that adequate consideration is not given to a limting role played by a single factor which may sometimes render the soil unsuitable for irrigation. The system suggested herein is free from that defect.

Another salient feature of this method is that the layer taken for assessment for any characteristic is the most limiting layer in the root zone. It is not necessary to consider all the layers, as suggested by Storie (1933) and Mehta et al. (1958).

Storie (1933) has given too much importance in his 'Factor A' to the degree of weathering, while in his 'Factor B' he considers only the texture of the surface soil, neglecting completely the characteristics of the subsoil. The rating system proposed here is simpler than those proposed by Storie (1933) and Thorne and Peterson (1954), and yet differentiates the essential characteristics clearly.

Climatological Considerations

(a) *Aridity.* Water needs of the plants mainly depend upon aridity or evapotranspirability of water by the climate and hence a higher potential evapotranspiration, reduces the production per unit of water applied and vice versa. Hence from a national point of view, it is desirable to prefer such areas with low potential evapotranspiration to high potential ones for the economic use of irrigation water. Selection of areas with low evapotranspiration also enables more extensive irrigation and thus ultimately greater production. In simple words, irrigate the cooler tract rather than a hotter tract and prefer winter irrigation to summer irrigation, other factors being non-limiting.

(b) *Cropability.* As the development of the land for irrigation involves heavy costs for leveling, constructing irrigation channels and drains, it is necessary that irrigated farming be done throughout the year. If the climate is free from frost hazards, typhoons and gales, and if it permits cropping around the year, it is the best area for bringing under command.

Miscellaneous Factors

The miscellaneous factors include presence of some unfavorable non-basic characteristics such as soil-borne [illegible] disease, noxious weeds, near-

Table 3

Score Card for Rating Important Physical and Chemical Characteristics in Evaluation of Land for Irrigation Commands

Description	Available water-holding capacity of top one-meter layer	Permeability to water	Depth to water table	Soluble salt content	Exchangeable sodium percentage
	A	B	C	D	E
Excellent	3	3	3	3	3
Good	2	2	2	2	2
Fair	1	1	1	1	1
Poor	0	0	0	0	0

ness of hardpan, infertility, etc., the presence of which is a limiting factor in crop production. These limitations can be remedied but may involve high costs, depending on the intensity of the problems.

Humanitarian Considerations

Profits alone can never be the sole factor in selecting areas for irrigation commands. The humanitarian considerations are equally important in many places. There may be acute hardships faced by a community in a particular tract in obtaining the bare necessities of life, such as food and water. There are several places in India, in the dry farming areas of the south and in the Rajasthan Desert where drinking water is a priced commodity. It is necessary to move several miles to bring a bucket of water. Under such circumstances, it becomes a dire necessity to supply water in that tract for bare existence. Extensive protective irrigation is needed in such tracts for general welfare of humanity, and economics hardly enters the picture.

Thus it can be seen that it is necessary to have a thorough knowledge about the various physical and chemical characteristics of the soil and meteorological factors and economic conditions of the inhabitants before putting it under irrigation, to avoid hazards of development of waterlogging, salinity and alkali problems. Pre-irrigation surveys are, therefore, conducted to give complete information of the proposed command area (Raychaudhuri, 1964). After a pre-irrigation survey, only the most suitable areas should be brought under command. Post-irrigation surveys are then conducted within a period of five years after the operation of the project to examine the changes that have taken place in various physical and chemical properties. If any problems have developed then proportionate increased care is necessary.

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Table 2

Limits for Different Characteristics in Evaluation of Land for Surface Irrigation

Description	Texture of surface soil as well as sub-soil	Available water-holding capacity (mm. of water per meter soil depth)	Topography (Slope percent)	Potentiality of water-rise after introduction of irrigation. Depth from the surface level	Minimum permeability in root-zone (mm./hr.)	Minimum non-capillary porosity (percent)	Maximum soluble salt content in root zone	Maximum exchangeable sodium percentage in root zone	pH	Depth of soil (cm.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Excellent	Loam	Greater than 175	0-1	Always below 300 cm.	15-25	Greater than 20	Less than 0.20	Less than 5	6.5-7.5	Greater than 150
Good	Clay-loam or Sandy-loam	100-175	1-3	Always below 200 cm.	10-15 or 25-50	15-20	0.20-0.30	5-10	7.5-8.5 or 5.5-6.5	50-150
Fair	Clayey or Fine sandy	25-100	3-10	Below 100 cm.	5-10 or 50-125	5-15	0.30-0.50	10-15	8.5-9.5 or 4.5-5.5	10-50
Poor	Coarse sandy or Gravelly	Less than 25	Greater than 10	Within 100 cm.	Less than 5 or more than 125	0-5	Greater than 0.50	Greater than 15	Greater than 9.5 or less than 4.5	Less than 10

EVALUATION OF SPRINKLER METHOD OF IRRIGATION AND ITS COMPARISON TO FURROW METHOD

by

B. Bahrani, Ph.D., M. Javan and Y. Mehdizadeh *

Abstract

The sprinkler system of the College of Agriculture's Experimental Farm was tested in a series of experiments for the effects of overlap, wind and time of operation (day and night). The application and distribution efficiencies have been used as criteria for this evaluation.

The sprinkler method of irrigation was also compared with the furrow method on two crops of chick peas and potatoes, in two consecutive years. The change in soil apparent density, the yield and the crop quality have been taken as the criteria for this comparison.

The results of these studies are as follows:

(1) The wind velocity caused a significant decrease in distribution efficiency of the sprinkler system.

(2) In the sprinkler system the evaporation losses were far greater during the day than at night.

(3) Comparing the application and distribution efficiencies of the sprinkler system for thirty-three and seventy-seven percent overlap, it is concluded that the thirty-three percent overlap gives better results.

(4) In the chick pea crop, the drops of water from the sprinklers caused the top soil to be compacted.

(5) The sprinkler method gave a better yield of chick peas and potatoes.

(6) The average potatoes tuber weight was much greater for the sprinkler method.

Introduction

The sprinkler method of irrigation has been started recently in Iran, but it has not been evaluated yet for all environmental factors. This method of irrigation has the advantage of lower water losses, simplicity of operation, and practicability on all kinds of land topographies.

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Among its disadvantages are its high cost, the skills demanded for its operation, and of course the fact that it is not adaptable for all environmental conditions. In some cases, the sprinkler method may be hazardous or not economically feasible for a particular soil or crop condition.

Many experiments have been done in all parts of the world on sprinkler irrigation, the results of which mostly show that the method is more efficient, less time-consuming, and gives better results on shallow rooted crops (5). Taylor (7), studying the effect of soil moisture tension on the yield of various crops under both sprinkler and furrow irrigation, has reported that it is much easier to keep soil moisture tension below a certain level in the sprinkler method. His results show that it takes almost twice as much water to keep the average soil moisture tension under the furrow method as it does under the sprinkler method. There is only one published report of an experiment on sprinkler irrigation in Iran. That is an experiment done at Karaj Agricultural College on beans (3). This experiment shows that the method has a greater application efficiency and produces a greater yield.

The objectives of this study are: (a) to evaluate the sprinkler system of the College of Agriculture's Experimental Farm and test it for the effects of wind, overlap, and time of operation (day or night); (b) to compare the sprinkler with the furrow method from the viewpoint of yield, crop quality and effect on physical conditions of soil.

Evaluation of Sprinkler Method*

A German-made sprinkling system, called Perrot, model KSKR, was used in this study. The system was recommended for twenty hectares of land by the manufacturing company, and had a capacity of sixty-six cubic meters per hour.

The recommended design of the system is a main pipe with four laterals and a total of twenty-four nozzles. The nozzles' opening was six millimeters and needed 4.35 atmosphere of pressure for proper operation.

* For further information about this experiment see reference No. 6.

The method used for evaluation of the system was the one recommended by Criddle and others (2). The crop under irrigation was alfalfa. While the whole system was in operation, two adjacent nozzles were chosen, on which six different experiments, as shown in Table 1, were run. These experiments were done at two different overlaps (thirty-three and seventy-seven percent)* and at two different times (day and night), under different wind velocities. The duration of sprinkling in each run was exactly four hours in each experiment. The pressure, the discharge rate, and the radius of sprinkling were the same in all runs. Soil samples were taken to a depth of forty-five centimeters for moisure determination one day before and after each irrigation. Samples were taken from four different locations chosen at random; and in each location, three samples with fifteen-centimeter intervals. A set of spray gauge cans installed on the corners of a network of squares 3x3 meters in size. The depths of the water caught by these cans were measured after each run.

The application efficiency of irrigation was calculated by the use of equation

$$Ea = \frac{Ws}{Wa} \times 100 \quad (1)$$

and by two methods: one by using soil sampling data and the other by using water measurements of the gauge cans. In the former case, "Ws" of equation (1) is stored water in the soil calculated from the sampling data, and "Wa" is the amount of water applied by the sprinklers (measured by the volumetric sampling). In the latter case, "Ws" is the average depth of water caught in cans and "Wa" is applied water.

* The laterals were made of six-meter-long pipes which were jointed together, so that thirty-three and seventy-seven percent intervals represent twenty-four and eighteen meters of spacing.

The distribution efficiency was calculated by the use of equation

$$Ed = 1 - \left(\frac{y}{d}\right) 100 \qquad (2)$$

and with the two above methods of calculating application efficiency. In this equation "d" is the mean depth of stored water (calculated from sampling or gauge can data) and "y" is the average numerical deviation in depth of water stored in the soil (calculated from sampling data, or calculated from gauge can data) during each irrigation. The use of equations (1) and (2) was introduced by Israelsen and Hansen and has been used for many years (5).

Comparison with the Furrow Method

This experiment was also conducted at the College's Experimental Farm and was repeated on two crops: chick peas and potatoes, in two consecutive years (1964 and 1965). The first-year experiment was on chick peas, which were planted in rows fifty centimeters apart. The whole field was first irrigated by furrows until the plants were germinated, and then was divided into six plots of fifty by twenty meters size. From then on, three of these plots were irrigated by sprinklers and the other three by furrows. The furrow and sprinkler plots were alternately adjacent to each other. In each irrigation the time was controlled and the discharge rate was measured (for furrows by Parshall flumes, and for sprinklers by the volumetric measurement of discharge rate of each nozzle).

The second-year experiment was on potatoes, which were planted in rows eighty centimeters apart. All other things were done exactly as in the first-year experiment, except that at harvest time the yield of 160 square meters from the center of each plot was weighed and converted to yield per hectare, samples were taken from the tubers of each plot, and the average weight of one tuber was determined for each plot.

Results and Discussion

The results of six different experiments on the sprinkler system are shown in Table 1. As is shown in this table in experiment No. 1, where the wind velocity was the greatest (about seven times as much as the others), the poorest distribution efficiency was obtained. The fifth column of Table 1 shows the application efficiency calculated from gauge can data. The difference between these figures and 100 indicates the evaporation losses in each run. These figures indicate greater evaporation losses during the day (the average loss for day being 15.5 and that for night being 6.8 percent). To compare the two overlaps, the figures of Table 1 are averaged out and are shown in Table 2. This table shows that the thirty-three percent overlap gave a much better application efficiency than the seventy-seven percent overlap, but the distribution efficiency was slightly greater for the seventy-seven percent overlap. This means that the seventy-seven percent overlap gave a slightly higher distribution efficiency, but that due to greater application efficiency, the use of thirty-three percent overlap is more economical. These results are as a whole in agreement with those reported by previous investigators (one and four).

Table 3 shows the apparent densities of the top-soil and sub-soil under the two methods of irrigation for the first-year experiment. These figures indicate that the apparent density of the top soil measured at harvest time was greater for the soil under sprinkler irrigation, the difference being statistically significant. The apparent densities for the sub-soils under the two irrigation methods did not show a significant difference. It is obvious that the greater value for the apparent density of the top-soil in sprinkler irrigation is due to the compaction effect of the sprinkler drops, which can affect only the top-soil and not the sub-soil. In Table 4 the yields of the chick peas for the two methods are shown. The water use was 24.73 and eighteen centimeters for the sprinkler and furrow methods respectively (these data are the rate of soil moisture depletion after the plots were irrigated by furrows and sprinklers). It is seen in Table 4 that the yields of seeds and plant tops were greater for the sprinkler method. Table 5 shows the yield of potatoes and the average weight for one tuber for the two methods. The water use in this case is 41.9 and 42.9 centimeters for sprinkler and furrow methods respectively. The average soil moisture tension in the root zone measured by tension meters for the two methods was calculated also to be 0.6 and 0.62 atmosphere for sprinkler and furrow methods respectively. The data of Table 5 also indicate a higher yield and heavier tubers for the sprinkler method. The results of apparent density measurement did not show a significant difference between the top and sub-soils under the two methods of irrigation in the potato experiment. This can be attributed to the fact that for a potato field more hoeing and mounding is common, which makes the soil more porous, and this modifies the compaction effect of sprinkler drops.

Conclusions

(1) The wind velocity caused a significant decrease in distribution efficiency of the sprinkler system.

(2) In the sprinkler system the evaporation loss was greater during the day than at night.

(3) Comparing the application and distribution efficiencies of the sprinkler system for thirty-three and seventy-seven percent overlap, it is concluded that thirty-three percent overlap gives better results.

(4) In the chick pea crop, the drops of water from the sprinkler caused the top soil to be compacted.

(5) The sprinkler method gave a better yield of chick peas and potatoes.

(6) The average potato tuber weight was much greater for the sprinkler method.

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Table 1

Values of application efficiency (Ea) and distribution efficiency (Ed) calculated from gauge can and moisture sampling data for six different experiments

No.	Time	Overlap	Velocity Wind	Ea W	Ea M	Ed W	Ed M
1	D	33	7.5	88.7	86.2	60.7	66.67
2	N	33	1.0	96.8	93.2	73.4	77.00
3	N	33	0.5	95.3	95.77	76.2	69.4
4	D	77	1.0	84.56	76.0	79.8	77.0
5	D	77	2.0	80.34	64.9	78.24	62.5
6	N	77	1.0	87.6	72.0	70.35	83.4

Table 2

Mean values of Ea and Ed for thirty-three and seventy-seven percent overlaps. (Data of Table 1 with the exception of those of Run 1 is used for obtaining this Table)

Overlap	Wind Velocity	Ea		Ed	
		W	M	W	M
33	0.75	96.0	94.5	74.8	73.2
77	1.00	83.1	70.6	76.1	80.9

Table 3

Apparent density values for ten samples of top and sub-soil under sprinkler and furrow methods of irrigation

	Sprinkler		Furrow	
	Sub-soil	Top-soil	Sub-soil	Top-soil
	1.45	1.44	1.64	1.26
	1.39	1.47	1.46	1.22
	1.43	1.33	1.69	1.05
	1.14	1.44	1.18	1.25
	1.42	1.63	1.39	1.33
	1.36	1.63	1.37	1.27
	1.32	1.43	1.32	1.19
	1.37	1.41	1.30	1.18
	1.27	1.48	1.32	1.31
Averages....	1.35	1.49	1.41	1.24

Table 4

Yield and water use of chick pea crop under sprinkler and furrow methods of irrigation

	Furrow			Sprinkler		
Plot Number	1	3	5	2	4	6
Seeds	656	833	944	1856	1188	896
Kilograms per Hectares						
Average		**744**			**1313**	
Plant tops	1698	1778	2064	4260	2710	2136
Kilograms per Hectares						
Average		**1846.9**			**3035.6**	
Water use, centimeters		18.00			24.73	

Table 5

Yield, average tuber weight and water use of potatoes under sprinkler and furrow method of irrigation

	Furrow			Sprinkler		
Plot Number	1	3	5	2	4	6
Yield, Tons per Hectare	20.1	19.0	20.0	25.8	23.0	22.6
Average		**19.7**			**23.8**	
Average tuber weight, grams	51.0	45.0	46.8	67.0	73.0	81.0
Average		**47.9**			**75.9**	
Water use, centimeters		**42.9**			**41.9**	

STUDIES ON THE USE OF SALINE GROUNDWATER FOR IRRIGATION

by

Muhammad Hussain*

Introduction

In the salinity control and reclamation Project I there is a fairly large number of tubewells which are pumping water with relatively high salt concentration and high residual sodium carbonates. Mention was made of this in the paper on "Problem of Waterlogging and Salinity."

Regular observations are being made in the fields to see the effects of such water on both crops and soils under existing irrigation practices. Laboratory studies are also in progress, utilizing synthetic waters of compositions similar to those of tubewell waters, to develop suitable irrigation practices to solve the ill effects of alkalinity and salinity. Partial results of these experimental data are discussed here.

Material and Method

This experiment was conducted in specially designed three by three-foot pits in rows five feet apart. These pits were prepared by digging three by three by ten-foot holes which were lined with mud-brick walls, duly plastered inside with cement (three inches thick), with surface covering of bitumen, to intercept the lateral seepage. To permit free percolation, the bottoms were not plastered. These pits were then refilled with the soils of known chemical and physical characteristics.

In all, seventy-two such pits were used, from which twenty-four pits were needed for each of the following crop rotations:

(1) Maize-berseem-cotton-sorghum-gram

(2) Maize-melilot-sugar cane-vetch-wheat

(3) Maize-alfalfa-wheat-sorghum-gram

Each of the above sets of rotation consisted of the following treatments:

(1) Depth of irrigation application

Set (A) Six-inch irrigation application on each turn with the different quality of water as

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under (2) below.

Set (B) Four-inch irrigation application on each turn with the different quality of waters as under (2) below.

Set (C) Three-inch irrigation application on each turn with different quality of water as under (2) below.

(2) Quality of irrigation water applied

(i) Irrigation with water having an EC of 650 micromhos from the tubewell water available in the laboratory.

(ii) Irrigation with synthetic water having an EC of 2000 micromhos.

(iii) Irrigation with synthetic water having an EC of 2500 micromhos.

(iv) Irrigation with synthetic water having an EC of 3000 micromhos.

(3) Interval of irrigation

The timing was kept the same in all the depth of irrigation applications except in the case of maize crop falling in all three rotations.

Thus there were twelve (three by four) treatments, with two replications for each type of treatment.

The first water shown in Table 1 is considered to be normally of good quality. But the RSC is slightly high. The three following waters are prepared synthetically to achieve a desired composition.

The experiment started in July, 1962. Maize was the first crop at the beginning of each rotation. Throughout the duration of the experiment, the soil samples were collected for analysis in all the pits before sowing and after the harvest of each crop.

The laboratory analysis of water used for irrigation is given in Table 1:

Table 1

Analysis Results of Water Used for Irrigation
Milli - equivalent per liter

Conductivity in micromhos cm at 20°C	pH	Ca	Mg	Na	CO_3	HCO_3	C1	SO_4	Total Cations	T.S. by Evaporation ppm	Res. Na_2CO_3 meq per liter	SAR
650	8.38	1.70	2.50	5.40	——	6.90	1.9	0.70	9.60	543.8	2.70	3.72
2000	8.40	0.09	1.55	18.00	——	1.90	9.1	8.60	19.60	1431.0	0.30	19.98
2500	8.40	0.10	1.60	22.35	——	2.45	11.4	10.20	24.05	1788.7	0.75	24.13
3000	8.45	0.15	1.85	26.80	——	2.90	14.2	11.70	28.80	2146.5	0.90	26.80

For the maize crop only, the total number of irrigations was varied, by having different water application intervals of four, eight and twelve days for each. Thus the total amounts of water applied to each crop under different treatments varied. In arriving at the total water applied, the amount of rainfall received during the growth of the crop was also taken into account. In case of other crops grown subsequently in all the rotations, the interval of irrigation was the same for all depths of irrigation applications.

All other agricultural practices, such as fertilizer application, etc., were the same as employed by the farmers.

Results and Discussion

The data collected and the observations made in respect to the total irrigation application for each crop and for each rotation under different treatments of varying quality of water, the yield results and the physico-chemical changes in the soil profile are discussed herein.

Rotation No. 1: Maize-Berseem-Cotton-Sorghum-Gram

The rotation was started in July, 1962, and completed in April, 1965. During the growth period five crops of the rotation utilized a total irrigation of 276-acre inches in Set "A"; 204-acre inches in Set "B" and 165-acre inches in Set "C." Cropwise, utilization is as shown in Table 2.

Table 2

Total Water Applied, Inclusive of Rainfall (in Acre Inches)

Crop	Set A	Set B	Set C
Maize	70.42	50.42	40.42
Berseem	71.33	49.33	38.33
Cotton	70.88	50.88	40.88
Sorghum	43.30	37.30	34.30
Gram	20.17	16.17	11.17
Total	276.10	204.10	165.10

The variations in the yield results of the crops grown and the cumulative effects on soil of irrigation waters of different salinity levels under three sets of irrigation applications, viz., six inches, four inches and three inches depth of each irrigation, are given in Table 3.

From a study of the yield and soil analysis results, it is revealed that gram is very sensitive to irrigation application with saline water, although the amounts of salts in the soil profiles were close to the permissible limits of salt content. It is also noticed that under the same amount of irrigation there is not much variation in the yields with the application of water of different salt concentration. There is, however, a variation in the yields, even with irrigation of the same quality of water under the three sets of different irrigation application treatments, viz., six, four and three-inch increment each time. The lower yields are mainly due to low irrigation application. This is true for maize, berseem, cotton and sorghum. But in case of gram, as already stated, the yields have also been affected unfavorably with increasing salinity in the irrigation water in all three sets of irrigation applications in "A," "B" and "C" respectively. The results show that in a period of about thirty-three months of irrigation application of varying quality of irrigation water there is no significant effect on yields of maize, berseem, cotton and sorghum.

The cumulative effects of irrigation with different irrigation applications and with different qualities of water are depicted in Table 5.

Under set "A" with six inches of irrigation depth the salt content of the soil profile remained within the permissible limit, although the trend toward the increase of salinity is there. The cumulative effect on soils for a greater number of years of irrigation is yet to be determined.

Under sets "B" and "C," however, there is a marked increase in the salinity status of soil profile, with the irrigation applications of waters having an EC of 2000, 2500 and 3000 micromhos. It is also noticed that the salt balance in the soil profile is greatly disturbed with the use of water of high salinity and low water application. However, in all the three sets of irrigation applications the accumulation of salts during the

Table 3

Effect of Variable Quality of Water on Crop Yields

Crop	Set	Depth of irrigation application in inches	Surface application (inches)			EC of water used for irrigation in micromhos			
			Rain-fall	Irriga-tion	Total	Tubewell water 650	2000	2500	3000
						Yield in Maunds per acre of green matter			
Maize	A	6	10.42	60.00	70.42	208.25	211.00	284.70	282.50
	B	4	10.42	40.00	50.42	213.00	202.90	220.90	194.30
	C	3	10.42	30.00	40.42	182.90	179.90	53.00	190.00
Berseem	A	6	5.33	66.00	71.35	315.24	312.40	309.25	304.40
	B	4	5.33	44.00	49.33	312.50	310.40	335.17	302.60
	C	3	5.33	33.00	38.33	290.72	285.40	287.96	286.67
						Yield in Maunds per acre of cotton seed			
Cotton	A	6	10.88	60.00	70.88	12.74	10.74	11.50	11.62
	B	4	10.88	40.00	50.88	12.92	12.23	11.49	11.62
	C	3	10.88	30.00	40.88	12.23	11.50	11.50	11.50
						Yield in Maunds per acre of green matter			
Sorghum	A	6	25.30	18.00	43.30	1264	1244	1253	1257
	B	4	25.30	12.00	37.30	1254	1246	1235	1114
	C	3	25.30	9.00	34.30	1147	1167	1136	1117
						Yield in Maunds per acre of grain			
Gram	A	6	2.17	18.00	20.17	10.4	0.96	0.5	Failed
	B	4	2.17	14.00	16.17	10.0	Failed	Failed	Failed
	C	3	2.17	18.00	20.17	10.0	f 9.00	11.17	9.3

duration of this rotation did not exceed to such an extent as to have retarding effects on the growth of the crops except gram, as already mentioned.

The above results show conclusively that when there is a scarcity of water, the saline waters can be used under special irrigation practices, for raising of wheat, cotton, maize, berseem and sorghum, as long as the salinity content in the soil profile does not exceed the permissible limit. Gram is very sensitive to saline water. But, of course, it can be replaced by some suitable crop in the rotation.

Alkalinity Hazard

Alkalinity hazards created by the use of the waters of low salt concentration and high residual sodium carbonate, as also by waters of high salinity but low residual sodium carbonate content, have also been studied in the laboratory, using saturation extract analysis of the three upper feet of soil profile before and after the completion of the rotation. The inference drawn from this investigation is discussed briefly below:

Tubewell water (EC 650 micromhos; RSC 2.70 meq/1). With the use of this water there is a general decrease in Ca+Mg content of soil and a corresponding increase in the SAR of soil.

In case of six-inch irrigation increments and total water application of twenty-three acre feet for the whole crop rotation, the increase in SAR is twenty-eight percent with four-inch irrigation and water application of seventeen-acre feet, the increase in SAR is thirty-two percent. This shows that with heavy irrigations and large quantities the effects of RSC can be reduced to some extent.

The variation in the salt content of soil within five-foot depth of the soil profile before and after the completion of full crop rotation is given in Table 4:

Table 4

Accumulation of Salts as Affected by Different Water Quality

Set	Depth of soil profile (feet)	Irrigation applications with waters of different salt concentration (micromhos) — Salt content of the soil profile before and after the completion of crop rotation (percentage)								Total surface application Rain plus Irrigation (inches)
		T/well 650		2000		2500		3000		
		Before	After	Before	After	Before	After	Before	After	
A	1	0.20	0.16	0.19	0.19	0.18	0.19	0.16	0.22	276
	2	0.18	0.17	0.18	0.19	0.18	0.20	0.16	0.22	
	3	0.13	0.13	0.19	0.19	0.18	0.20	0.18	0.20	
	4	0.12	0.16	0.22	0.22	0.19	0.20	0.22	0.18	
	5	0.14	0.14	––	0.20	0.16	0.16	0.19	0.17	
B	1	0.21	0.16	0.21	0.24	0.17	0.25	0.23	0.22	204
	2	0.15	0.17	0.19	0.23	0.20	0.24	0.20	0.27	
	3	0.17	0.15	0.22	0.23	0.20	0.26	0.21	0.29	
	4	0.13	0.19	0.22	0.24	0.23	0.23	0.22	0.28	
	5	0.15	0.17	0.20	0.23	0.23	0.28	0.22	0.28	
C	1	0.28	0.14	0.20	0.20	0.16	0.22	0.13	0.22	165
	2	0.26	0.15	0.22	0.26	0.15	0.23	0.20	0.28	
	3	0.26	0.20	0.25	0.25	0.19	0.27	0.11	0.28	
	4	0.25	0.16	0.20	0.26	0.20	0.26	0.20	0.32	
	5	0.25	0.19	0.20	0.30	0.11	0.30	0.15	0.30	

Synthetic water (EC 2000 micromhos; RSC 0.3 meq/1). In this case, with six, four and three-inch depth of irrigation application each time, the increase in SAR is 15.0, 18.4 and 23.3 percent respectively. The increase in SAR is mainly due to the fact that the ratio of Na to Ca+Mg is widened as a result of the increase in sodium salts, which is due to use of water of high salt concentrations. The effects of RSC are more severe with low amounts and light irrigation applications.

Synthetic water (EC 2500 micromhos; RSC 0.75 meq/1). With six, four and three inches of irrigation each time, the increase in SAR is 21.2, 26.0 and 33.0 percent respectively. The higher increase in SAR is partly due to the comparatively high RSC content and partly due to the high salinity of the irrigation water.

Synthetic water (EC 3000 micromhos; RSC 0.9 meq/1). The percentage increase of SAR in this case is 24.0, 36.6 and 68.6 for the irrigation applications of six, four and three inches respectively. Hence, the increase in SAR is still higher than in previously tested soils. This is due

Table 5

Increase in the Salt Content of Soils with the Use of Different Quality of Water under Different Sets of Irrigation

Set	Depth of Irrigation (inches)	Quality of water used for irrigation micromhos — Percentage increase in the salt content of the soil profile				Total surface application (inches)
		EC 650	EC 2000	EC 2500	EC 3000	
A	6	–	1	7	9	276
B	4	3	9	21	25	204
C	3	–	19	54	82	165

to the corresponding increase in RSC content of the water. The effects of RSC become seve. with decreasing amounts and light irrigation applications.

Rotation No. 2: Maize-Senji (Melilot)-Sugar Cane-Guara (Vetch)-Wheat

This rotation was started in July, 1962, and completed in April, 1965. Five crops in the rotation utilized a total irrigation of 272-acre inches in Set "A," 198-acre inches in Set "B" and 161-acre inches in Set "C." The amounts applied to different crops is presented in Table 6:

Table 6

Total Water Applied Inclusive of Rainfall (in Acre Inches)

Crop	Set A	Set B	Set C
Maize	46.42	34.42	28.42
Senji (Melilot)	49.00	33.00	25.00
Sugar Cane	111.38	79.38	63.38
Guara (Vetch)	38.75	32.75	29.75
Wheat	26.17	18.17	14.17
Total	271.72	197.72	160.72

The yield results of the crops grown under different irrigation applications of varying qualities of water are given in Table 7:

Table 7

Effect of Variable Quality of Water on Crop Yields

Crop	Set	Depth of irrigation application in (inches)	Surface application (inches) Rainfall	Irrigation	Total	EC of water used for irrigation (micromhos) Tubewell Water 650	2000	2500	3000
						Yield in Maunds per acre of green matter			
Maize	A	6	10.42	36.00	46.42	209.28	198.57	125.12	155.17
	B	4	10.42	24.00	34.42	182.50	195.79	199.06	184.23
	C	3	10.42	18.00	28.42	188.00	171.73	167.12	183.72
Melilot	A	6	1.00	48.00	49.00	512.48	518.24	510.40	498.87
	B	4	1.00	32.00	33.00	502.68	495.64	482.74	476.16
	C	3	1.00	24.00	25.00	474.64	469.23	436.27	417.16
						Yield in Maunds per acre of cane			
Sugar Cane	A	6	15.38	96.00	111.38	723.00	737.00	737.00	723.00
	B	4	15.38	64.00	79.38	782.00	861.00	782.00	857.00
	C	3	15.38	48.00	63.38	818.00	797.00	772.00	719.00
						Yield in Maunds per acre of green matter			
Guara (Vetch)	A	6	20.75	18.00	38.75	231.49	115.12	42.99	30.25
	B	4	20.75	12.00	32.75	210.50	121.00	101.70	35.00
	C	3	20.75	9.00	29.75	212.25	121.00	58.51	15.12
						Yield in Maunds per acre of grain			
Wheat	A	6	2.17	24.00	26.17	29.28	29.28	30.40	29.10
	B	4	2.17	16.00	18.17	21.96	21.24	25.62	21.96
	C	3	2.17	12.00	14.17	15.98	18.30	25.62	23.28

The variation in the salt contents of soil within five feet depth of the soil profile before and after the completion of full crop rotation is given in Table 8:

Table 8

Effect of Several Different Water Qualities on the Accumulation of Salts in Soils

Set	Depth of soil profile (feet)	Irrigation applications with waters of different salt concentrations in micromhos								Total surface applications Rain plus Irrigation (inches)
		EC 650		EC 2000		EC 2500		EC 3000		
		Salt content of the soil profile before and after the completion of crop rotation in percentage								
		Before	After	Before	After	Before	After	Before	After	
A	1	.18	.16	.20	.18	.19	.19	.18	.22	272
	2	.19	.12	.16	.20	.16	.19	.17	.20	
	3	.15	.14	.17	.18	.19	.22	.25	.20	
	4	.26	.18	.20	.17	.16	.19	.19	.21	
	5	.17	.19	.15	.20	.18	.15	.19	.22	
B	1	.15	.17	.25	.18	.14	.24	.19	.24	198
	2	.17	.15	.27	.17	.22	.21	.22	.24	
	3	.14	.18	.15	.22	.23	.20	.20	.25	
	4	.25	.19	.12	.22	.18	.22	.18	.24	
	5	.13	.17	.15	.22	.18	.24	.19	.23	
C	1	.18	.16	.17	.24	.12	.24	.12	.24	161
	2	.24	.18	.13	.22	.22	.22	.14	.24	
	3	.20	.20	.16	.22	.11	.22	.16	.27	
	4	.18	.20	.16	.23	.10	.22	.15	.28	
	5	.13	.15	.22	.19	.10	.16	.13	.26	

Crop yields and soil analysis results reveal that among the five crops grown in the rotation, guara (vetch) is most sensitive in respect to saline water. In the growth period of vetch a heavy rain, amounting to 20.75 inches, was also received, but in spite of this, the crop could not withstand the effects of irrigation with saline waters. In case of other crops there was no appreciable effect on crop growth due to saline irrigation. There is, however, a variation in yields even with the irrigation of the same quality of water under the three irrigation sets, viz., six, four and three inches each time. The observation has been made that with large amounts and heavy irrigation applications high yields have been obtained.

The cumulative effects of saline water with different irrigation applications and with different qualities of water can be depicted from Table 9:

Table 9

Increase in Salt Content with the Use of Different Qualities of Water under Specified Sets of Irrigation

Set	Depth of Irrigation (inches)	Quality of water used for irrigation (micromhos)				Total surface application (inches)
		EC 650	EC 2000	EC 2500	EC 3000	
		Percentage increase in the salt content of the soil profile				
A	6	–	5	7	7	272
B	4	2	7	17	22	198
C	3	–	30	63	84	161

Under this rotation the trend of accumulation of salts is similar to rotation No. 1 when different sets of irrigation applications with varying water quality are compared. This is probably due to the utilization of almost the same amount of water under all sets of irrigation applications.

Alkalinity Hazard

Results of effects of various waters on soil alkali conditions are presented below:

Tubewell water (EC 650 micromhos; RSC 2.7 meq/l). In this case there is a general decrease in Ca+Mg content of soil and a corresponding increase in SAR. With the six-inch irrigation water each time, the total application is 22.66-acre feet in the whole rotation and the increase in SAR is twenty-two percent. With four-inch irrigation application and a total amount of sixteen and a half-acre feet, the increase in SAR is twenty-six and a half percent. With three-inch increment of irrigation and a total quantity of 13.4 acre feet, the increase in SAR is thirty-three percent.

Synthetic water (EC 2000 micromhos; RSC 0.3 meq/l). In this case, with six, four and three inches of irrigation application each time, the percentage increase in SAR is 15.7, 19.8 and 23.0 respectively. This increase in SAR is mainly due to the fact that the ratio of Na to Ca+Mg is widened. The widening of the ratio occurs because of the increase in the sodium salts created by the use of water of high salt concentration.

Synthetic water (EC 2500 micromhos; RSC 0.75 meq/l). When six, four and three inches each irrigation is applied then the increase in SAR is 18.1, 22.4 and 27.0 percent respectively. The increase in SAR is relatively high, due to comparatively high RSC content, and partly due to high salinity of the irrigation water.

Synthetic water (EC 3000 micromhos; RSC 0.9 meq/l). With six, four and three inches depth of irrigation, the percentage increase in SAR is 22.5, 41.3 and 71.0 respectively. Here the increase is still more significant due to a corresponding increase in RSC of the water and perhaps more so because the content of soluble salts is very high. Prolonged use of this kind of water quality will impair specific measurable influence on a soil profile.

Rotation No. 3: Maize-Alfalfa-Wheat-Sorghum-Gram

This rotation also covers five crops which utilized total irrigation water of 226-acre inches in set "A," 168-acre inches in set "B," and 136-acre inches in set "C." Cropwise, utilization is as given in Table 10:

Table 10

Total Water Applied, Inclusive of Rainfall (in Acre Inches)

Crop	Set A	Set B	Set C
Maize	34.42	26.42	22.42
Alfalfa	95.33	65.33	50.33
Wheat	32.82	22.82	17.82
Sorghum	43.30	37.30	34.30
Gram	20.17	16.17	11.17
Total	226.04	168.04	136.04

Cumulative effects of irrigation water of different salinity levels under three sets of irrigation application, viz., six, four and three-inch depth in each irrigation on the yields of crops, are given in Table 11:

Table 11

Effect of Variable Water Quality on Crop Yields

Crop	Set	Depth of irrigation application (inches)	Surface application (inches): Rainfall	Irrigation	Total	EC of water used for irrigation (micromhos): Tubewell Water 650	2000	2500	3000
						Yield in Maunds per acre of green matter			
Maize	A	6	10.42	24.00	34.42	207.60	218.20	154.00	178.52
	B	4	10.42	16.00	26.42	31.00	198.00	167.84	25.96
	C	3	10.42	12.00	22.42	163.69	179.62	158.80	155.60
Alfalfa	A	6	5.33	90.00	95.33	540.22	538.16	484.31	519.34
	B	4	5.33	60.00	65.33	509.31	498.54	484.31	469.50
	C	3	5.33	45.00	50.33	459.24	449.32	448.30	438.65
						Yield in Maunds per acre of grain			
Wheat	A	6	2.82	30.00	32.82	35.00	37.30	37.00	37.10
	B	4	2.82	20.00	22.82	37.30	36.80	35.00	32.30
	C	3	2.82	15.00	17.82	33.10	32.70	32.70	30.40
						Yield in Maunds per acre of green matter			
Sorghum	A	6	25.30	18.00	43.30	1209.75	1205.25	1195.00	1165.70
	B	4	25.30	12.00	37.30	1220.00	1218.25	1225.00	1231.80
	C	3	25.30	9.00	34.30	1268.20	1343.60	1270.70	1178.25
						Yield in Maunds per acre of grain			
Gram	A	6	2.17	18.00	20.17	8.40	---	1.45	---
	B	4	2.17	14.00	16.17	7.60	---	---	---
	C	3	2.17	9.00	11.17	6.50	---	---	---

Changes in the salt balance of soil within five-foot depth of the soil profile before and after the completion of the full crop rotation are shown in Table 12:

Table 12

Accumulation of Salts in Soil as Affected by Water Quality

Set	Depth of soil profile (feet)	EC 650 Before	EC 650 After	EC 2000 Before	EC 2000 After	EC 2500 Before	EC 2500 After	EC 3000 Before	EC 3000 After	Total surface applications: Rain plus Irrigation (inches)
		Irrigation applications with waters of different salt concentration (micromhos) — Salt content of the soil profile before and after the completion of crop rotation (in percentage)								
A	1	.26	.18	.20	.19	.23	.24	.19	.25	226
	2	.17	.15	.14	.20	.19	.20	.11	.23	
	3	.20	.14	.19	.22	.17	.25	.21	.26	
	4	.18	.16	.20	.23	.16	.23	.20	.20	
	5	.14	.12	.24	.18	.19	.19	.24	.21	
B	1	.18	.19	.26	.24	.14	.17	.20	.26	168
	2	.15	.19	.17	.22	.16	.25	.22	.32	
	3	.14	.17	.16	.22	.12	.25	.18	.31	
	4	.15	.18	.17	.24	.20	.19	.19	.27	
	5	.19	.14	.18	.18	.18	.21	.16	.24	
C	1	.11	.17	.10	.22	.15	.23	.13	.29	136
	2	.13	.16	.12	.20	.14	.19	.15	.32	
	3	.14	.16	.20	.27	.14	.32	.17	.31	
	4	.11	.14	.22	.19	.13	.22	.15	.29	
	5	.16	.15	.13	.27	.18	.28	.15	.31	

Behavior of these crops in respect to the irrigation water of varying salinity is almost identical to the crops in the two previous rotations. In this case too the gram crop has been adversely affected by the use of water of high salinity although the salt content in the soil profile was close to the permissible limit.

The additive effects of salt in irrigation water on soil receiving different irrigation applications and different quality of waters are presented in Table 13:

Table 13

Increase in Salt Content with the Use of Different Qualities of Water under Different Sets of Irrigation

Set	Depth of Irrigation (inches)	Quality of water used for irrigation (in micromhos) EC 650	EC 2000	EC 2500	EC 3000	Total surface application (inches)
		Percentage increase in the salt content of the soil profile				
A	6	—	5	18	21	226
B	4	7	19	37	47	168
C	3	13	50	67	103	136

The comparative study of the salt balance under the three crop rotations shows that in this case even six-inch irrigation is not sufficient to check the input of salts because the total irrigation applied in this case was low as compared to rotations No. 1 and 2. It is observed that when water of EC 3000 is used, the increase in salts is about twenty-one percent in rotation No. 3, compared to nine and seven percent in rotations No. 1 and 2 respectively.

Under set "B" with four-inch irrigation applications and set "C" with three-inch irrigation applications, the input of salt is still higher than in rotations No. 1 and 2. As already mentioned, this is due to a lesser amount of water applied. From this it can be concluded that not only the depth of each irrigation application counts in the maintenance of salt balance, but that the total quantity of water plays a major role.

Alkalinity Hazard

Data showing the effects of various water qualities on the alkalinity status of soil are discussed next:

Tubewell water (EC 650 micromhos; RSC 2.7 meq/l). With the use of this water there is general decrease in the Ca+Mg content of soil and corresponding increase in SAR.

In an irrigation adding six inches of water each time, which amounts to a total of 18.8 acre feet in a whole rotation, the SAR will increase to 21.6 percent. With a four-inch irrigation and the total being fourteen acre feet, the increase in SAR is 30.2 percent. On the other hand, the three-inch irrigation each time increases the SAR to 33.3 percent.

Synthetic water (EC 2000 micromhos; RSC 0.3 meq/l). Using this water at a rate of six, four and three inches each time, the increase in SAR is 12.7, 39.4 and 101 percent respectively. This increase is mainly due to the fact that the ratio of Na to Ca + Mg is widened because of the increase of sodium salts received from water of high salt concentration.

Synthetic water (EC 2500 micromhos; RSC 0.75 meq/l). An increase in the SAR from 17.3, 58.2 and 112 percent is observed when the irrigation rates are maintained at six, four and three inches respectively. The higher increase in SAR in this case as also in the above one is due to comparatively high RSC content of irrigation water and partly due to high salinity of irrigation water.

Synthetic water (EC 3000 micromhos; RSC 0.9 meq/1). When these waters are used for irrigation the percentage increase of SAR in soil is 30.6, 119 and 142 for the irrigation of six, four and three inches respectively. Here the increase is still higher than in the other synthetic waters. This is due to the increase in RSC content of irrigation water and to the increase in the content of soluble salts.

The overall general increase in the salt content and SAR of the soil profile as a result of the use of waters of different qualities shows that this rotation is less unfavorable for the maintenance of salt balance than rotations No. 1 and 2 under all sets of irrigation. This is mainly due to less water being applied.

Conclusion

The experimental data indicate that waters of low salinity level but with high RSC are as injurious as the waters of high salinity with low RSC. However, water having both high salinity and high RSC will deteriorate the soils at a much faster rate. It is also observed that by the use of waters of poor quality but with high irrigation applications, the soil deterioration period resulting from the use of such waters may be prolonged. The actual complete deterioration in each case will, however, be determined in subsequent years by a continuation of the experiment.

In the maintenance of a salt balance in the soil, the depth of each irrigation application is as important as the total quantity applied in a particular crop rotation. This seems to hold true for water with high salinity and RSC.

The experiment showed that crops less salt-sensitive can be grown successfully for a certain period of time when irrigation waters of inferior quality are applied copiously to maintain a high rate of dilution or frequently to keep the soil moist at all times.

The effects of poor quality water on deterioration of normal soils is significant, but it is perceptibly slower than previously assumed. It is conceivable and quite probably true that in salt-affected soils the cumulative effects of salt from poor quality irrigation water will be such as to prevent germination and plant growth even of the more salt-resistant plants such as wheat and cotton. The quantitative effects of inferior water on salty soils is presently under study at the Land Reclamation Directorate.

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IRRIGATION APPLICATION TRIALS TO MEET THE PEAK NEEDS OF CROPS DURING SHORT SUPPLY PERIOD

by

Ch. Muhammad Hussain*

Sufficient water supply is available in West Pakistan's rivers during the month of September. The supply, however, subsides in the next month when there is a keen demand for water for maturing the standing summer crops and for sowing the following winter crops.

If normal irrigation practices are followed, cotton requires one more irrigation in the month of October, which is a short-supply period. Under the circumstances, either cotton receives less irrigation or the sowing of rabi crops is delayed. To solve some of this difficulty, experiments were designed at various experiment stations to see what effect it would have on crop yield to supply enough water in September to store sufficient moisture in the root zone for utilization by the crop in the subsequent period.

The experiment was conducted at Bhallewala and Haveli Experiment Stations, with the following treatments:

(1) Six-inch irrigation to be applied during the last week of September.

(2) Four-inch irrigation to be applied during the last week of September.

(3) Three-inch irrigation to be applied during the last week of September, followed by three-inch irrigation in the middle of October.

Twelve equal plots of one-fourth acre size were selected for the experiment at Bhallewala in loam type of soil, with deep soil profile. There were four replications of each treatment. The average yield of seed cotton under the three treatments are given in Table 1.

From the results it is evident that a six-inch irrigation in the last week of September is as good a treatment as with three inches irrigation in September, followed by three inches in October.

At Haveli Farm the experiment was conducted with the same treatments but the size of

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Table 1

Average Yield of Seed Cotton in Maunds per Acre at Bhallewala Reclamation Farm

Treatment	Yield of Seed Cotton in Maunds per acre during 1962	1963	1964	1965	Average
(1) Six-inch irrigation to be applied during last week of September	7.12	6.92	8.81	7.19	7.51
(2) Four-inch irrigation to be applied during last week of September	6.40	6.69	7.12	7.00	6.80
(3) Three-inch irrigation to be applied during last week of September, followed by three-inch irrigation in the middle of October	7.00	7.75	8.25	7.77	7.69

(One maund equals eighty-two pounds)

the plot was one-tenth of an acre. The average yields of seed cotton for the last five years from the above three treatments is tabulated in Table 2:

Table 2

Average Yield of Seed Cotton in Maunds per Acre at Haveli Reclamation Farm

Treatment	Yield of Seed Cotton in Maunds per acre during 1961	1962	1963	1964	1965	Average
(1) Six-inch irrigation to be applied during last week of September	7.20	7.41	11.12	9.25	6.81	8.36
(2) Four-inch irrigation to be applied during last week of September	4.83	4.58	9.60	7.52	5.25	6.36
(3) Three-inch irrigation to be applied during last week of September, followed by a three-inch irrigation in the middle of October	6.13	7.50	11.50	9.75	6.88	8.35

(One maund equals eighty-two pounds)

In this case also a six-inch irrigation in the last week of September proved most beneficial.

It is thus concluded that enough moisture can be stored by applying excess irrigation to cotton in the last week of September to meet the peak needs of water in the short-supply period of October.

STUDIES ON IRRIGATION PRACTICES FOR INCREASED PRODUCTION AND SALINITY CONTROL

by

Ch. Muhammad Hussain*

Introduction

In the use of canal supplies in the fields, the importance of even distribution of water has been recognized by the government since the advent of canal irrigation. In canal irrigation projects, along with construction of canals, the government has undertaken the construction of water courses of the area in a unit irrigation block. Legislation was passed for distribution of water among different holders of the land, but use of water in the field was left to the cultivator. However, the importance of proper use of canal supplies was emphasized by the Irrigation Department as early as 1929 in special instructions issued by the chief irrigation engineer. At that time emphasis was placed on dividing an acre plot into four parts, but preference was given to a one-eighth acre plot. These instructions were not based on any experimentation but just on common sense for the even distribution of water in the field. With the advance in irrigation science, the importance of proper and even distribution of moisture in the effective root zone is now more apparent in irrigated agriculture.. Various factors such as the size of stream, infiltration rate, slope, physico-chemical characteristics of the soil, nature of the growing crops, etc., are involved in the determination of size and shape of the plot for uniform and proper moisture distribution. Mode of cultivation and the type of implements also greatly influence irrigation practices. Under mechanized cultivation, improved irrigation practices can be adopted without any difficulty. Where the draught animals and primitive type of implements are still in use, improved irrigation practices cannot be so easily introduced.

Salinity control can be exercised to a great extent even under present irrigation amounts, provided the cultivators take care of proper leveling of land, layout of fields in proportion to the amount of water available, and uniform application of water over the entire strip of land. Investigations have brought to light that one of the major causes of upward movement of salts, water-

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logging, and uneven distribution of soil moisture in the root zone is uneven application of water over the surface of the land. This also has the effect of subjecting the crop to considerable variation in soil moisture stress over various parts of the plot.

With such problems in view, irrigation experiments are in progress in the Directorate of Land Reclamation of the Irrigation Department of West Pakistan, to study the use of existing available water supplies in order to obtain high crop yields and to arrest the spread of salinity. These up-to-date observations are discussed here.

Layout

Two blocks of seven acres each were selected at Bhallewala Farm (Montgomery District), Haveli Farm Shorkot (Jhang District) and Leiah Farm, for laying out the experiment. These blocks were further sub-divided into different plots varying in size from one-eighth of an acre to one acre, as shown in the layout plan (Appendix 1). Table 1 shows the seven methods of layout of fields and irrigation. The area under each treatment was one acre. Plot size with its dimensions and location of water inlets and water courses as laid out for the trial are also given in this table:

Table 1

Sr. No.	Plot Designation	Plot Size, Dimensions and Location of Water Inlet	
(1)	A	One-acre plot (198′ x 220′).	With inlet in center
(2)	B	One-half-acre plots (99′ x 220′).	With water course on one side and inlets in center
(3)	C	One-quarter-acre plots (99′ x 110′).	With water course and inlets in the center of plots
(4)	D	One-quarter-acre plots (99′ x 110′).	With water course in center and inlets in the corner
(5)	E	One-quarter-acre plots (49′ x 220′).	With water course on one side and inlets in center
(6)	F	One-eighth-acre plots (55′ x 99′).	With water course and inlets in the center of plots
(7)	G	One-eighth-acre plots (25′ x 220′).	With water course on one side and inlets in center

Material and Methods

Soil texture in the experimental plots was fine sandy loam. The source of irrigation water was canal supply, with a capacity of one to 1.5 cusecs. The top six feet of soil were considered to be occupied by the principal rooting system of cotton and wheat respectively.

AC-134 cotton was sown during the summer and was followed by wheat C-591 during the winter.

Total water applied to the crops was equal for all the plots under the experiment. Irrigation water applied to the crops was measured by a Parshall flume. Other cultural operations performed were similar for all the treatments. Farm yard, chemical and green manures, when applied, were alike for all the plots under the treatments. All possible efforts were made to keep all the conditions other than layout the same as usual.

To study moisture distribution, soil samples were taken from different sites. A similar procedure was followed for this experiment at other sites, such as Haveli Reclamation Farm Shorkot and Reclamation Farm Leiah. The amount of water applied per acre to all the treatments in summer and winter at Bhallewala and Haveli sites is given in Table 2:

Table 2

Water in Acre Inches Applied to Experimental Cotton and Wheat at Bhallewala and Haveli Reclamation Farms

Year	Crops			
	B. R. F.		H. R. F.	
	Cotton	Wheat	Cotton	Wheat
1961-62	22.60″	14.10″	———	———
1962-63	25.86″	16.00″	32.25″	15.25″
1963-64	20.55″	17.63″	25.07″	———
1964-65	22.70″	———	———	16.25″

Observation

From the moisture samples the efficiency of irrigation by different methods was computed for 1962-63. The comparison is given in Tables 3 and 4.

The results indicate that one-eighth-acre plot (G) gives maximum irrigation efficiency:

Sixty-nine percent with wheat and seventy percent with cotton.

The results of soil analysis after two years of cropping cotton and wheat were examined. It was found that in the one-acre plot the salt patches appeared at the soil surface where the

Table 3

Water Application Efficiencies on Cotton, 1962, Bhallewala Farm

Layout of Irrigation Experimental Plots	Water applied in four irrigations after sowing cotton (inches)	Water added to root zone (inches)	Application efficiency (percentage)
(A) One-acre plot (198′ x 220′)	12.00	6.56	55
(B) One-half-acre plots (99′ x 220′)	12.00	6.64	55
(C) One-quarter-acre plots (99′ x 110′)	12.00	8.08	67
(D) One-quarter-acre plots (99′ x 110′)	12.00	7.47	62
(E) One-quarter-acre plots (49′ x 220′)	12.00	7.74	65
(F) One-eighth-acre plots (55′ x 99′)	12.00	8.28	69
(G) One-eighth-acre plots (25′ x 220′)	12.00	8.40	70

Table 4

Water Application Efficiencies on Wheat, 1962-63, Bhallewala Farm

Layout of Irrigation Experimental Plots	Water applied in three irrigations after sowing wheat (inches)	Water added to root zone (inches)	Application efficiency (percentage)
(A) One-acre plot (198′ x 220′)	9.00	4.76	53
(B) One-half-acre plots (99′ x 220′)	9.00	5.36	60
(C) One-quarter-acre plots (99′ x 110′)	9.00	5.68	63
(D) One-quarter-acre plots (99′ x 110′)	9.00	5.55	62
(E) One-quarter-acre plots (49′ x 220′)	9.00	5.45	61
(F) One-eighth-acre plots (55′ x 99′)	9.00	6.08	68
(G) One-eighth-acre plots (25′ x 220′)	9.00	6.21	69

field was under-irrigated; whereas the one-eighth-acre plots and one-fourth-acre plots facilitate uniform distribution of water which checks the rise of salts to the surface. The depth of penetration of moisture at the points away from inlets was more in the one-eighth-acre plots than in the one-acre plot (Figs. 2 and 3 appended). As a result, there were downward movements of salts in the one-eighth-acre plot while salt patches appeared at soil surface in the one-acre plot.

Results and Discussion

The trial was continued from 1961 to 1964 at Bhallewala, for 1962 to 1964-65 at Haveli and 1962 to 1964 at Leiah farms. Mean yield of seed cotton per acre at all these farms during these years is tabulated in Table 5.

The yield results of the crop in different years and the average yield at the farms indicate that these improved progressively with the decrease in the size of the compartment of an acre to be irrigated. This reveals that a more uniform distribution of irrigation water is attained with the reduction in the size and shape of the plot to be irrigated. From the yield results it is concluded that if the size of the plot is arranged in proportion to the size of the stream, the yield can be much increased. In cotton this increase has been observed to be 55.6 percent, 68.5 percent and 43.0 percent at Bhallewala, Haveli and Leiah Reclamation Farms respectively. Under Bhallewala conditions, the best yield of cotton was obtained from the area where one acre was divided into eight equal parts. The increase in yield by this way of layout compared to laying out the area in acres is 52.9 percent. There was an increase of 37.1 percent by irrigating one acre in four parts over not dividing a one-acre area. The difference in yield due to the position of inlets and water courses is not so significant. In case of one-eighth-acre compartments, the yield is better in the plots where the water course and inlets are in the center, at both Haveli and Leiah sites.

At Haveli Farm the layout of one acre into eight equal compartments, and irrigating them with water course through inlets positioned in the center of plots, gave the best yield: 68.5 per-

Table 5

Average yield of seed cotton in maunds per acre

Layout of Irrigation experimental plots	Bhallewala Farm					Haveli Farm			Leiah Farm			
	1961	1962	1963	1964	Average	1961	1965	Average	1962	1963	1964	Average
(A) One-acre with inlet in center	4.60	4.95	5.03	6.00	**5.14**	4.91	3.07	**3.37**	1.98	4.73	9.50	**4.05**
(B) One-half-acre plots with water course on one side and inlet in center	5.11	5.12	5.50	6.50	**5.56**	5.11	3.56	**4.03**	2.00	5.00	10.25	**4.32**
(C) One-half-acre plots with water course and inlets in the center of plot	6.73	6.95	6.13	8.87	**7.14**	5.84	6.48	**5.32**	2.50	7.24	10.31	**5.00**
(D) One-quarter-acre plots with water course in center and inlets in the corner	6.98	6.68	6.03	8.13	**7.00**	5.31	6.19	**5.08**	3.00	5.80	10.37	**4.80**
(E) One-quarter-acre plots with water course on one side and inlet in center	6.84	6.32	6.06	8.61	**7.00**	5.71	6.12	**5.27**	2.50	6.20	10.34	**4.80**
(F) One-eighth-acre plots with water course and inlets in the center of plots	7.11	7.13	7.25	9.20	**7.67**	6.18	7.19	**5.79**	4.00	8.23	10.39	**5.65**
(G) One-eighth-acre plots with water course on one side and inlets in center of plots	7.34	7.15	7.28	10.15	**8.00**	6.52	7.12	**5.88**	4.00	8.69	10.51	**5.80**

One maund equals eighty-two pounds.

cent, 45.9 percent and 12.6 percent higher than the other three methods of layout, viz., one-acre plot, one-half-acre plots and one-fourth-acre plots.

The results at Leiah Farm are in agreement with those obtained at the other two farms and the increase in one-eighth-acre plots over the one-acre, one-half-acre and one-fourth-acre plots has been calculated as 43.2 percent, 34.3 percent and 19.1 percent respectively.

The cotton in the trial was followed by wheat during winter. The yield results of this crop are tabulated in Table 6:

Table 6

Treatment	Average yield of wheat in maunds per acre					
	Bhallewala Farm			Haveli Farm		
	1962-63	1963-64	Average	1962-63	1964-65	Average
(A) One-acre with water course on one side and inlet in center	12.25	14.38	13.31	10.00	11.12	10.56
(B) One-half-acre plots with water course on one side and inlet in center	12.75	14.38	13.56	10.25	11.62	10.93
(C) One-quarter-acre plots with water course and inlet in the center of plot	14.50	17.38	15.94	10.37	12.75	11.56
(D) One-quarter-acre plots with water course in center and inlets in the corner	17.88	16.94	17.41	10.50	13.25	11.87
(E) One-quarter-acre plots with water course on the side and inlet in center	16.88	17.44	17.16	10.75	13.50	12.12
(F) One-eighth-acre plots with water course and inlet in the center of plot	20.38	20.44	20.41	12.50	15.12	13.81
(G) One-eighth-acre plots with water course on one side and inlet in center	21.38	21.18	21.28	12.00	15.16	13.58

The yield results of the wheat crop also confirm the conclusions drawn for the cotton crop: the smaller the compartment to be irrigated, the better the yields obtained. In this case the increase in yield in a one-eighth-acre plot over one-acre, one-half-acre and one-fourth-acre plots was 56.6 percent, 53.7 percent and 24 percent respectively under Bhallewala conditions and 26.7 percent, 25.4 percent and 15.6 percent respectively under the soil and water conditions at the Haveli Reclamation Farm.

The difference in yield of crops under one-eighth-acre plots due to the position of the water course is not significant. However, besides the size and shape of plot the position of water course and inlet is important in view of the size of the stream, slope of land and infiltration rate of the soil.

Summary

In salinity control measures, the uniform distribution of irrigation supply by laying out the fields in suitable plot sizes plays an important role. This has been ascertained from the experiments conducted under arid conditions in West Pakistan. The experiment was laid out to include the existing and proposed improved irrigation practices at three representative farm sites of Bhallewala (Montgomery District), Haveli Shorkot (Jhang District) and Leiah Farm. The irrigation water was from a canal supply with an outlet discharge varying from one to one and a half cusecs.

Observation of water application efficiency at Bhallewala site for the year 1962-63 reveals that one-eighth-acre plots give the maximum irrigation efficiency of seventy percent in case of cotton and sixty-nine percent in case of wheat, with outlet head delivery of 1.12 cusecs.

The results on the cotton crop under this trial show an increase in yield obtained from one-eighth-acre plots, compared to one-acre plots, as 55.6 percent, 68.5 percent and 43 percent at Bhallewala, Haveli and Leiah sites respectively.

The yield of wheat that followed cotton gave the higher return in case of one-eighth-acre plots compared with one-acre, half-acre and quarter-acre plots, by 56.6 percent, 53.7 percent and 24.0 percent respectively under Bhallewala conditions, and 26.7 percent, 25.4 percent and 15.6 percent under Haveli conditions. The difference in yield of crops merely due to the position of water course and inlets is not so significant.

It is concluded that more uniform distribution of irrigation water is attained with the decrease and amendment in the size and shape of the plot to be irrigated, and one-eighth-acre has proved a most suitable size of plot for this purpose.

LAY OUT OF EXPERIMENT ON IRRIGATION PRACTICES

DISCHARGE 1·12 C.S

THE PORTION THAT REMAINED UNIRRIGATED ______

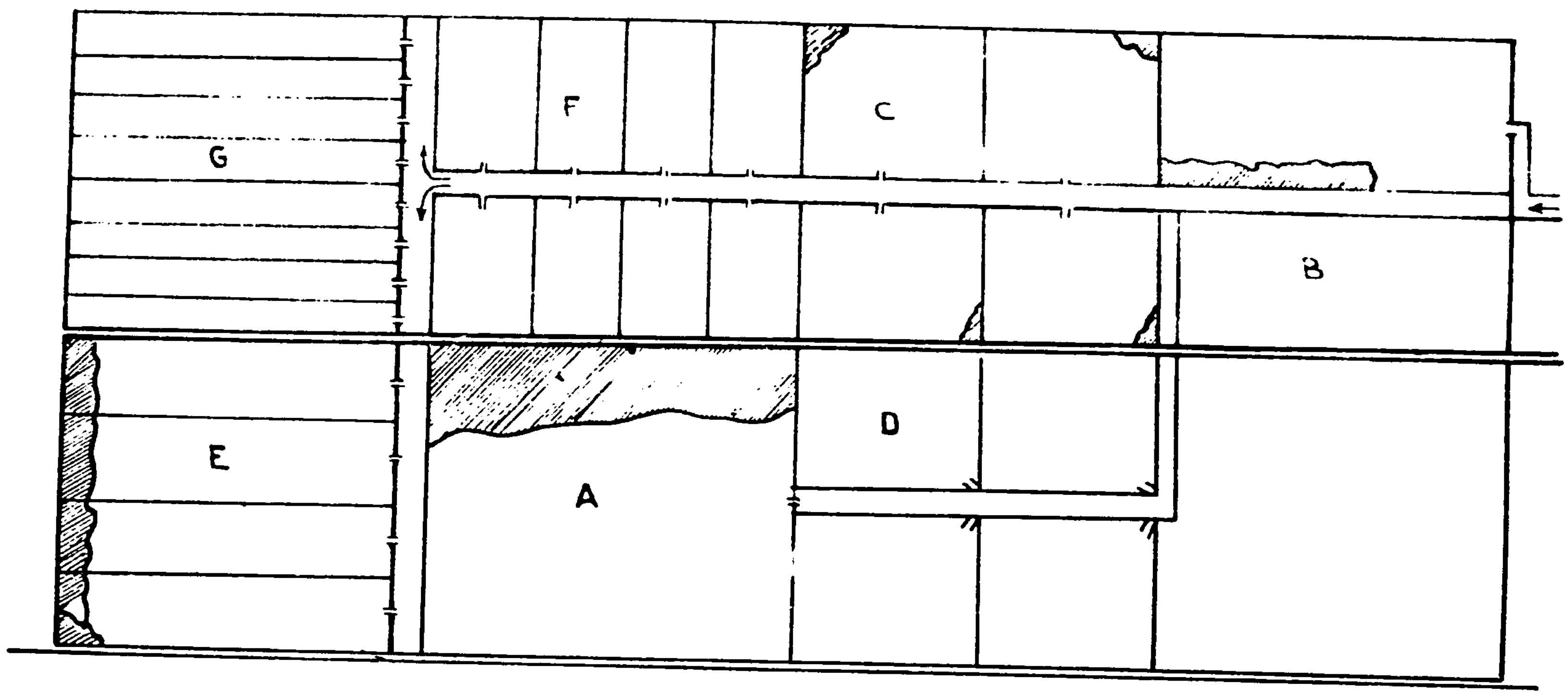
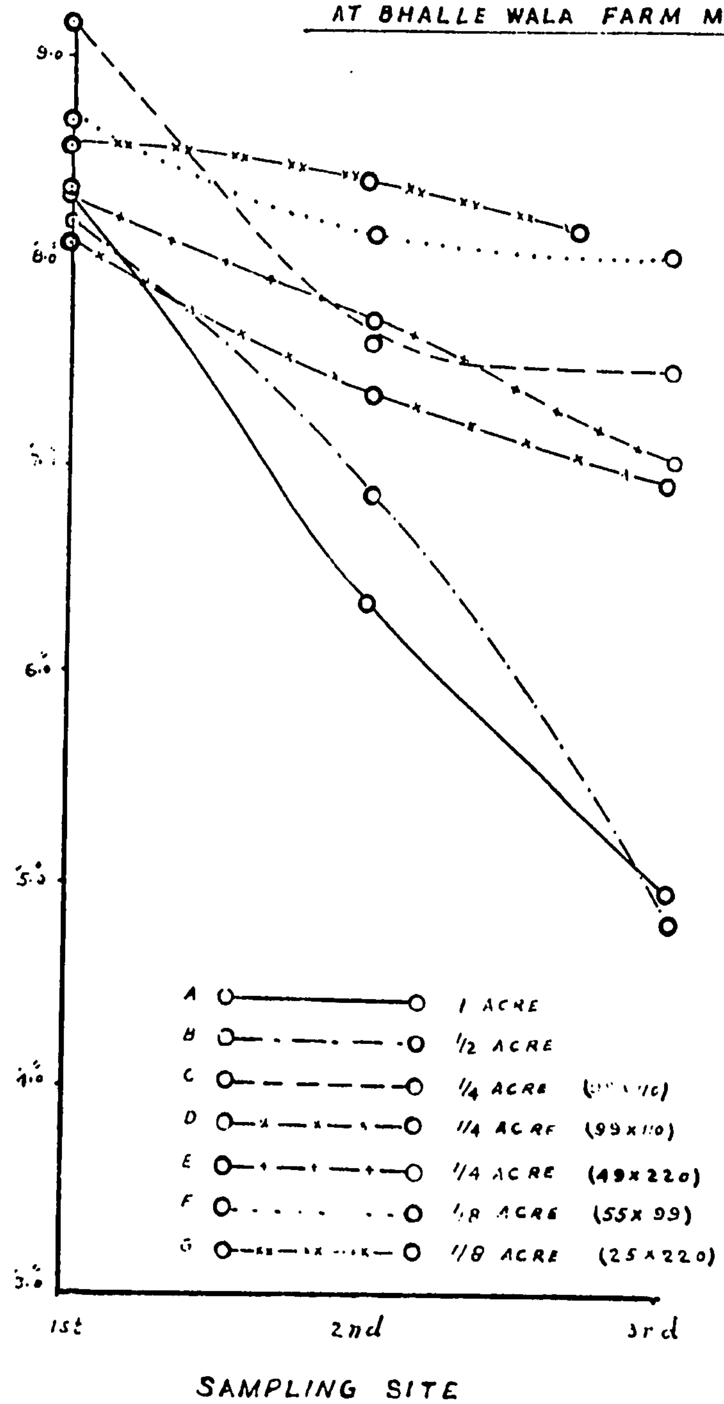


FIG. 2

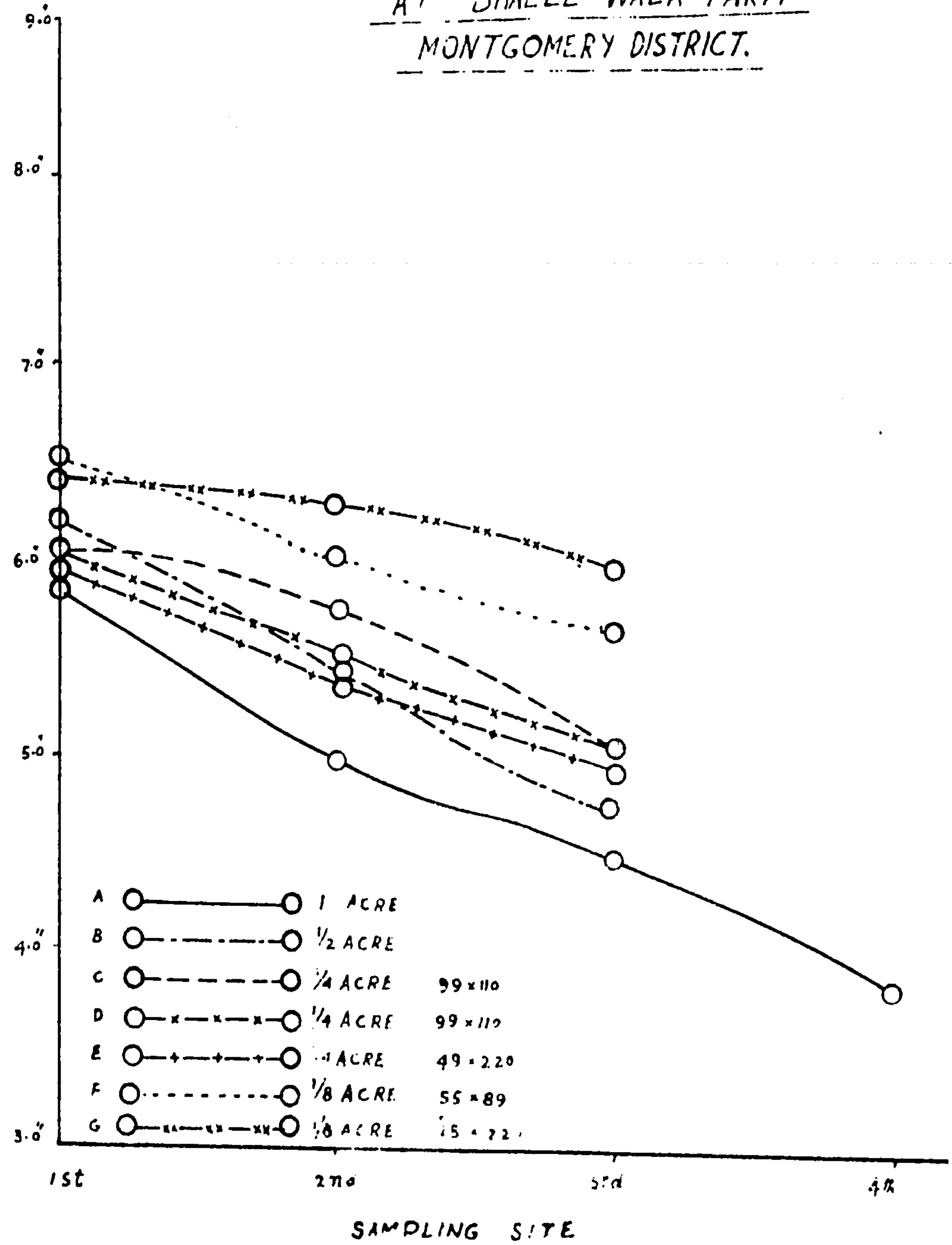
DISTRIBUTION OF MOISTURE
AT DIFFERENT SITES
WITHIN COTTON PLOTS OF SUMMER 1962
AT BHALLE WALA FARM MONTGOMERY DISTT:



1st-CLOSE TO INLET OF WATER.
2nd-MID WAY OF THE FIELD
3rd-AT FURTHER EXTREME END.

FIG 3

DISTRIBUTION OF MOISTURE AT DIFFERENT SITES WITHIN WHEAT PLOTS OF WINTER 1962-63. AT BHALLE WALA FARM MONTGOMERY DISTRICT.



1st - CLOSE TO INLET OF WATER

2nd - MID WAY OF THE FIELD

3rd }
4th } AT FURTHER EXTRME ENDS.

CARTOGRAPHIC AND PHOTOGRAPHIC FACILITIES FOR SOIL AND WATER DEVELOPMENT PROJECTS IN TOPRAKSU

by

Mehmet Akdogan*

Introduction

Technical personnel of TOPRAKSU are currently hampered in their field work by lack of adequate cartographic facilities, services and training. There is an urgent need for cartographic aids, which most technologically developed countries recognize as vitally necessary working tools for efficient and economic use of men and materials in all types of surveys for various purposes. The alternative is laborious, time-consuming and costly hand operation field methods in a country where the number of competent trained technical and professional personnel are very limited. It is urgently necessary that cartographic aids and services be provided and used to the fullest extent possible, for maximum economy and efficiency in conducting surveys.

At present in Turkey, technical, professional, supervisory and administrative personnel are not adequately supplied with aerial photographs and base maps to be used for planning soil conservation and irrigation activities correctly, adequately, efficiently and economically. Development of the TOPRAKSU Cartographic Office is a start toward development of cartographic services.

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Organization

Objectives of the five-year Turkish National Development Plan related to the soil and water conservation program are to achieve land use adjustments and treatment that will conserve soil and water resources; establish a more permanent and stable agriculture; reduce the hazards of flood and sedimentation; and assure the most productive long-term use of soil and water.

TOPRAKSU General Directorate recognized that cartography is essential for carrying out the development projects and accordingly the TOPRAKSU Cartographic Office was established in the TOPRAKSU organizational structure in 1965. It is the function and duty of the Cartographic Office to furnish complete cartographic services for land development projects, including preparation of soil maps for soil survey, drafting and reproduction services for planning, preparation of large scale maps for special purposes, and other essential cartographic services for such activities as irrigation, drainage and land consolidation.

The Cartographic Office has some specially trained technicians and some special equipment. A few persons perform cartographic service economically with this equipment under the direction and supervision of a few highly competent specialists. Eventually, improved and extended training and equipment will make possible fulfillment of the Cartographic Office mission and duties.

In many cases, specialized cartographic equipment can handle all the work of a particular kind required for a number of TOPRAKSU regional offices. The prompt use of Cartographic Office services can be an important factor in the low cost of work of the Soil Conservation and Farm Irrigation General Directorate (TOPRAKSU) which could make possible orderly planning and could conserve time of field technicians on the job.

The Cartographic Office consists of three sections:

(1) Drafting and Map Construction

(2) Reproduction

(3) Aerial Photo Interpretation

Primary Mapping Activity

The mapping program of the TOPRAKSU General Directorate is primarily related to fulfilling the responsibility of the Ministry of Rural Affairs in the field of soil survey. The scale of early soil maps was variable and in most cases the maps were drawn on large and often unwieldy field sheets. A country-wide map of the soils of Turkey was published at 1:800,000 scale.

In recent years there has been an increasing demand for 1:25,000 scale soil maps which can be used for predicting engineering problems, fertility requirements and other planning. Detailed soil maps are needed, on which individual fields may be recognized clearly for such purposes. To meet these demands TOPRAKSU Cartographic Office has made a study of the economics of producing maps at a desirable scale to meet the needs of the users. It was found that the maps could be produced by cartographic methods at considerably lower costs than could the older type maps.

Base maps are prepared in advance at the scale of 1:25,000, on which cultural and drainage features are shown. Field sheet data, such as detailed soil maps, land-use capability maps, land-use maps, fertility maps, physiographic maps, and structural maps, are transferred to the basic map by using photogrammetric procedures. Field work which has been done on aerial photographs is plotted on the base maps by use of an overhead reflecting projector. In some cases, base maps are not available for a given area. In such instances, the base map can be made by using the slotted-templet method of map preparation. The base maps are reduced to a scale of 1:100,000 as publication maps. The production program is now well underway. Soil maps permit publication of practically all the detail mapped by the field surveyor.

Aerial Photo Interpretation

The majority of mapping work should be done on aerial photographs furnished by TOPRAKSU Cartographic Office. The photographs are used in the field for drawing soil boundaries and for plotting other data relevant to soil and water conservation plans, watersheds, etc.

Photo interpretation has come to be generally recognized as a device for reducing the cost and improving the accuracy of most surveys and planning work which deals with the land. The engineers from TOPRAKSU Cartographic Office serve as instructors in photo interpretation at TOPRAKSU training centers.

To make a soil survey in a given area, first, the photo interpretation work is done on aerial photographs in the TOPRAKSU Cartographic

Office. In this way, photo interpretation maps are prepared. A field crew then works in the assigned field area, especially in sample areas for soil survey. Then, systematic analyses are completed.

The term "cartography" in TOPRAKSU General Directorate is used in its broad sense. It includes mapping activities, photogrammetry, plane table surveying, general drafting, documentary photography, and reproduction of maps, charts and other materials by direct printing process. These services are provided in the TOPRAKSU Cartographic Office by three engineers, one specialist in photography, and about forty soil and water conservation technicians.

The following services are provided by the Cartographic Office:

(1) Supplies aerial photographs as contact prints or enlargements for TOPRAKSU regional offices.

(2) Assists in the development and execution of cooperative mapping projects with the other mapping offices.

Furnishes leadership in the preparation of soil maps for publication.

(4) Furnishes aerial photographs as required for efficiency in making soil surveys, engineering and watershed protection surveys and plans, for soil conservation planning and land consolidation.

(5) Maintains a file of maps and drawings for reference by technicians.

(6) Maintains relations with the Army Map Service, Cadastral Office and other governmental cartographic offices.

(7) Obtains, for use throughout the service, maps prepared by other agencies.

(8) Performs drafting for the technical and administrative personnel of TOPRAKSU General Directorate.

(9) Directs and furnishes technical leadership for the cartographic work of TOPRAKSU General Directorate.

(10) Produces soil and capability maps.

(11) Compiles photo-mosaics (control, semi-controlled and uncontrolled) for soil surveys, watershed protection, and land consolidation projects.

(12) Makes area measurement for soil surveys.

(13) Makes general administrative maps.

(14) Files negative tracings and copies of maps, charts and other materials.

(15) Provides facilities for processing direct copy work, such as ozalid and photo-copy.

(16) Prepares charts, graphs, maps, slides, and photographic reproductions.

(17) Compiles general administrative maps from available maps and charts.

(18) Copies soil survey field sheets for regular service needs.

(19) Prepares and reproduces new cartographic visual aids materials.

(20) Interprets aerial photos for:

(a) Soil survey.

(b) Accurate delineation of watershed boundaries, drainage patterns, flood plains and silt-producing areas.

(c) Identification and classification of the land use patterns for economic evaluation.

(d) Tentatively selecting potential agricultural engineering structure sites (reservoirs, dams, stock ponds, canals for drainage and for irrigation).

(21) Makes available topographic maps at the scales of 1/200,000, 1/100,000, 1/25,000 and in some limited areas at 1/5,000.

(22) Makes available aerial photographs at scales of 1/35,000, 1/18,000 or 1/20,000.

(23) Makes available maps with topography and cadastral information at 1/5,000 scale in selected areas.

(24) Provides a class "B" printing plant for printing materials for the service including

maps, technical guide sheets, technical handbooks, forms, illustrations, etc.

(25) Conducts cartographic training in the proper use of existing base maps, in the compilation or construction of special purpose maps, the evaluation of existing base maps, scale and position reliability, and determines whether they contain an adequate amount of data for the special purpose administrative or operational maps to be compiled.

MEASURING DEVICES FOR FARM TURNOUTS AND PIPES

by

Korkut Ozal and Ethem Ozsoy*

Synopsis

With the extensive development of water resources and the ever increasing cost of water exploitation, the use of water needs to be made with more conscientiousness.

One of the prerequisities to use water efficiently is the measurement of water. In irrigation practice, on the other hand, costly measuring devices cannot be justified. Consequently the development of inexpensive, simple and reasonably accurate measuring devices is of important concern.

In this paper various devices which have been or are being developed for the purpose are discussed briefly.

Introduction

(A) THE NEED FOR AND IMPORTANCE OF WATER MEASUREMENT IN IRRIGATION PRACTICES

The measurement of irrigation water is becoming an important problem. It will gain more importance as the available water resources approach to full development and the cost of exploitation increases. An irrigation system is designed primarily to make maximum use of available water. The area that may be irrigated is dictated by the amount of water available.

Effective control and measurement of irrigation water, with a certain degree of accuracy throughout the irrigation system from the point of diversion to the farm turnout, are necessary for the following reasons:

(1) To facilitate an efficient and successful irrigation practice.

(2) To execute the legal obligations concerning water priorities and water rights.

(3) To reduce the waste of water and to permit a more effective administration of water.

(4) To have a reasonable basis for charging water users.

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(5) To insure an equitable distribution of water.

(6) To establish and maintain good and cordial relationships among the parties involved in the distribution and use of water.

To achieve the above purposes, irrigation water should be measured at various points: collection points, secondaries, tertiaries and farm turnouts. Among these, the most important point of measurement in an entire irrigation system is the farm delivery point. The measurement at this point serves many of the above objectives.

(B) Characteristics of an Ideal Farm Measuring Device

The measurement of water at farm turnouts involves various factors. There are several points that must be considered in selecting a control and measurement device best suited to the given site. Generally a good and acceptable device should have the following properties:

(1) Easy and simple regulation and measurement of water with less need of skilled manpower.

(2) Reasonable accuracy and consistency with associated stability and safety.

(3) A low resistance to the flow with a consequent low head loss.

(4) Be adaptable to the fluctuations of discharge.

(5) Be able to operate in flow. of unfavorable conditions: silt, weed, debris, etc.

(6) Be economical in installation as well as in operation and maintenance.

To point out the importance of the last item, the following example may be given:

If one considers a project area of 10,000 hectares, there needs to be a main canal measurement device, at an estimated cost of 5,000 TL. There will be approximately ten secondaries and 200 tertiaries at approximate costs of 2,000 TL. and 500 TL. each respectively. If one assumes two and a half hectares to an average farm, there will be 4,000 farm turnouts at an estimated cost of 100 TL. each. It can be seen that the cost of all the measuring devices above the farm turnouts is (5,000 plus 20,000 plus 100,000 equals 125,000) while the cost of farm turnout measuring devices is 400,000 TL. In other words, if a thirty percent saving in the installation cost is achieved, the total saving may be as high as the combined cost of all the other water measuring devices in the system.

(C) Devices Presently Used for Water Measurement

(1) Generally speaking, water measuring devices may be classified into two groups:

(a) *Those devices that measure the quantity* (by weighing or by volumetric measurements).

(b) *Those devices that measure the rate of flow (velocity or discharge)*.

(2) Regardless of the volumetric or velocity measurements, a measuring device consists of two distinct parts:

(a) The first part is the primary element that is in contact with the water. It may accelerate the flow or it may be influenced by the flow.

(b) The second part translates the interaction between the flow and primary element into volumes or rates of flows. In a weir, for example, the weir blade is the first part that accelerates the flow and the gage upstream in the weir pool is the second part.

(3) Devices used for the measurement of water in irrigation canals are generally of the "rate measuring" types.

In Table 1 various types of most commonly used measuring devices and their characteristics are summarized. There are other devices that are also being used to a limited extent, such as dividers, modules, semi-modules and flow vanes. At the moment, however, they are not considered economically applicable to water measurements at the farm turnouts.

DEVICE	Discharge formulae Q (m^3/sec)	Head loss	Relative Accuracy	THE COST AND DIFFICULTY OF			PROBLEMS AND ADDITIONAL REQUIREMENTS		
				Construction	Operation	Maintenance	Sediment	Debris	Additional Requirements
Contracted Rectangular weir	$1.84(L-0.2H)H^{3/2}$	High	High	High	Low	med	High	med	point gage
Suppressed weir	$1.84\ L \cdot H^{3/2}$	"	"	Medium	"	"	"	"	"
Cipoletti weir	$1.86\ L \cdot H^{3/2}$	"	"	High	"	"	"	"	"
90° V notch weir	$1.34\ H^{2.48}$	"	"	"	"	"	"	"	"
Parshall flume	$J \cdot H_a^n$	medium	medium	"	"	Low	Low	Low	gage
Orifice	$2.7 \cdot A \cdot H^{0.5}$	Low	Medium	Low	"	med	med	High	"

L = weir crest length (m) H = Hydraulic head (m) A (Discharge area) (m^2)

J, n are constants

W (Throat width) m	0.1	0,3	0,5	1.0	2.0
J	0,236	0,634	1,159	2,397	5.418
n	1,557	1,522	1,541	1,569	1,572

Table 1. Relative merits of measuring devices for open channels

Past and Present Water Measurement Practices in Turkey

(A) LOCAL IRRIGATION PROJECTS

In the past the measurement of water in the local irrigation systems was mainly to execute water rights. Usually there was not a storage facility within the system. So the water which was diverted from the source was to be rationed among the users in accordance with their established water rights. For such a purpose the division of the flow rather than the measurement of it was important. In achieving this purpose the following procedure was usually followed:

(1) The flow was divided by means of constant area orifices. A constant area orifice consisted of a stone plate with a circular opening. Since the head behind the orifice was the same for all the orifices and canals, a reasonably just rationing of discharge was possible.

(2) The discharge diverted from the canal this way was rationed among the users by a rotation on a time basis. Each user was entitled to a certain hour of water delivery.

(B) EARLY STATE PROJECTS

With growing concern for irrigation development in Turkey, the government has assumed the leading role. In earlier projects the water was not distributed on a volume basis. The charge was made on the basis of irrigated area and the type of crop. Consequently the farm turnout was not equipped with a measuring device. A reasonable explanation for this situation can be given as follows:

(1) The water is distributed by a rotation method. The available water had to be distributed among the users since there was no storage facility for water not needed.

(2) The land was so fractioned that the total cost of measuring devices was prohibitively high.

(3) Neither the farmer nor the operating crew was sufficiently educated and experienced to properly use measuring devices.

(C) THE PRESENT SITUATION

Parallel to the development of irrigation, reasons for not having a measuring device at farm turnouts gradually disappeared. Storage structures have been built. So the demand method of water distribution could be introduced, the irrigation systems are being designed to serve several farms from a delivery point where water could economically be measured and rotated among the farms. Farmers and operating crews are now in a better position to employ water measurement devices.

As a result of the foregoing changes the device shown in Fig. 1 was developed to measure water. This device is adapted from a constant head orifice. Since the water is still being sold on an area basis, the orifice gate is not being installed at the moment, but the guides for its future installation are provided. This type is designed to be cast in place.

Since the cost involved in turnouts is considerable, efforts have been made to reduce the cost of each unit by introducing prefabricated elements. By such an approach a better quality is generally provided. In Fig. 2 the design of such a prefabricated turnout is shown.

In both Figs. 1 and 2 the water level in the tertiary canal will be controlled by a stop-log to be put into the grooves left for the purpose.

The cost of the above types is about 1000 TL. Approximately fifteen to twenty percent of the cost can be allocated to the measurement purpose.

(D) FUTURE DEVELOPMENTS

In recent years some of the irrigation distribution systems in Turkey have been designed to consist of elevated flumes, because of the economy and because of the shorter duration of const. c- tion.

All the elements are prefabricated, and it seems that in the future more of the irrigation projects will be of this type.

The delivery of the water to individual farms is made by means of plastic syphons (Fig. 3). The use of plastic syphons facilitates water delivery from every point so it is highly adaptable to changing property patterns. Besides, by plastic syphons water measurement can be made.

In case of large water requirements, more plastic syphons may be used in parallel. Their cost is far below the cost of permanent farm turnouts mentioned above.

The water level in the flume is controlled either by canvas checks or, better, by timber or steel gates employing the joint of flumes as gate guides.

The total cost of syphon, connecting elements and canvas check is below 250 TL.

In Photographs 1 and 2 the use of plastic syphons is illustrated.

Research

Research is being conducted to develop a device at the least possible cost. This problem is approached from the following angle: The flow regulation at the farm turnout requires two control gates, one on the tertiary and one on the farm ditch. If those gates can also be used to adjust and/or to measure the discharge, the cost of measurement can be substantially reduced.

One of the research projects was undertaken by the DSI (State Hydraulics Works Department). The result of the research is shown in Fig. 4. A study of this figure reveals that this solution does not require any equipment in addition to that needed for water control. A major disadvantage of this device, however, is the number of parameters involved in measurement. Since the gate opening is submerged, the flow through the orifice is controlled not only by its opening but by the downstream water level. Consequently, the measurement of a flow could be achieved by a trial-and-error process.

Another research project was undertaken by the Middle East Technical University at Ankara. At the end of the first step the results shown in Fig. 5 were obtained. In this solution the downstream water level from the farm turnout was kept at such a height that the flow under the gate was of the free flow type. By streamlining the entrance the effect of the discharge in the tertiary on turnout discharge is minimized. Research is continuing to investigate the effect of downstream submergence and the geometry of the tertiary canal.

Measuring Devices for Pipes

Measurement of water in pressure conduits has received widespread attention from various branches of engineering. Very sensitive devices, such as venturi tubes, flow nozzles, thin plate orifices, centrifugal meters, pitot and prandtl tubes, flow meters, etc., have been developed and are being used for accurate measurement of the closed conduit flow. Such devices, however, are so expensive that under the prevailing conditions one cannot economically justify their use for irrigation water measurement in a developing country like Turkey.

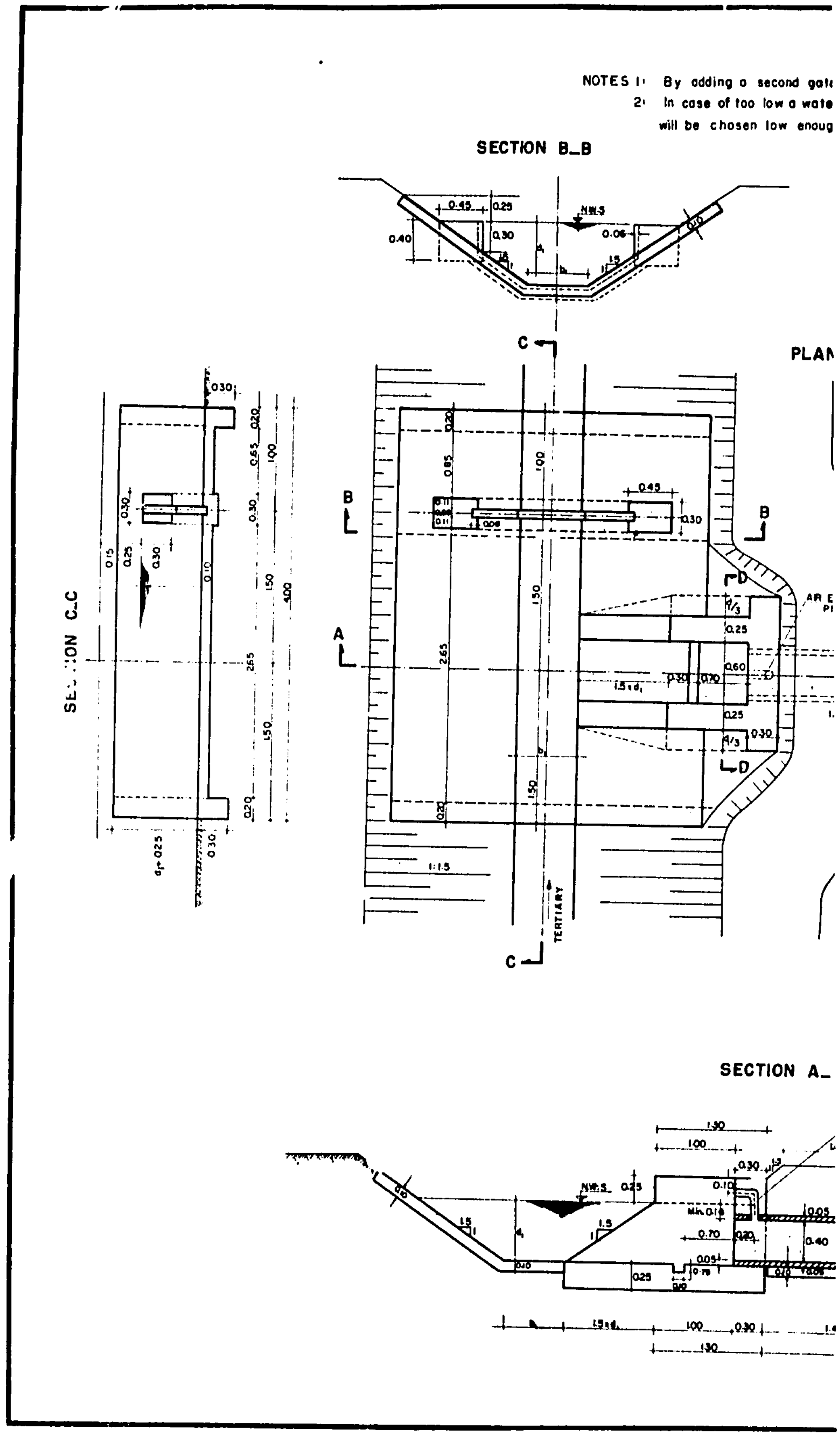
On the other hand, the use of low pressure conduits in irrigation systems will no doubt rapidly extend in the near future. It is therefore important now to develop a system that will render a simple, reasonably reliable, and inexpensive measurement of water.

The simplest approach to this problem is to use the flow path coming from a closed conduit, in the form of a free jet, as an indicator of the mean velocity. Water measurement by such an approach is here outlined:

Vertical Pipes

The flow leaving a vertical pipe of a diameter (D) will attain a maximum height of (H).

Lawrence and Braunworth have conducted extensive research for the above type of flow. They distinguished two distinct types of flow, with a transition zone in between:



NOTES 1: By adding a second gat
2: In case of too low a wate
will be chosen low enoug
SECTION B_B
N.W.S
PLAN
SECTION C_C
TERTIARY
1:1.5
AIR E
SECTION A_
N.W.S.
1.5

e used as a constant head orifice.
tertiary the bottom of the turn_out

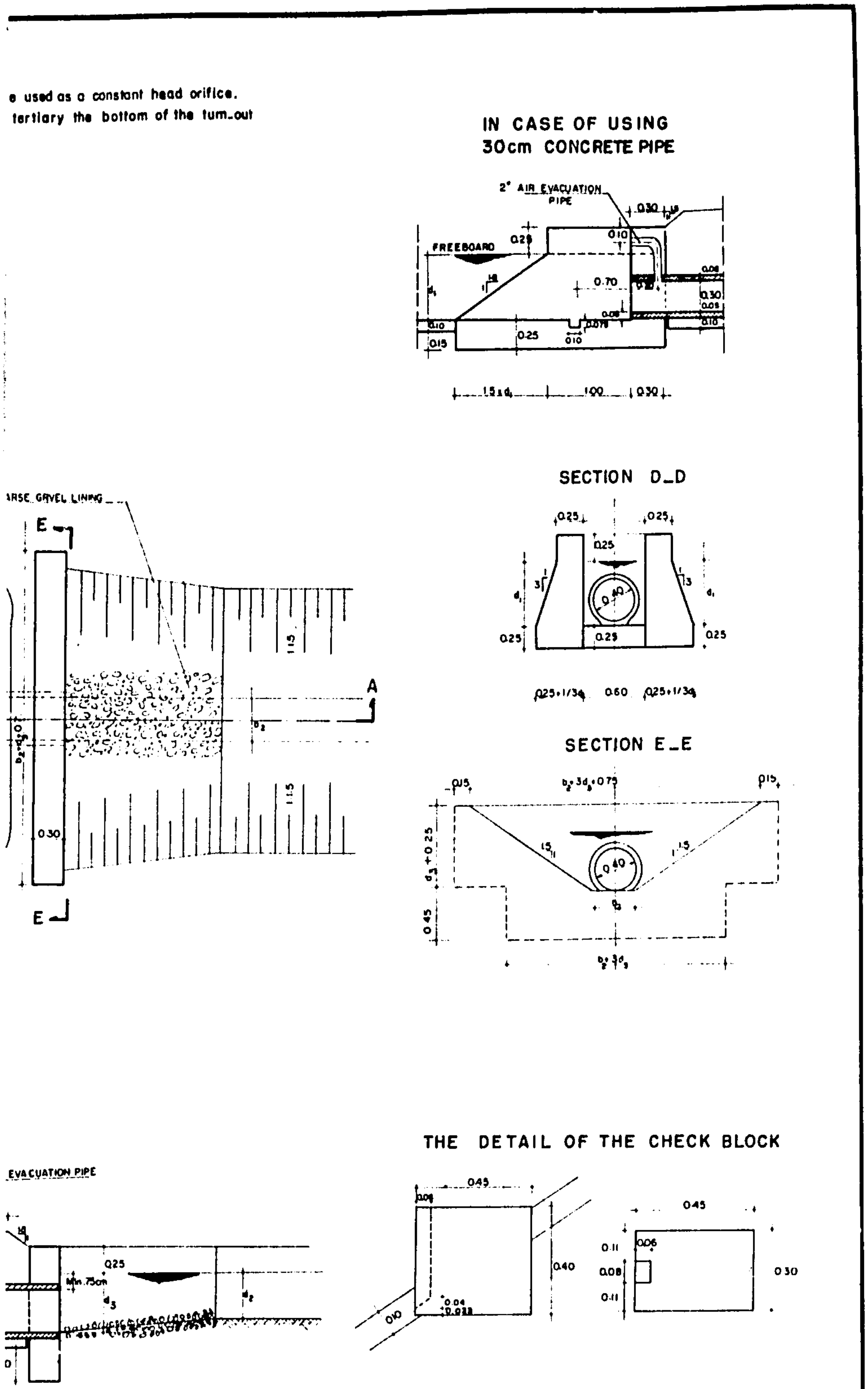
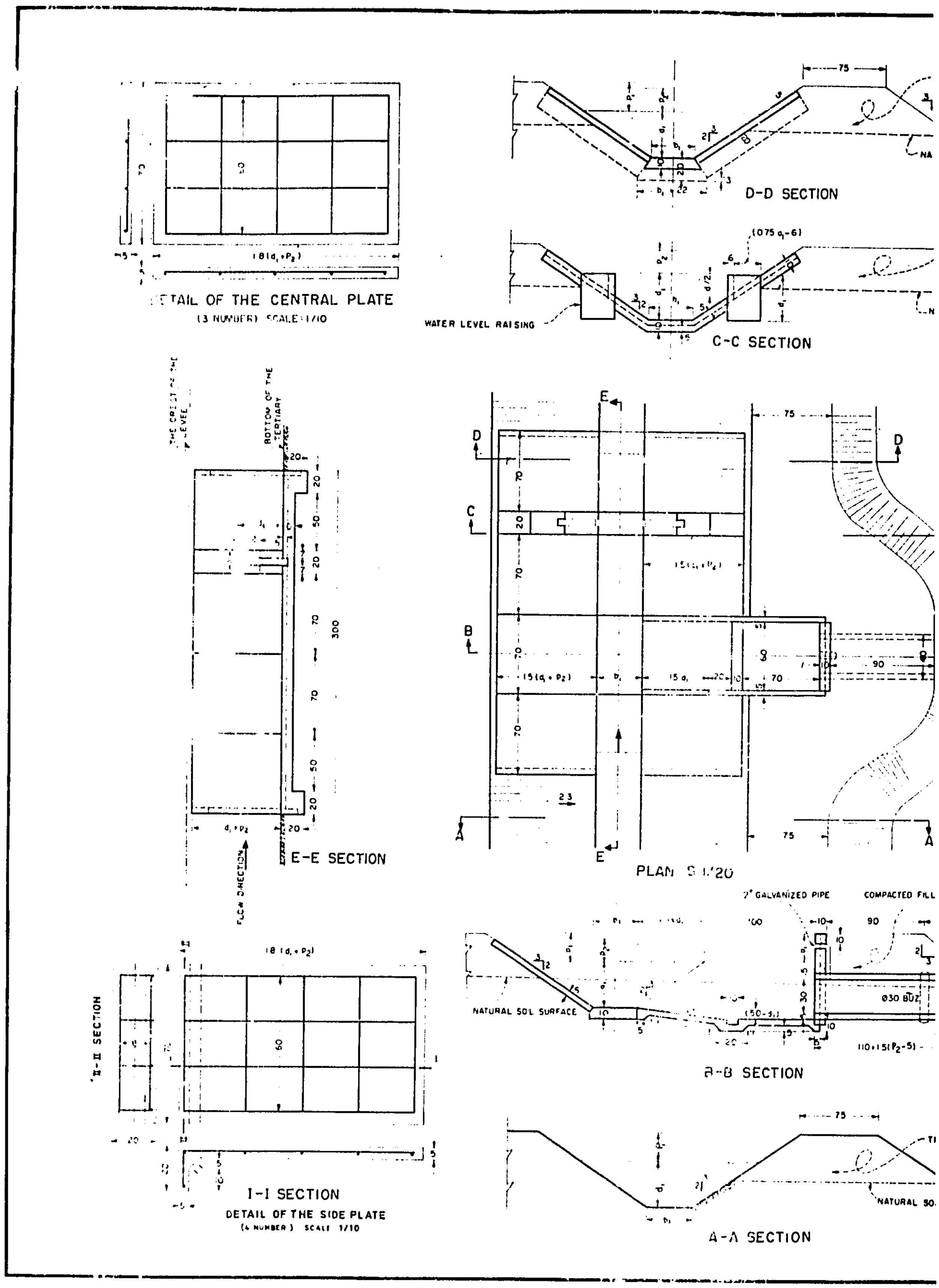
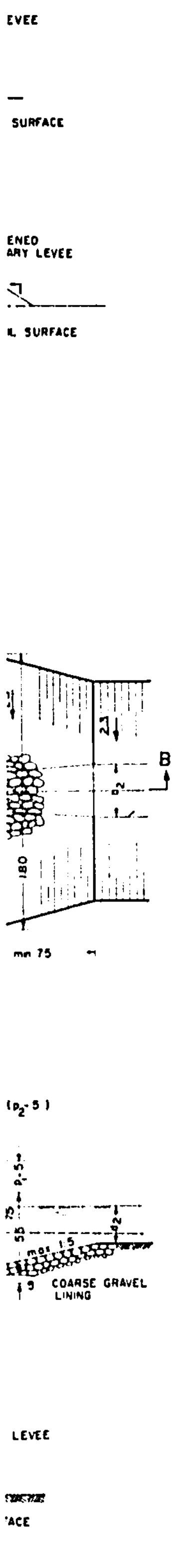
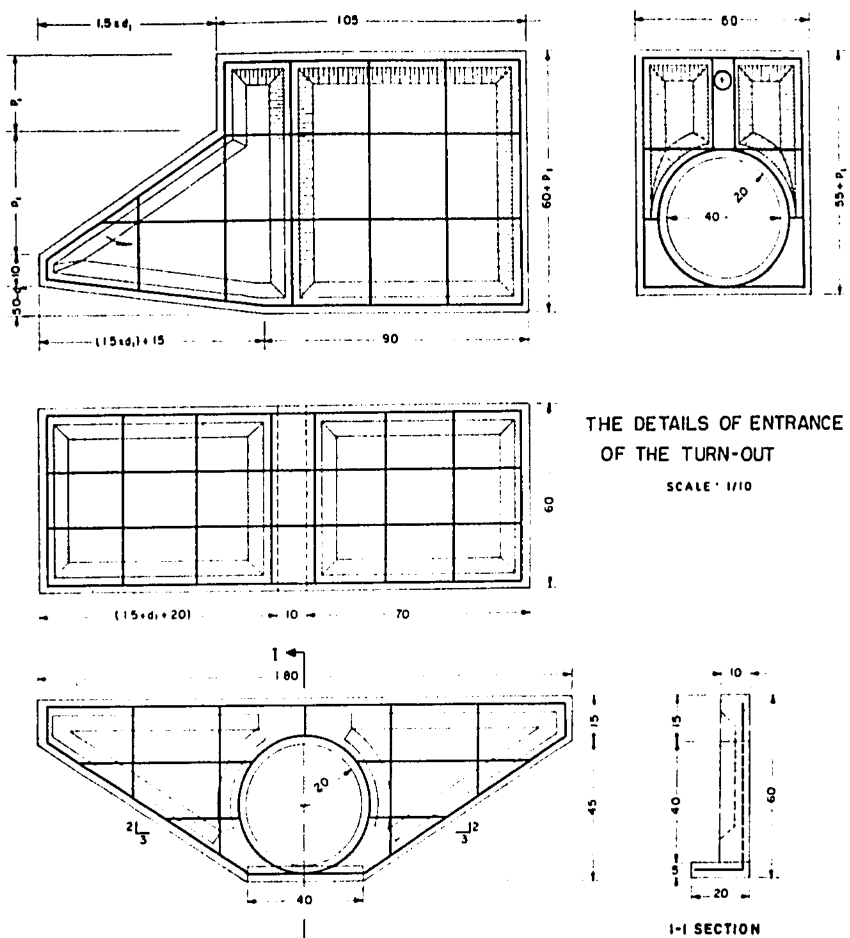


FIGURE : I. DSİ STANDARD FARM TURN_OUT EQUIPPED WITH CHECK GATE AND MEASURUMENT DEVİCE



DETAIL OF THE CENTRAL PLATE
(3 NUMBER) SCALE 1/10
D-D SECTION
C-C SECTION
WATER LEVEL RAISING
THE CREST OF THE LEVEE
BOTTOM OF THE TERTIARY
E-E SECTION
FLOW DIRECTION
PLAN
2" GALVANIZED PIPE
COMPACTED FILL
NATURAL SOIL SURFACE
B-B SECTION
I-I SECTION
II-II SECTION
DETAIL OF THE SIDE PLATE
(4 NUMBER) SCALE 1/10
A-A SECTION
NATURAL SO





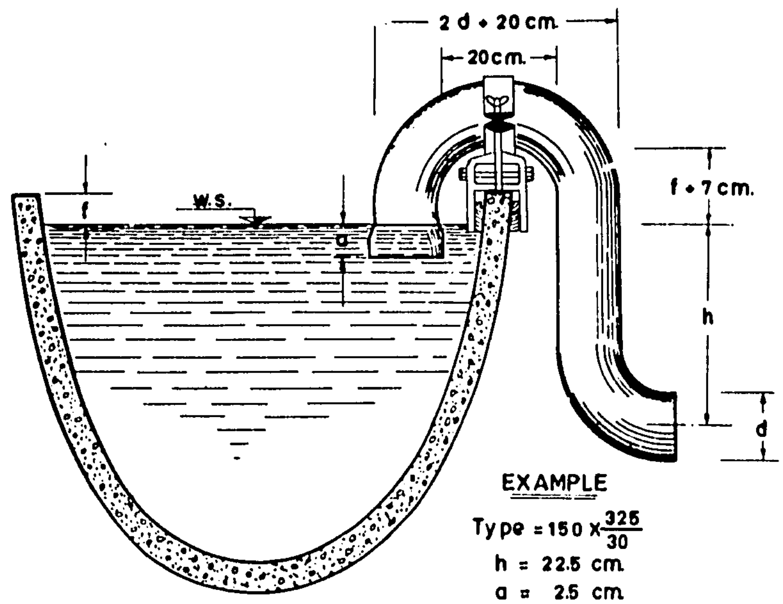
THE DETAILS OF ENTRANCE BOX
OF THE TURN-OUT
SCALE : 1/10

THE DETAİL OF DOWNSTREAM
HEAD WALL OF THE TURN-OUT
SCALE : 1/10

NOTES:
1- This design is prepared as a Standart type, it can be fitted to the particular conditions existing at the site
2- The prefabricated reinforced concrete elements will be manufactured by a concrete having 400 kg cement charge per m^3 c' aggregate
3- Reinforcement bars are of ø6mm and their joints will be formed by welding The maximum spai of reinforcement is 30 cm
4- The joints of concrete pipes and air evacuation pipes will be made by 400 kg cement charged mortar
5- The block to bank up the water table is of 250 kg cement charged prefabricated concrete, the finishing of their installation will be made by 250 kg cement charged mortar
6- By the addition of one gate turn-out will be used as a constant head orifice measuring device
7- All the dimentions are in cm

FIGURE : 2
DSİ PREFABRICATED STANDART
FARM TURN-OUT

FARM TURN-OUT IN ELEVATED FLUME TYPE TERTIARIES



EXAMPLE

Type = 150 x $\frac{325}{30}$

h = 22.5 cm.

a = 2.5 cm.

Q = 24.0 lt/sn.

THE CHARECTERISTICS OF PLASTIC SYPHONS

Type	d Diameter cm.	f Free Board cm.	a Depth of submergence cm.	h Syphon Head cm.	Q Discharge lt/sec
100 x $\frac{225}{10}$	10	5	12.5	22.5	10
		10	7.5	17.5	9
		15	2.5	12.5	7.5
100 x $\frac{325}{13}$	10	5	12.5	32.5	13
		10	7.5	27.5	11.8
		15	2.5	22.5	10
100 x $\frac{425}{15}$	10	5	12.5	42.5	15
		10	7.5	37.5	13
		15	2.5	32.5	11
150 x $\frac{225}{24}$	15	5	12.5	22.5	24
		10	7.5	17.5	21
		15	2.5	12.5	18
150 x $\frac{325}{30}$	15	5	12.5	32.5	30
		10	7.5	27.5	27
		15	2.5	22.5	24
150 x $\frac{425}{35}$	15	5	12.5	42.5	35
		10	7.5	37.5	32
		15	2.5	32.5	29

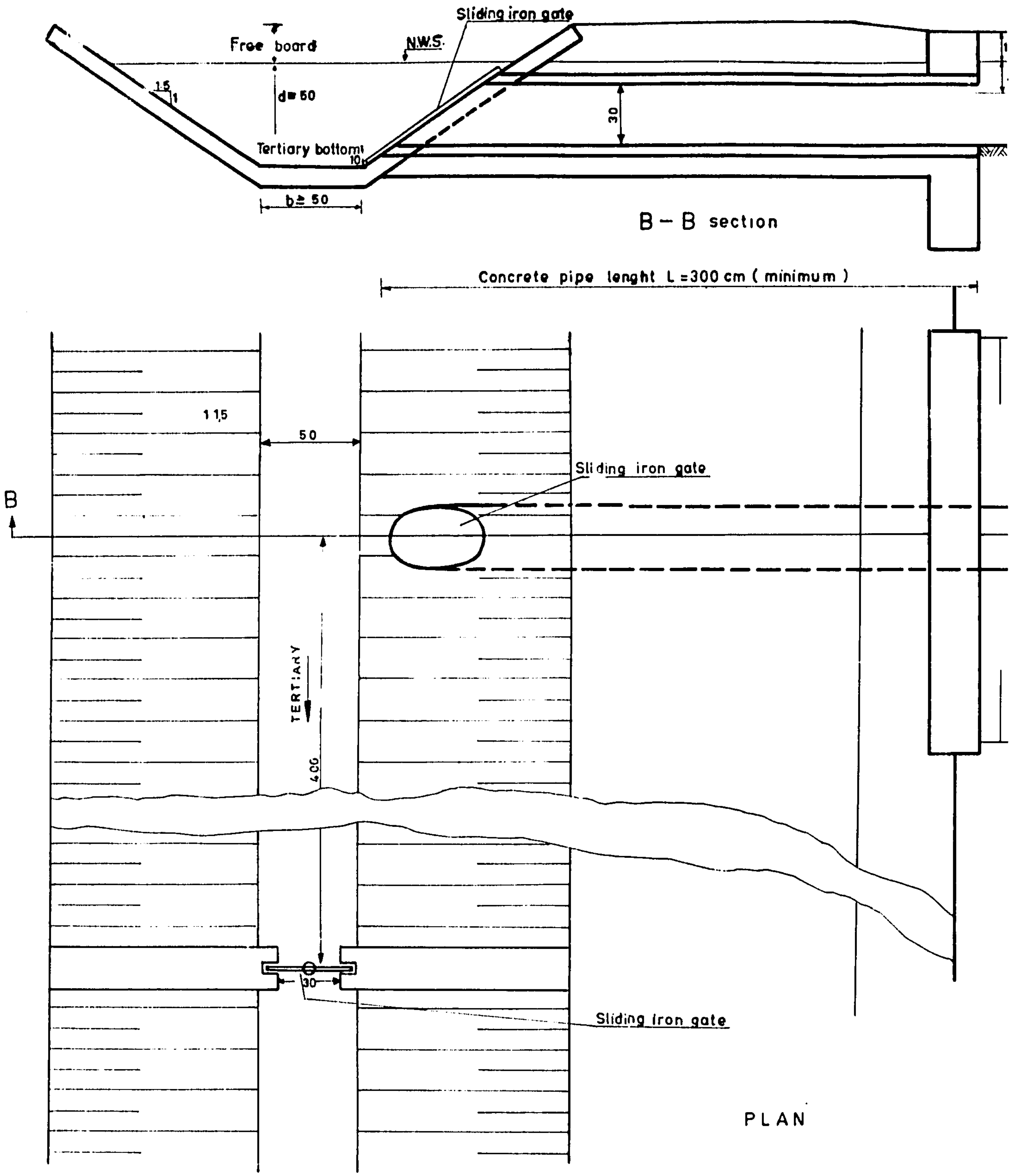
EXPLANATION: Type = 150 x $\frac{325}{30}$

325 — Max. Syphon Head (m m.)

150 — Outside diameter of syphon mm.

30 — Max. discharge (lt/sec)

FIGURE : 3


Sliding iron gate
Free board
N.W.S.
1,5
1
d = 50
30
Tertiary bottom
10
b ≥ 50
B – B section
Concrete pipe lenght L = 300 cm (minimum)
1 1,5
50
Sliding iron gate
B
TERTIARY
400
30
Sliding iron gate
PLAN

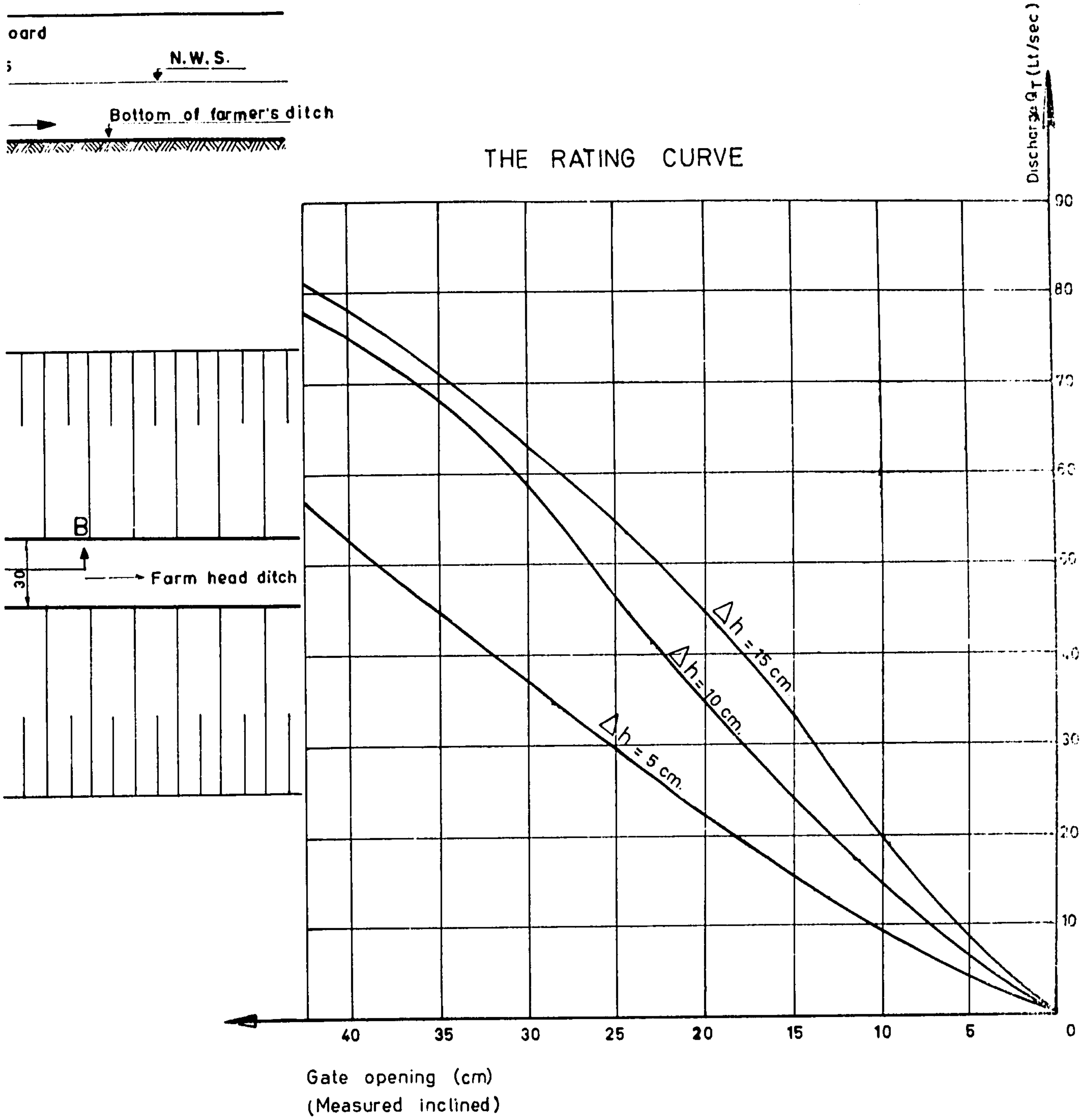
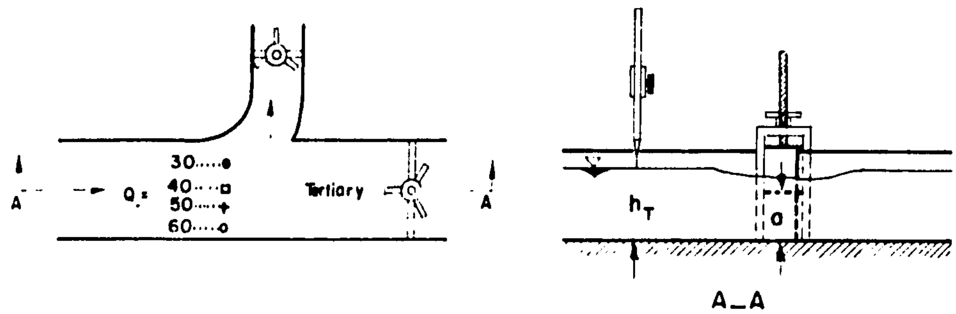
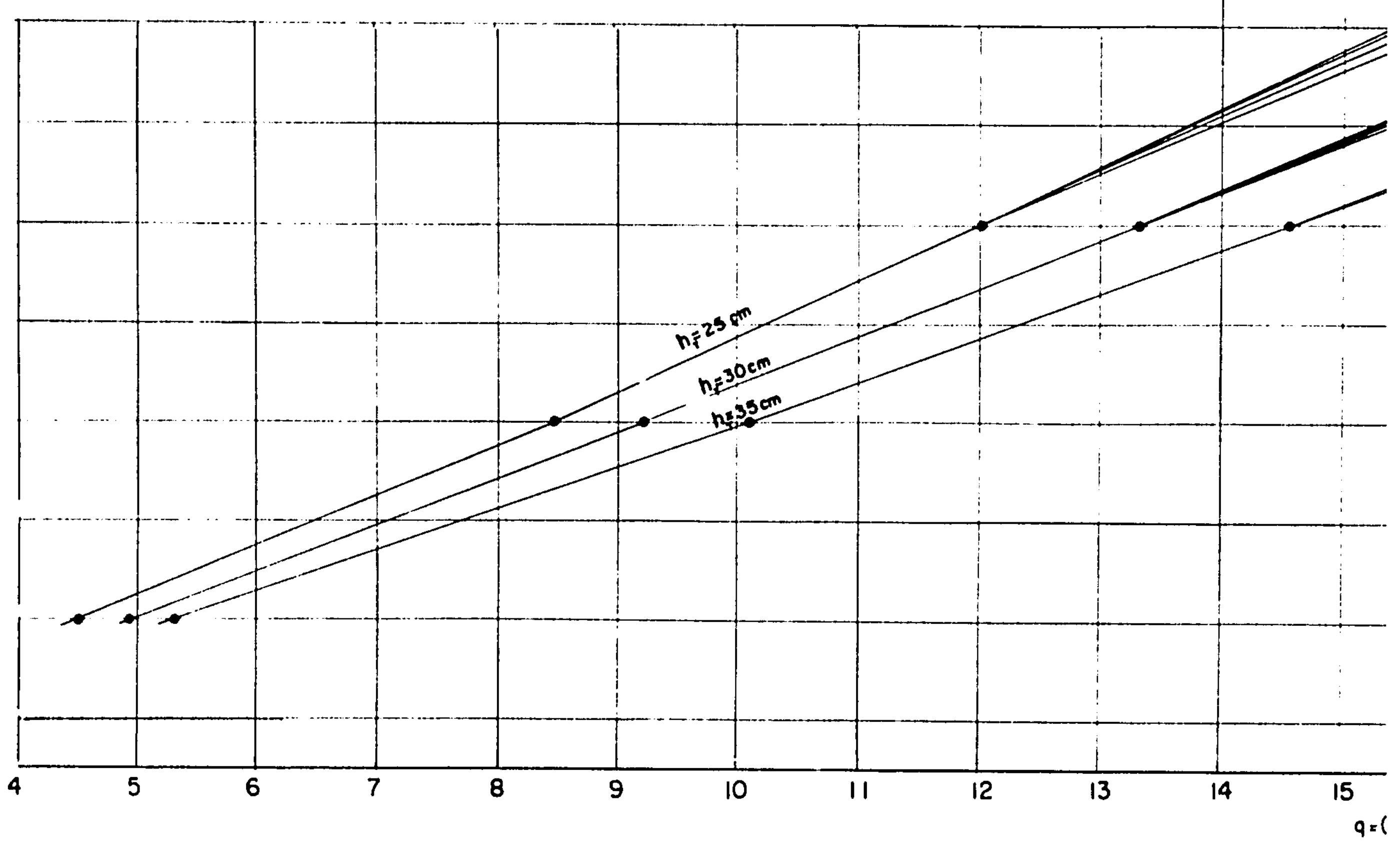


FIGURE: 4 DSİ RESEARCH PROJECT FOR FARM TURNOUT MEASURING DEVICE



A
Q =
30
40
50
60
Tertiary
A
h_T
a
A_A



h_T=25 cm
h_T=30cm
h_T=35cm
4
5
6
7
8
9
10
11
12
13
14
15
q=(

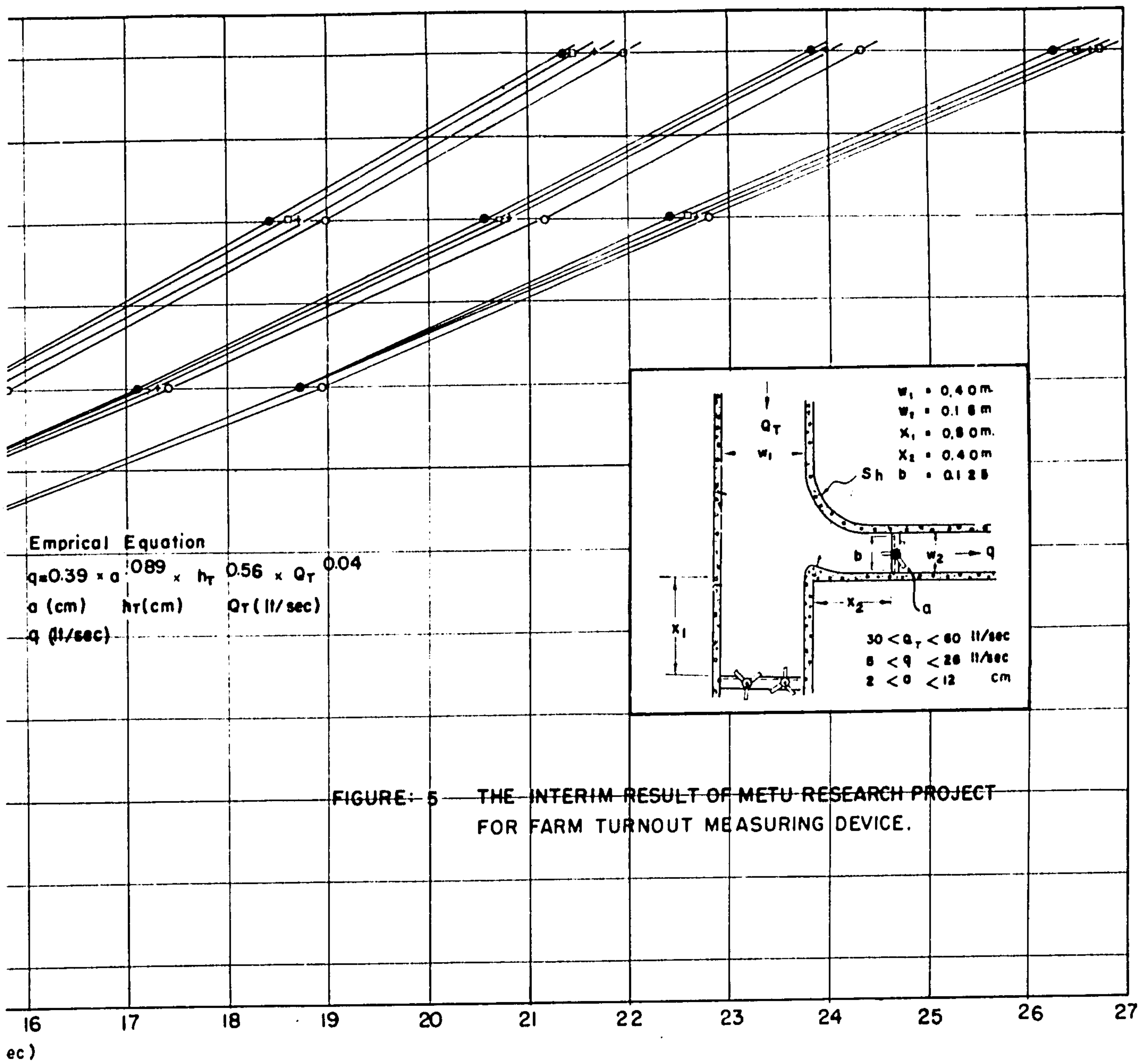
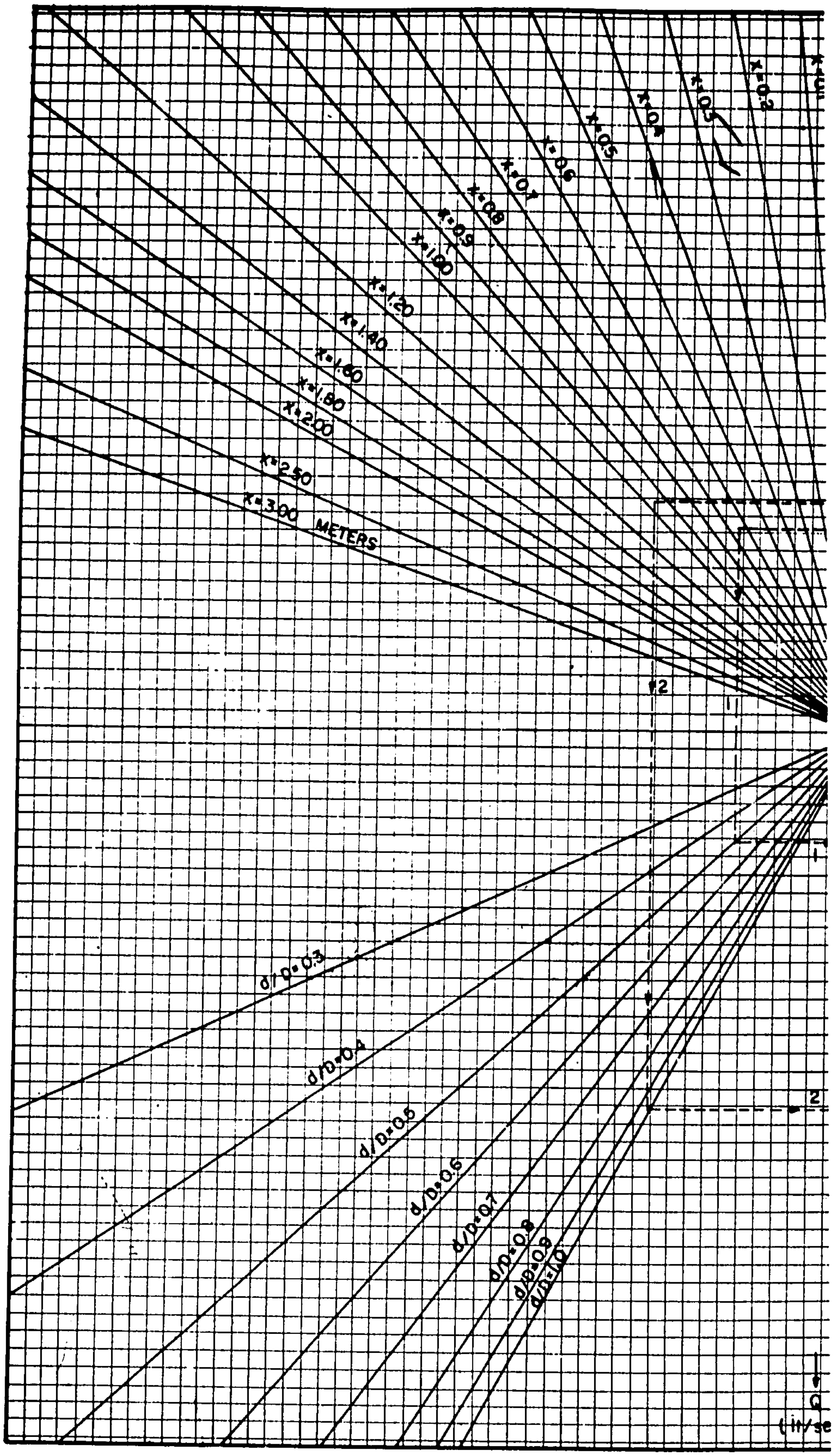
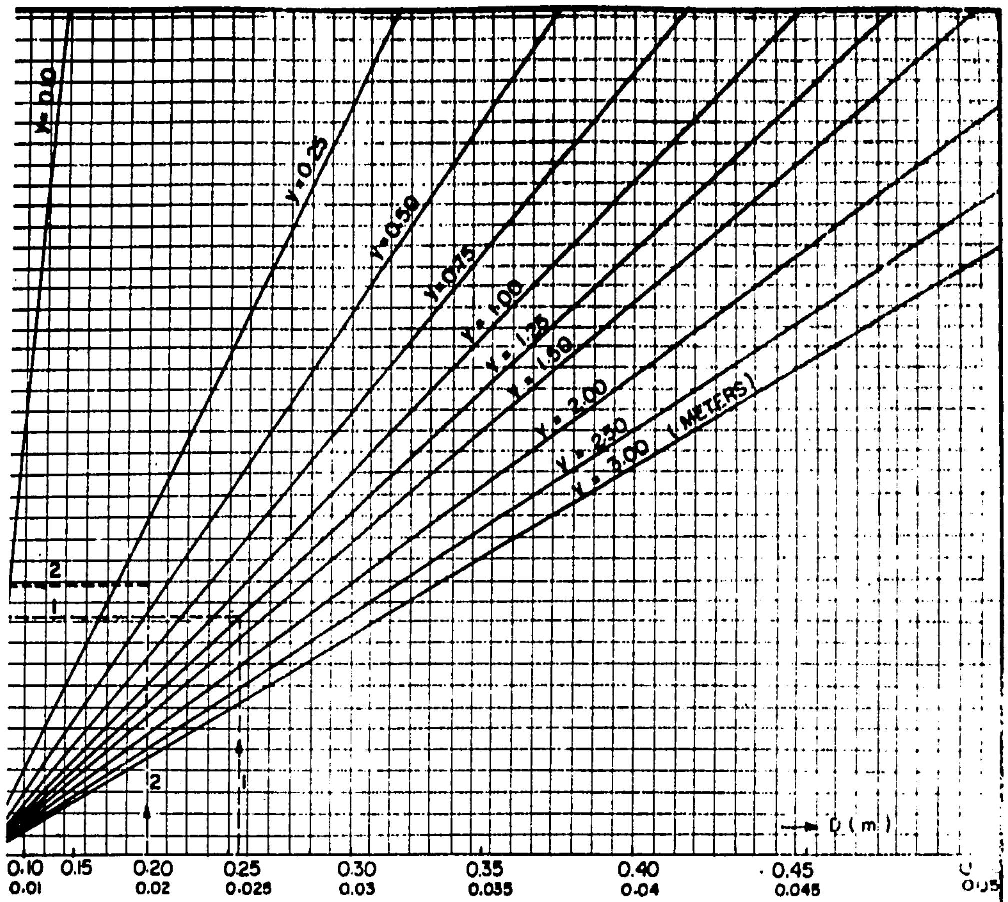
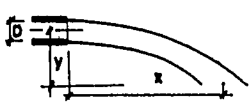


FIGURE: 5 THE INTERIM RESULT OF METU RESEARCH PROJECT FOR FARM TURNOUT MEASURING DEVICE.



X=0.2
X=0.3
X=0.4
X=0.5
X=0.6
X=0.7
X=0.8
X=0.9
X=1.00
X=1.20
X=1.40
X=1.60
X=1.80
X=2.00
X=2.50
X=3.00 METERS
d/D=0.3
d/D=0.4
d/D=0.5
d/D=0.6
d/D=0.7
d/D=0.8
d/D=0.9
d/D=1.0
Q





$$Q = ka \cdot 1{,}74 \frac{D^2 \cdot x}{\sqrt{y}}$$

Q = Discharge (m^3/sec)

ka = d/A = $\frac{\text{Partial Area}}{\text{Full Area}}$

D = inside diameter (m)

x = Horizontal distance

y = Vertical distance

Example 1 ·	D = 25 cm d/D = 0.5	x = 0.65 m. y = 1.25 m.	Q = 31,3 lt/sec.
Examle 2 ·	D = 2 cm d/D = 1.0	x = 0.95 m. y = 0.40 m.	Q = 1.06 lt/sec.

FIGURE: 8 · DISCHARGE DETERMINATION OF HORIZONTAL PIPES·

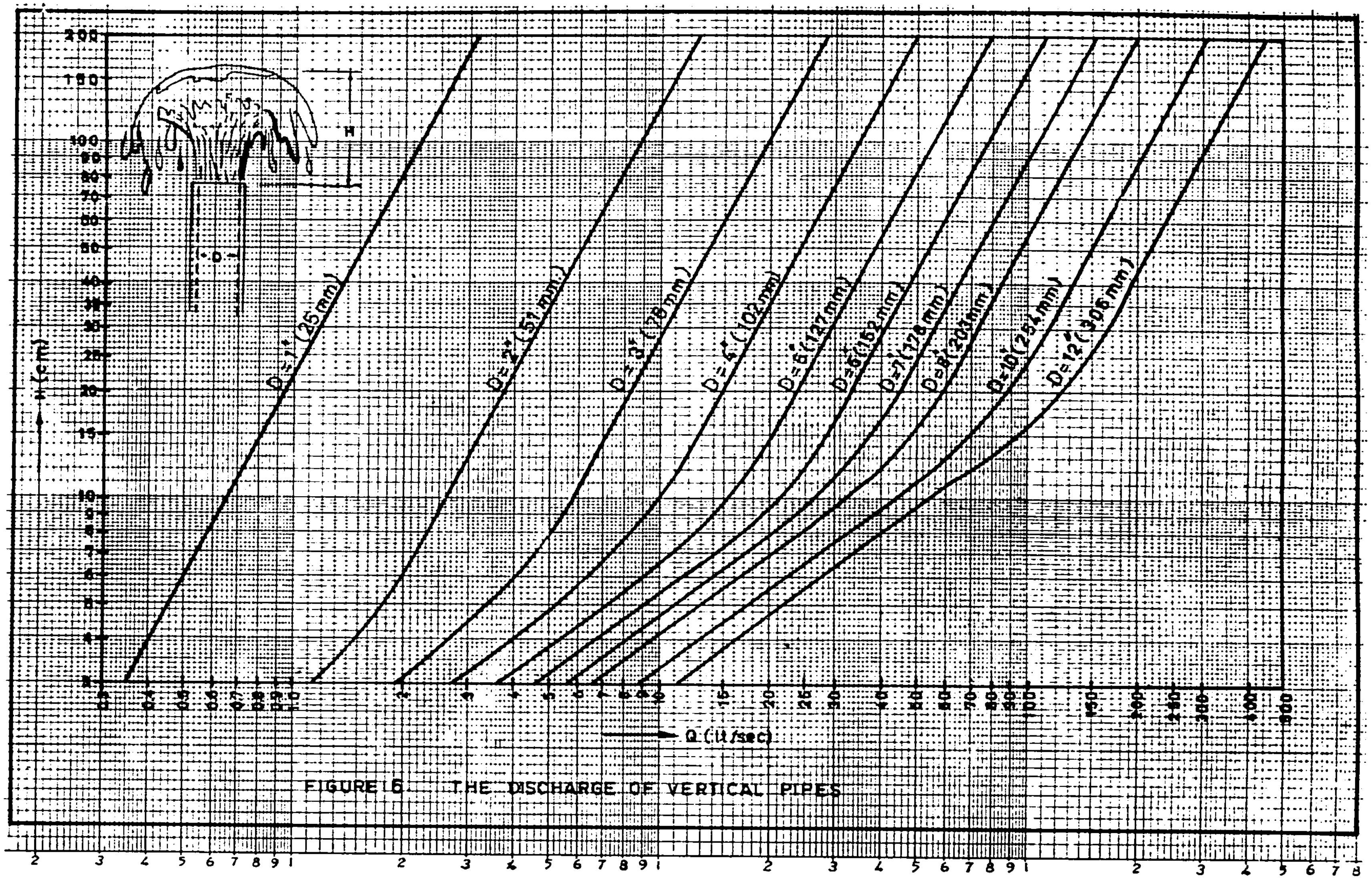


FIGURE 6. THE DISCHARGE OF VERTICAL PIPES

For H $>$ 1.4 D the discharge is of a pipe flow type and the following empirical equation holds:

$$Q = 3.309 \; D^{1.99} \; H^{0.53} \quad (1)$$

For H $<$ 0.37 D the flow is that of a circular weir and the discharge is given by

$$Q = 5.466 \; D^{1.25} \; H^{1.35} \quad (2)$$

In both equations Q is an m3/sec, and D,H are in meters.

In Fig. 6 the graphical solution of the above equation is given.

Horizontal Pipes

The free jet leaving a horizontal pipe will follow a parabolic path if the friction between water-air and water is neglected. The equation of this parabola is given by

$$Y = \left(\frac{g}{2 V_0^2} \right) X^2 \quad (3)$$

Where "V_0" is the velocity at the end of the pipe and "X, Y" are the coordinates of a point on the jet trajectory (Fig. 7).

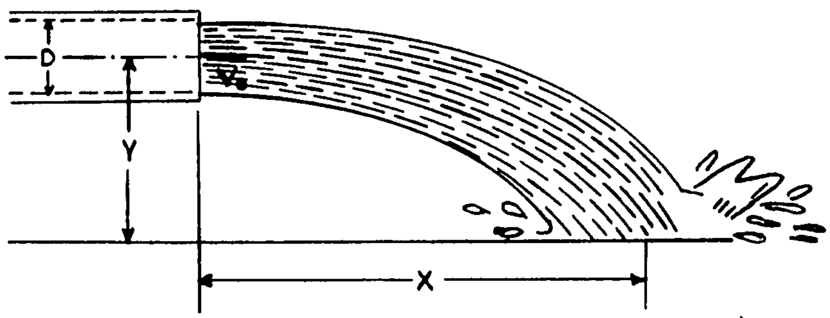


FIGURE:7. Measurement of water at horizontal jets

Solving "V_0" from the above equation and writing the discharge in terms of ka = a/A, where "a" is the area of flow at the end of the pipe (a = A in case of full flow), one obtains:

$$Q = ka.1,74 \frac{D^2 X}{y} \quad (4)$$

"ka" is a function of "d/D" (the ratio of partial depth to full depth), so the above equation can be solved by a chart shown on Fig. 8.

Conclusion

A brief discussion of water measurement at farm turnouts and pipes has been presented. From the discussion it can easily be seen that there is still much to do in this field, and better and cheaper instrumentation of farm turnouts is still to be achieved.

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(1) *Fluid meters.* ASME. 1959.

(2) *Water measurement at farm turnouts.* Adnan GUR, 1965, master's thesis submitted to MTEU.

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(6) *Measurement of pipe flow by the coordinate method.* F. W. Greeve, Purdue University, 1928.

(7) *Water Transmission.* Korkut OZAL, MTEU, 1965.

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CHAPTER XI

Education and Training

PLANS FOR EDUCATION AND TRAINING IN IRRIGATION IN CYPRUS

by

J. Ian Stewart and Savvas J. Chimonides*

Introduction

From the Cyprus Country Report you will have ascertained the following:

(1) Irrigation has always played a vital role in Cyprus, and this is truer today than ever before.

(2) Prior to 1946, irrigation meant essentially spate irrigation: the annual spreading of flood water across unleveled lands for cereal production.

(3) Today irrigation means year around pumping of groundwater for production of a wide assortment of high value fruit and vegetable crops. From this small sector of our arable lands we produce fully half the value of our total crop production, and fully three-fourths the value of our total agricultural exports (both crop and animal products). These figures illustrate the tremendous importance of our groundwater resources to the economic well being of Cyprus.

(4) These past twenty years have been a period of rapid expansion of groundwater use, with the result that development has become over-development. Strong measures are in order to avoid the loss of a substantial portion of the meaningful gains we have recently made.

(5) Since the founding of the Republic in 1960, the government, with the welcome assistance of technical cooperation programs from abroad, has made great strides toward gathering the multitude of data required for evaluation of our situation, for formulation of policy, for action programs designed both to alleviate problems and to vigorously develop our remaining unused water resources (primarily surface water).

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(6) Basic to improvement, as we are all aware, is a sound and continuing program of education and training. These terms are used here in the broad sense to include observation, surveys, research, etc., for self-education as to the true nature of our water-use situation; advising higher levels of government on our findings and their meanings, to assist in formulation of policy and necessary legislation; informing our parallel agencies of government with whom we will implement actual improvement works in the field; training our staff personnel and theirs to perform these works; informing suppliers and contractors of trends and expected needs; finally, the vital step of training farmers to utilize modern irrigation systems efficiently, and offering them continuing advice on all related matters through an informed Agricultural Extension Service. "Education and training" must include all of these things and more.

Farmers' Situation and Viewpoint

The introduction of deepwell boring equipment and pumps (essentially a post-World War II phenomenon) offered our farmers an opportunity unparalleled in all our history to tap and have full control of vast quantities of water available throughout the year for the production of high value specialty crops which return an average of fifteen to twenty times as much as their dry land production does even if we include the extensive spate irrigated lands. True, the new waters were expensive by comparison with the familiar spate waters (pumping costs average seven to eight mils per cubic meter), but the returns were sufficient to cause the farmers to overlook the costs. They were also sufficient to make both farmers and government overlook the fact that the average efficiency of water use was, and still is, very low, probably under forty-five percent. But for purposes of calculation—placed at fifty-three percent in this paper—this is the natural result expected under the circumstances. There was no history of land leveling, of piped or lined conveyance channels, or of any mode of irrigation other than wild flooding. There were no irrigation experts in the country, neither domestic nor foreign, and in fact there appeared to be little use for them.

By 1956, however, the problems were becoming apparent. Water levels were falling in many areas, and sea water intrusion had already destroyed the coastal portion of the Famagusta aquifer, with serious losses to the citrus industry, and the same process had begun noticeably near Limassol and Morphou. But the struggle for independence had begun, and control measures were ineffective.

Today the situation regarding efficiency of water use is fast improving (see paper on "Water Use Improvement Project"), and legislation making possible the control of groundwater extraction has now been passed. Details of administrative and enforcement procedures are currently being elaborated. However, certain needs to cope with the situation are self-evident; they would apply in virtually any over-pumping situation, and these measures will be discussed when we have completed our presentation of the situation.

Coming back to the farmer today: he is fast realizing that both control of groundwater extraction and improvement in water-use efficiency are not only beneficial to him, they are necessary to the stability of his livelihood. Consequently, such wasteful practices as wild flooding can no longer be said to be typical. Long weed-choked earth conveyance channels are being replaced with pipelines, and land leveling practices are showing improvement. Much remains to be done, but the point is, the farmers themselves are rapidly realizing this and are eager to cooperate with the government in improvement programs, so we may look forward to important progress from this point forward.

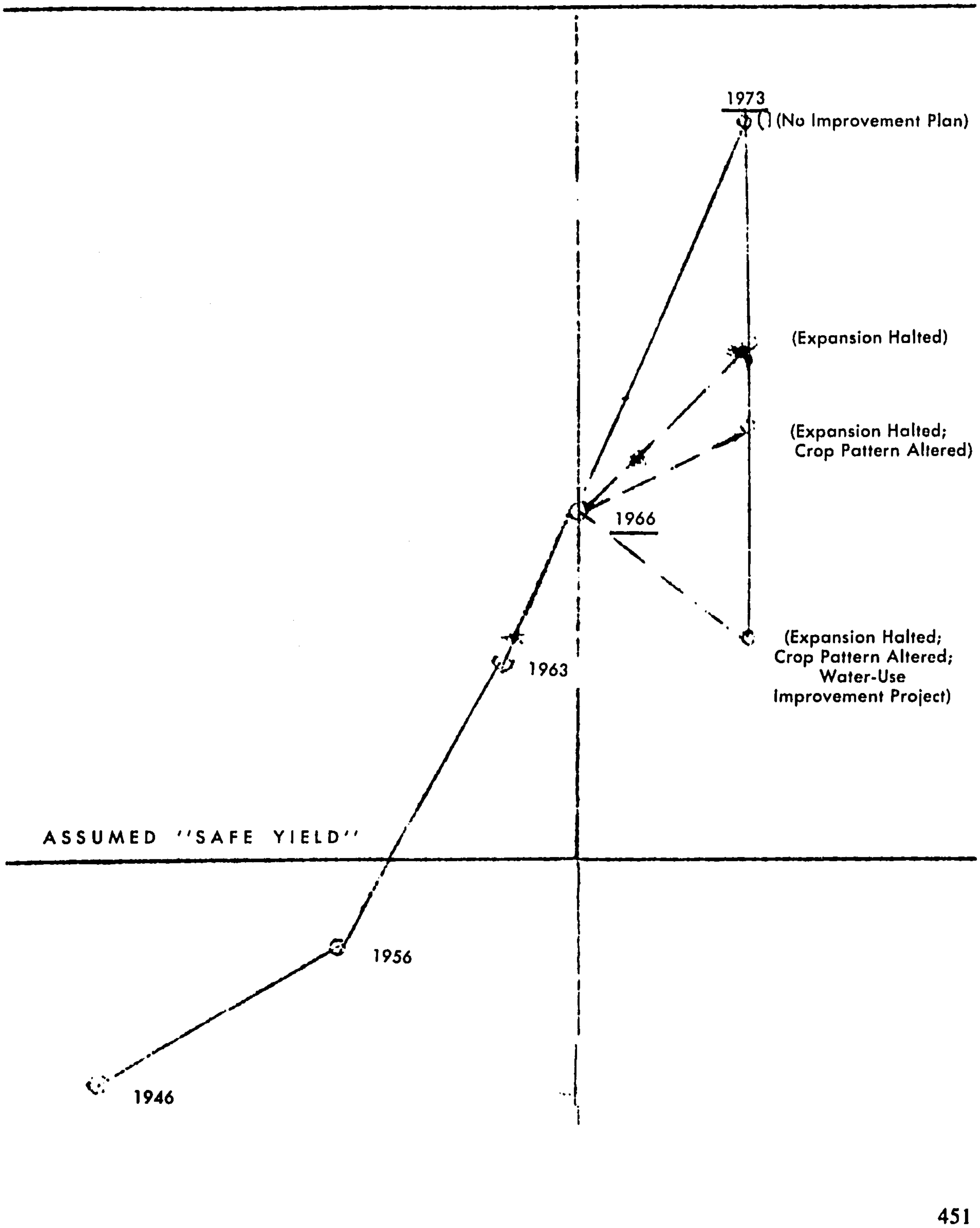
What the Water-Use Chart (Table 1) Shows

(1) In 1946 groundwater extraction was far below our assumed "safe yield." At that time deepwells were rather new, and certainly few, in Cyprus.

(2) By 1956 pumping had increased markedly, and although still well below the overall safe yield, it had resulted in local problems, notably the loss of considerable citrus from sea water

Table 1

Chart of Groundwater Development with
Suggested Possible Procedure
for Overcoming Pumping Deficit



intrusion along the coastal belt at Famagusta. Salinization of wells had begun also near Limassol and Morphou.

(3) Today we pump far above our safe yield and the problems are multiplying. A real danger exists which will require immediate and firm control measures for its containment.

(4) The solid line continuing on up shows what we could expect by 1973 in the way of groundwater extraction if no corrective measures were to be taken.

(5) Basically we arrive at these facts:

(a) *We are dangerously overpumping.*

(b) *The only solution is to pump less.* Recharge works and development of supplemental sources, while helpful in isolated cases, cannot begin to cope with the problem. The quantities of water involved, the time factor, the cost factor, location of supplies with respect to needs, the requirement for a stable year around supply, etc., each place this approach out of the question.

(c) *Government must take control of pumping,* and establish a balance between extraction and recharge.

(d) *Farmers will require assistance* to maintain incomes at present levels in the face of reduced water supplies.

(6) The above facts suggest certain broad lines of procedure, the expected effects of which are shown in Table 1 by the dotted lines leading to successively lower levels of extraction as each is applied. The first dotted line illustrates the effect to be achieved by government establishing pumping quotas for each borehole sufficient to irrigate the present crop area and pattern at fifty-five percent water-use efficiency—a basic measure designed to halt expansion of the irrigated area until a balance can be achieved. Note, however, that this line still shows a rise in extraction until 1973, which reflects the increasing needs of those citrus plantations already established, but not yet mature. Our new water legislation enables the setting of such pumping quotas. The second dotted line (next lower) shows the potential combined effects of establishing pumping quotas as above, and of inducing the farmers to alter their cropping pattern to one which embodies an increased percentage of those crops which give a very high return per unit of water required, thus maintaining incomes while reducing water requirements. Much study of crop economics and marketing potential will be necessary prior to the establishment of goals; that is to say, prior to the selection of a final cropping pattern toward which to aim. But as the chart illustrates, the water savings from such a shift in crop types could be very important to the solution of the overall problem. An example of the type of alteration in cropping pattern spoken of would be something like this:

Crop Category	Percent of Groundwater Presently Used	Percent of Groundwater Used after Shift
Early Vegetables	2	2
Normal Season Vegetables	50	20
Deciduous Fruits	7	15
Citrus	40	60
Vines	1	3

Note: The present cropping pattern is approximately as shown above according to available figures, but the pattern shown after the shift is offered merely to illustrate the point, and does not constitute a suggestion either to government or farmers. Next we will present a table showing the returns per unit of water required by our principal irrigated crops, first at the supposed present efficiency of water use of fifty-three percent, and then at the average water-use efficiency we hope to attain of seventy-seven percent for tree crops and sixty-eight for other crops. (Refer to paper on Water Use Improvement Project.)

The third dotted line (bottom line) shows the expected combined effect from the two measures described above, and from increasing water-use efficiency as mentioned above in the reference to Table 2, and as described in detail in the WUIP paper. However, it should be pointed out that the present WUIP extends only to 90,000 donums irrigated from boreholes, while the effect shown on the chart supposes that all farmers irrigating with groundwater improve efficiency to the levels given. The urgency of the situation is underscored on the water-use chart, where we see that over-pumping will still exist even after all three of these basic approaches are completely and successfully carried out. Recharge works and dam projects for supplemental supplies may prove to be a partial answer to this remaining increment, but cannot wholly satisfy the need for the reasons cited above. Of course, there remains one major aquifer undeveloped, the Paphos area, which is capable of making up this deficit. But it appears inevitable that some losses of present plantations will occur in established areas despite our best efforts. It is for this reason we welcome from the USA the recent feasibility studies for desalinization of sea water. These studies show cost estimates to be lower than our present costs of surface water development. This is a large and stable supply potential for our future expansion.

Explanations: A Cyprus Government Donum is approximately one-third acre or two-fifteenth hectare.

Columns 5 and 9 list the total annual water requirement per donum of each crop at the stated water-use efficiency; given in cubic meters per donum.

Columns 6 and 10 show the gross return to the farmer per cubic meter of water required at the stated WUE; given in mils per cubic meter. A Cyprus pound equals 1,000 mils.

Columns 7 and 11 show Net Return in mils per cubic meter; however, still including water costs. Therefore, this figure represents the maximum the farmer could pay for water to irrigate the given crop at the stated WUE.

Analysis and Discussion of Table 2

Listing of crop categories by returns per unit of water requirement:

(1) Early vegetables

(2) Deciduous fruits

(3) Strawberries and bananas

(4) Citrus

(5) Normal season vegetables, including carrots and potatoes

(6) Fodder crops

Early Vegetables

Extent: Limited, first by water, second by climate; market potential unknown.

Where grown: Small coastal areas climatically suited (Paralimni, Chlorakas, Ayia Marina).

Importance: Considerable on the local market; good potential for export.

Present water sources: Mostly groundwater with pumping exceeding recharge.

To hold and expand: Dams are just going into operation at Chlorakas and Ayia Marina. Recharge works have been constructed to catch and infiltrate rain waters at Paralimni, where the most critical situation exists and where there is no river to dam. A measure of the need for, and the value of, water at Paralimni is the fact that farmers supplement their own supplies, with water brought by tanker truck from distant boreholes at an average cost of 150 mils per cubic meter. The dams mentioned will easily be able to preserve the present early vegetable area and perhaps bring about some overall increase.

Deciduous Fruits

Extent: Approximately 25,000 donums in 1963, located mostly in the mountainous areas and irrigated from mountain streams and springs.

Importance: Very important in the local market, obviating the necessity for imports of these fruits. Not much export.

To hold and expand: The need is to firm up the present supplies, which vary with rainfall. Sealed reservoirs such as built at Prodromos are likely the best answer. Not much expansion will be possible with present supplies, even though supplemented by dam storage, because of the extreme rainfall variability.

Table 2

Crop Returns Per Unit of Water Required
(For Present and Improved Water-Use Efficiencies)

Crop	Gross per Donum £	Net per Donum £	Situation Prior to Improved Water Use Efficiency — (WUE): WUE (Per-cent)	Ann./Don. Water Req. (m^3)	Gross Return (mils/m^3)	Net Return (mils/m^3)	Situation Following Improved Water Use Efficiency — (WUE): WUE (Per-cent)	Ann./Don. Water Req. (m^3)	Gross Return (mils/m^3)	Net Return (mils/m^3)
Deciduous Fruits										
Apples	438	376	53	1,275	343	295	77	880	498	427
Cherries	238	158		1,275	187	124		880	271	180
Pears	212	148		1,275	166	116		880	241	168
Peaches	206	149		1,275	161	117		880	234	169
Plums	150	88		1,275	118	69		880	170	100
Citrus										
Lemons	131	79	53	1,725	76	46	77	1,190	110	66
Valencias	105	82		1,725	61	48		1,190	88	69
Jaffas	66	43		1,725	38	25		1,190	55	36
Other Fruits										
Bananas	300	170	53	2,340	128	73	77	1,610	186	105
Strawberries	262	174		840	312	207	68	680	385	256
Early Vegetables										
Cucumbers	800	658	53	780	1,025	844	68	610	1,310	1,077
Tomatoes	675	525		870	776	604		680	992	772
Peppers	560	403		735	762	550		575	974	702
Okra	450	297		435	1,034	683		340	1,323	874
Egg Plants	402	247		870	462	284		680	591	363
Summer Squash	350	208		320	1,092	650		250	1,400	832
Sweet Melons	261	141		790	331	179		615	425	229
Green Beans	230	78		545	422	143		425	541	184
Watermelons	195	66		790	247	84		615	317	107
Normal Season Vegetables										
Okra	90	65	53	820	110	79	68	640	140	101
Egg Plants	81	51		1,190	68	43		930	87	55
Tomatoes	80	50		1,190	67	42		930	86	54
Peppers	75	45		1,095	68	41		855	88	53
Sweet Melons	70	43		1,130	62	38		885	79	49
Watermelons	68	41		1,130	60	36		885	77	46
Green Beans	65	41		880	74	47		685	95	60
Cucumbers	60	32		780	77	41		635	94	50
Summer Squash	60	32		920	65	35		715	84	45
Potatoes, Carrots										
Spring Carrots	60	30	53	435	138	69	68	340	176	88
Autumn Carrots	60	30		480	125	62		375	160	80
Spring Potatoes	40	20		565	71	35		440	91	45
Autumn Potatoes	40	20		840	48	24		655	61	30
Fodder Crops										
Lucerne (Hay)	59	43	53	2,400	25	18	68	1,870	32	23
Lucerne (Green)	49	35		2,400	20	15		1,870	26	19
Sudan Grass	44	31		1,980	22	16		1,545	28	20
Sorghum (2 cuts)	29	20		1,695	17	12		1,200	24	17
Sorghum (1 cut)	19	10		945	20	11		735	26	14
Maize	20	11		1,520	13	7		1,185	17	9

Strawberries

Extent: Very little at present, but bright future, both for local market and for export.

Where grown: Scattered patches with concentration and a cooperative in one village. However, they may be grown almost anywhere in Cyprus. Since they are a very high-return crop, they may utilize small quantities of water, which may be available here and there with a high development cost. In other words, their production is like that of early vegetables, but not so restricted climatically.

To hold and expand: Groundwater; either in small undeveloped (as yet) areas, or by using present supplies for strawberries in preference to present crops.

Bananas

Extent and present irrigation: Very small acreage at present, all in Paphos District; irrigated from streams and groundwater.

Importance: Important for local market, as production is insufficient to meet the needs, and considerable quantities are imported. Could conceivably become a good export crop in time.

To hold and expand: No particular threat to the present acreage, but water supplies for expansion may be difficult to obtain. Dams in Paphos District will provide some. Water requirements per donum are very high, but returns per cubic meter of water required are very high also.

Citrus

Extent: Very extensive in Morphou, Famagusta, Limassol and Kyrenia areas.

Importance: Important locally and very important for export.

Present irrigation: Irrigated almost exclusively with groundwater due to being an evergreen crop, and from the fact citrus requires warm growing conditions as found in the low altitude plains areas. Irrigation is required almost the year around, so a reliable and steady water source is essential. Falling groundwater levels pose a real and immediate threat to this very important industry.

To hold and expand: Although expansion of acreage is even now proceeding very rapidly, our fight for the next few years at least will be to maintain present earnings from citrus. No suitable new sources of water are available and the present sources are depleting rapidly. Dams are incapable of providing the steady supplies required, but may help by providing supplemental water to cut down on the needs for pumping. (Example: Polemidhia Dam for Zakaki area.)

Normal Season Vegetables Including Carrots and Potatoes

Extent: Most important acreage-wise, potatoes and carrots rank with citrus in importance for export earnings. Other vegetables mostly for local market.

Present irrigation: Mostly groundwater; almost exclusively so for summer crops.

To hold and expand: As with citrus, to continue the high earnings from these crops will be difficult. Water from dams will be useful for recharge of aquifers or for directly supplementing pumped supplies. But as a prime supply, there are severe drawbacks (reliability, cost, low use-efficiency). Therefore, it is very questionable that dam projects are the answer for preservation, much less expansion of our flourishing vegetable industry.

Fodder Crops

Extent: Not great.

Importance: Important to the growing dairy industry, and to other animal enterprises. In the future we hope they will be important to mixed farming (animals-crops), of which little exists in Cyprus today.

Present water sources: Mostly saline aquifers in the central plain.

To hold and expand: Obviously returns from these crops do not justify the use of good quality groundwater, which can be as easily employed for high return crops. The cost of dam project waters puts them out of the picture also. Expansion therefore will be limited, and will come from further tapping of saline groundwater unsuitable for higher return crops.

Summary

The foregoing should have made clear the fact that there is no great threat to our production of a wide variety of specialty crops for local consumption, but difficulties may be expected in maintaining our production of important export crops which require, above all, a steady supply of water, and which are now irrigated from our depleting aquifers. Development of surface supplies is not, and in the future will not be, the answer, for several reasons already expounded. The only possibility in sight, and fortunately it appears more promising every year, is desalinization of sea water. Costs are high, but it has the tremendous advantage of absolute stability. Let us explore this sentence a bit further: Regarding costs, the latest feasibility studies for a large scale (150 million US gallons per day) desalinization plant to be built in California, show a water cost of 20 to 28 mils per cubic meter. Adding some for distribution, we arrive at a figure below what we are presently paying for dam project water. There is one insurmountable drawback in that this plant, to produce water at this cost, must also produce a tremendous amount of electrical energy, more than Cyprus could begin to utilize today. But for how long will this be true? As for the water supply, it is a farmer's dream: An absolutely reliable supply of first quality water available all year around to grow any crop suited to the climate and soils, and for which a market exists. In Cyprus that includes a wide variety of high return crops which can easily pay such a water cost. There is little question in our minds that this is the eventual answer. The next ten years are the real question.

Self-Education

Recognizing the over-pumping problem and its significance to the economy, the government began to take the steps required to become acquainted with the details of the situation in order that workable policy and legislation could be formulated and put into force, and that effective action programs could be planned and implemented for the alleviation of the problems in the field. Experts were invited from abroad to help with assessment, and to offer advice on procedure, legislation and policy. Fellowships were arranged through the United Nations TAB and through bilateral assistance programs, notably USAID, for Cypriots to take post-graduate studies in water use abroad. In 1959 the Water Use Section of the Department of Agriculture was founded, and immediately began intensive studies of the factors basic to any water use improvement program.

These factors are:

(1) Crop water requirements

(2) Moisture holding characteristics of our chief irrigated soils

(3) Comparison trials of water-use efficiency using various irrigation systems

By 1963 the results of these studies had brought us well into the farm demonstration phase, and the Water Use Improvement Project had been formulated and accepted in principle by the government. In that year also, the co-operative FAO-Cyprus Government-sponsored Agricultural Reseach Institute was founded and assumed responsibility for the research aspects of the above studies, and for all other questions relating to water use (see Country Report). Meanwhile the Water Development Department, also under the Ministry of Agriculture and Natural Resources, was constantly expanding both the scope and quality of its related hydrological surveys of groundwater (well numbers, locations, owners, outputs, pumping hours, water levels, etc., and crop types, locations, and water used by each). Complementing these surveys have been two selected area hydrological studies by French and German teams (completed), and a major, island-wide UN Special Fund Hydrological and Minerological Survey which began in 1963, and continues today for the purposes of locating and evaluating the potential of all groundwater sources in the island. (Another UNSF project is presently contemplated for the study of surface sources and their development potential, the feasibility study of the Paphos area watersheds, and the formulation of a master plan for water development and use in Cyprus.)

In 1961 and 1962 respectively, model legislation on water and on land consolidation was drafted by UN experts working in concert with government officials. The final draft of the water legislation has recently become law.

From 1961 several UN and USAID experts have worked directly with the Water Development Department for the furtherance of surface water development schemes, and from 1962 a UN expert has been assigned to work with the Water Use Section for the improvement of water use at the farm level.

Major contributions to our knowledge, in addition to those mentioned above, have come from USAID by provision of agricultural economics experts to the Planning Bureau of the Government, by provision of Peace Corp volunteers who have made valuable surveys of water-use practices in specific areas under the guidance of the Water Use Section, and by establishment of local training courses in advanced surveying techniques for government technicians, particularly of the WDD and the Water Use Section.

Today most of these activities are continuing and expanding, and although our need for basic information is far from satisfied, we have come far enough along the path that the principles, if not all the details, of how we must proceed to solve our problems in water use are clear to us. Considering then the point we have reached in self-education, the urgency of our over-pumping problem, and the fact that our new legislation is now at hand, we find ourselves at the most crucial stage for education and training, for our success with these will determine our success with our field programs in the end. At present we must present to government (higher levels) detailed project proposals for the steps which must be taken to cope with our problems. We must inform it of our personnel requirements and prepare for both theoretical and practical training of new personnel locally and abroad as suits the needs. We must conduct a wide ranging and convincing educational campaign aimed at our irrigation farmers in order to gain their confidence and cooperation in carrying out the necessary measures—measures which directly affect their incomes and way of life. We must inform our parallel agencies of government of the situation and needs, and enlist their full cooperation in whatever facets of the projects apply to them. We must inform suppliers, contractors, credit agencies, and all other interested parties of our plans so that they may plan accordingly. Finally, we must inform the various sources of technical and financial assistance of our needs and plans so as to interest them and gain their active participation in our projects. If we are able to achieve success in these matters, there is no question of our ability to perform the works involved.

Our plans for education and training in water use revolve around the three major steps shown on the chart of groundwater development (Table 1):

(1) To establish pumping quotas for all boreholes.

(2) To offer advice, and possibly other forms of assistance, to farms on the selection of crops which will give them the highest possible return with respect to their supply of water.

(3) To offer all necessary technical and financial assistance to farmers to enable them to maximize their efficiency of water use. Only in this way can they maintain their incomes as their pumping quotas decline, to bring about the essential balance between extraction and recharge.

Things to be Done

To properly examine what must be taught and to whom, in connection with these steps, we must first outline briefly the things to be done:

(A) ESTABLISH PUMPING QUOTAS

(1) We must make accurate measurement of all water pumped.

(a) Water meters must be installed by the government on all boreholes, both to measure present use and future conformance with quotas.

(b) Periodic records of meter readings must be made by government representatives to guide quota revisions and measure degree of compliance.

(2) We must measure the effects of controlled pumping.

(a) Sufficient measurements, both as to numbers and locations, must be made of groundwater levels to accurately chart and establish the effects of pumping controls.

(b) Pumping quota revisions must be based primarily on this criterion.

Individual cropping considerations must influence quota revisions also. A well trained Agricultural Extension Service will be required to advise farmers as to crop selection, from all agricultural aspects, but always bear in mind the need to maximize return per unit of water requirement.

Normally revisions will accompany annual renewal of pumping permits, but should be earlier if crop types or water use efficiency are improved through government assistance.

(3) An accurate survey of the present (and recent) cropping pattern is essential for the initial establishment of pumping quotas.

(a) Aerial photographs are an invaluable tool for this work. They will permit greatly increased accuracy, and greatly reduced costs in terms of personnel, time and money.

Existing photos taken in the fall of 1963 at a scale of 1:10,000 will be extremely valuable for determination of history and areas of tree plantings, and locating and measuring sizes of irrigated plots.

Spring and fall photos of selected critical areas at a scale of 1:5,000 should definitely be obtained in 1966 to be utilized together with on-the-spot surveys of all irrigated crop types, areas, locations, and for perennial crops, ages and spacing.

(b) Farmer questionnaires, although an essential part of this survey, are not sufficient to attain the accuracy needed by themselves. Actual measurements of plot sizes, etc., are required, most of which is best done from photos.

(4) In establishment of initial pumping quotas we must also consider:

(a) The present status and urgency of the local groundwater problem.

(b) The needs for government assistance to maintain incomes with less water, and/or compensation for damages or abrogation of rights.

(5) Determine staff requirements; hire and train them for all of the above.

(B) OFFER ADVICE AND OTHER ASSISTANCE AS REQUIRED BY FARMERS FOR THE SELECTION AND SUCCESSFUL PRODUCTION OF HIGH RETURN—LOW WATER REQUIREMENT CROPS

(1) Improved economic studies of irrigated crop production and marketing are required.

(2) Continued and expanded determinations of crop water requirements are required.

(3) Training must be given to the Agricultural Extension Service on these matters and all others related to water use.

(C) WATER-USE IMPROVEMENT PROJECT*

(1) Recruit and train staff in surveying, mapping, soil and water sampling and analysis, interpretation of analytical results, choice of irrigation systems, design of systems, land preparation, irrigation theory and application to Cyprus, irrigation cost analysis, selection of crops, etc.

(2) Additional considerations for establishing highly efficient irrigation systems in new surface water projects, including needs for close co-

* See separate paper on this topic.

operation between farmers where supply is from a single unstable source, implications of land fragmentation, choice of crops as influenced by water supply timing and quantities, etc.

Conclusion: These Are Our Plans

(1) *To continue gathering and collating all information which becomes available* on the water-use situation in Cyprus, from whatever source.

(2) *To advise higher levels of government continually and fully on all water-use matters*: to submit detailed proposals for action for consideration by government where the situation appears to call for such. These functions will be performed generally through position papers and written project proposals or action proposals.

(3) *To continually inform (and be informed by) our parallel branches of government with whom we will be working* cooperatively for the solution of water-use problems. This will generally be carried out through periodic meetings, both formal and informal, and through correspondence. For some time now a very good working relationship has existed.

(4) *To conduct a continuing publicity campaign* so that all interested parties will have exposure to at least the broad outlines of our water-use situation and trends, as well as the measures to be carried out by government. This is done routinely in the newspapers by higher levels of government. The Department of Agriculture will be preparing news releases, helping to create television shows on irrigation, giving lectures and slide talks to interested groups, including government officials, farmers, students, etc.; preparing posters for public display, and other such means of publicity.

(5) *To train our staff as their duties require*: Fundamentally the work of the Water Use Section of the Department of Agriculture is related to the agricultural aspects of irrigation at the farm level. In the final analysis our only concern is that our scarce water resources be used to their highest potential good for the farmers using them and for Cyprus. But we must never lose sight of the fact that the water is used, or misused, as the case may be, on the individual farms, by farmers acting as individuals. All of our studies, all of our planning, must relate back to their ultimate effect on the single farmer. To follow our planning, he may be required to make rather sweeping changes in his life. In almost every case he will be asked to make a substantial monetary investment in pipes, pumps, valves, water meters, etc.—equipment which he likely knows little about, which may be confusing and even frightening to him. It will change his work habits, requiring him to work in some cases more, in most cases less, but in virtually all cases at times he is not accustomed to working. Many farmers will be asked to quit growing the types of crops they are equipped for and have knowledge of, and begin growing strange new crops they have little knowledge of, and perhaps lack equipment for. We tell him he will gain by all of this and then ask him to prove us right by investing his money, his time, and his inconvenience. Naturally he has strong doubts. For these reasons our staff personnel *must be right* when they make plans. They must understand the effects their plans will have on the individual farmer's mode of operation, and therefore on his life. Their requests must be practical, and they must be able to present convincing (and correct) reasons to the farmer to justify those requests, and to gain his confidence and active cooperation. They must have the knowledge to answer the farmer's questions in order to still his justifiable fears and doubts. Finally, when our plans are accepted, our staff must be competent to train the farmer to utilize his new system efficiently, for the system merely offers him the opportunity to be efficent; it is his manner of utilizing that system which will finally decide whether we have succeeded or failed. From this the following facts emerge:

(a) Our upper level personnel will make plans, design irrigation systems, direct the work of their subordinates, advise farmers on all water-use matters, including choice of crops, and train farmers in irrigation practices, plus a host of other duties. They must have university degree level training in the theory of irrigation and in soil-plant-water relationships. They must be given intensive on-the-job training both in the office and in the field. The more background and experience with actual irrigation farming they have the better.

For these positions we are hiring university graduates in agriculture and in engineering. Our plans are to send all of these people abroad for one year of irrigation science at the post-graduate level. An important consideration in this program is to locate them insofar as possible in areas of similar conditions, primarily conditions of climate, soils, and types of crops grown under irrigation. The plan is to send two such students each year, the others to stay here for on-the-job training, and of course to carry on the work of the Section. With the assistance of USAID and British Council Fellowships, this plan is now in operation; we presently have two of our staff members studying at the University of Arizona in Tucson and one in Silsoe, England. We intend to send two more in September of this year.

(b) Our technician staff will operate under the direction of the officers of the Section, and their duties will be many. They include surveying and mapping of farms, taking and analyzing soil and water samples, making calculations of soil moisture-holding characteristics, irrigation schedules (frequency and quantities), costs of irrigation systems, etc. They must be thoroughly trained in the proper installation and use of irrigation systems, and must be able to train farmers in these matters as well as answer most of the farmers' questions on all water-use matters.

For these positions we are hiring secondary school graduates with all possible background in farming and irrigation. Our plans for training (which began some time ago) include both formal training by means of short courses, and informal training on the job. Both of these categories of training include theoretical and practical applications. Several of our technicians have attended three-month courses in irrigation abroad. A few others have completed an advanced course in surveying and mapping techniques arranged under the auspices of USAID here in Cyprus. The rest of our technician staff will receive such courses as appropriate for their specific duties. Considerable experience has now been gained on the job both in the office and in the field.* Each month will now see an intensification of this training.

(c) Laborers will assist in all duties where applicable and will be trained on the job, both in theory and practice.

(6) *To educate and train farmers in water use and in related matters*: As pointed out above, this is where we stand or fall; it is of paramount importance. We have already described the public education aspects of this, and we have said that our officers and technicians will do the job for the individual. This will be done by irrigation demonstrations and by personal contact on individual farms. We will design and oversee the installation of the farmer's improved irrigation system, help him with crop selection, and provide him with a written schedule of irrigation frequency and amounts to apply. All of these things will be done in consultation with him to assure that they fit his other circumstances. We plan to provide him with publications on specific irrigation topics as they apply. We plan to check back when the system is actually in operation to assure that all is understood.

From this point onward, that is, for day-to-day operational questions, the Agricultural Extension Service will assume responsibility, and we will stand behind it as a source of technical information.

(7) *To train the Agricultural Extension Service in water use*: Our plans for this training are not fully crystallized, but they definitely include irrigation demonstration, lectures and slide talks on water use for the beat officers of the AES, providing them with copies of all pertinent reports and publications, and all possible on-the-farm contact between them and our own staff during the developmental phase. In addition, the administration of the AES will have in mind the desirability of irrigation background when recruiting new personnel.

* Refer to paper on WUIP.

HOW RESEARCH IS CARRIED TO THE FARMERS IN INDIA

by

A. P. Joseph*

Summary

Creation of irrigation facilities is only a means to an end in increasing crop production. To achieve increased production through irrigation there is need to increase the efficiency and effectiveness with which water is actually managed by the farmers.

First, farmers need farm irrigation and drainage systems that are properly shaped and leveled, with systems of channels, bunds and structures which will promote efficient application of irrigation water as well as facilitate disposal of excess water.

Second, farmers need better technical information to help them determine when and how much water is needed for maximum production.

Third, farmers need an assured supply of water, the resources for undertaking improved practices, and other resources for maximizing production.

This paper deals with the program undertaken for application of improved irrigation practices and making the research information available to farmers.

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Introduction

Creation of irrigation facilities is only a means to an end in increasing crop production. With irrigation the increase in production depends on how the farmer uses irrigation water, how he prepares the field, etc. When adequate attention is not paid to these factors, irrigation may lead to deterioration of soil fertility, development of salinity and alkalinity, waterlogging, etc. This is the actual experience in India and elsewhere. Frequently, there is a tendency in this country to over-irrigate the fields. Field-to-field flow and consequent flooding and wastage of water are still practiced in most of the old irrigation projects, growing paddy. Inadequate land grading and consequent non-uniform water application is a big hurdle in new irrigation projects. Lack of proper manuring and fertilizer application is another problem in irrigated areas. Research information for water management practices and cropping pattern for different regions are also inadequate.

Several agricultural research stations in India have been working on different problems of irrigated agriculture with a view to developing improved practices to be recommended to the cultivators. Several committees and working groups have examined the problem from time to time. Emphasis has been given to application of improved irrigation methods in the commanded areas of major irrigation projects. Comprehensive studies on all aspects of the problems of field irrigation and water use on a coordinated basis have been programmed for the future.

On the basis of data so far obtained and the experience gained from working with the farmers, it is possible to advise them broadly on some of the problems. This work is being conducted in this country through demonstrations at the research stations, individual farm demonstrations on improved irrigation practices, educational and training programs for the farmers, as well as through audio-visual aids.

This paper gives an outline of the steps taken to bring home to the farmers the benefits of research.

Problems in Efficient Use of Irrigation Water

The problems of carrying the results of research to the cultivators in India are many. In paddy areas, field to field flow is the common method of irrigation. There is an absence of water courses in a number of places, and distribution is defective in certain areas. Another hurdle to installation of improved irrigation practices is the small and fragmented holdings of the farmers. Efficient water distribution methods are rather difficult and not feasible in some cases without consolidation of holdings.

It has been the policy that water courses should be constructed by the farmers themselves. In most of the states this is being done through local institutions called Panchayats. Legislation has been introduced in some of the states to make this compulsory and, in case of default, for the work to be done by the government at the expense of the beneficiaries. Water courses being one of the important prerequisites for efficient distribution of irrigation water on the farms, great importance is attached to this program. The work of consolidation of holdings has also been started. Credit on easy terms is also arranged for the farmers. Similarly, other resources such as fertilizer, improved implements, etc., are also arranged to create conditions suited to obtaining maximum net returns from the irrigation investments the farmer has to make.

Dissemination of Research Information to the Farmers

Demonstration farms attached to research stations. There are a number of research stations as well as field experimental farms in India. Most of these have demonstration farms attached to them. The results of the research conducted in these research stations are demonstrated to the cultivators. The farmers in the neighboring areas can take advantage of this. Special "Farmers' Days" are arranged, when the improved practices are shown to the farmers and their benefits explained to them. Besides the agricultural research stations, there are trial-cum-demonstration centers set up by the central government as well as by state governments in major irrigation project areas. All these demonstrations go a long way toward making the farmers aware of the need for adopting modern methods of irrigation farming.

Demonstrations by the Extension Agency. When the intensive agricultural district program was started, it was felt that there was a need for helping farmers with their problems of water management. Accordingly, the Directorate of Extension, under the Ministry of Food & Agriculture, has launched a program of individual farm demonstrations on improved irrigation practices as a part of the package program. Work was started on this program in the year 1964, and special staff has been appointed in the package districts (one district in each state). Work under this scheme consists of helping the farmers for proper alignment and construction of field channels with necessary control and distribution structures, land grading and provision of adequate drainage. Guidance on water application schedules is also given:

The irrigation staff appointed in the package district contacts the farmers and explains to them the benefits of improved irrigation farming. Enthusiasm is created by showing films, charts, etc., and conducting village meetings. The farm lands of those who are willing to apply improved methods are surveyed, suitable irrigation systems worked out, and estimates made for construction of channels, structures, land grading, etc. The work is undertaken by the farmer under the technical guidance of the government staff. This is not an isolated program; the other improved farming practices, such as soil testing and fertilizer application, plant protection, improved implements, etc., are all integrated and applied as a package of practices.

The above type of demonstrations were started in 1964 and work is in progress in most of the states. Farmers were averse to this program in its beginning, due to their suspicion that the government may ultimately take away their lands, and also from fear that their production may go down due to land leveling. However, as a result of constant contact and persuasion by the Extension staff, and increased yields in the demonstration farms, the farmers have gradually started to take interest and are adopting the improved practices. In fact, in areas where the benefits of such work have been demonstrated, the farmers have started approaching government agencies for technical help in undertaking similar work on their individual farms. To give incentive to the farmers a subsidy of up to Rs.500/- ($100) is given to each such farmer for his initial outlay.

Similar programs in other areas have also been started by the state governments. Based on the results of these demonstrations, large scale programs for similar work on an area basis have been undertaken in a few states and are being planned in some others.

Education and Training. The improved irrigation-farming practices, demonstrated to the cultivators in their fields as well as on government farms, all need technical skill for planning and execution. This skill the farmers cannot acquire merely by seeing the demonstrations. Thus the need arises for training the farmers as well as the technicians, including officers, for expanding this program. The Government of India has recognized this and has initiated training programs to provide a sufficiently trained staff at the district level and village level and also to train farmers, with the ultimate objective of increasing production through improved irrigated farming. Practical training is given through the water-use workshops (of ten days' duration) organized for the progressive farmers. Besides explaining improved methods and showing the practical application of the methods, short educational tours are arranged for the farmers. In the training program for community development activities, irrigation and water-use courses are included for the village-level technicians. Special irrigation courses are also conducted. A three months' practical training course in irrigation, for agricultural inspectors, engineers, overseers and similar staff connected with the irrigation development, is also organized in almost every state. For the district-level officers, a two months' duration training course is being conducted periodically. Post-graduate specialized training in irrigation practices is also arranged by the agricultural universities.

Publicity. The publicity and information service has also been strengthened to educate the farmers in the results obtained by research. A few films have been produced and more are in the making. Similarly, large quantities of publicity material, such as posters, leaflets, etc., have been prepared by the Indian Council of Agricultural Research, the Extension Directorate, and other government agencies in cooperation with USAID, and distributed among the farmers.

Area Program. So far a selective approach has been taken for extension of improved irrigation practices. Although this program has made some headway, it has not been possible to cover all the area where irrigation potential is being progressively created. Therefore, a large area-wide program to help farmers better utilize irrigation water was started by the states in 1964. Since that time this program has been strengthened in the commanded areas of major and medium irrigation projects, and a new program called "Ayacut Development Program" is being launched by the central government for hastening the progress of efficient use of irrigation water.

KHUZESTAN WATER AND POWER AUTHORITY
DEZ PILOT IRRIGATION PROJECT

Selection of Technical Staff and on-the-Job Training

by

M. Yazdi*

The Khuzestan Water and Power Authority has made the training of farmers as well as of its own personnel a vital part of a development program to raise the general standard of living in the project area, and to increase the purchasing power of the people, thereby achieving economic and social progress.

Emphasis has been placed on this aspect of training to develop the ability of the farm population and increase crop production by the adoption of improved methods of irrigation and agriculture. It is apparent that this transformation cannot be realized without a marked change in the attitude and outlook of the farmers. It is unrealistic to expect farmers to accept new ideas without tangible proof of their profitability. Khuzestan Water and Power Authority personnel have been trained to transmit these new ideas to the farmers and familiarize them with their benefits through demonstrations which have been laid out.

For this purpose, academic as well as on-the-job training has been organized. Men, mostly high school graduates, have been recruited and trained in various operational phases of the project. This group will play an important role in filling the existing gap by acting as liaison between the key staff members who are responsible for the planning and execution of the Dez Pilot Project and the farmers and landowners who will ultimately benefit from the program.

The following are examples of the outlines of training programs used by the various sections of the Khuzestan Water and Power Authority, such as water distribution, irrigation operation

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and maintenance and agriculture.

Water Regulation and Irrigation Practices

A comprehensive course in water management and irrigation practices was organized for a period of one year. Candidates were instructed in:

(1) The organization and functions of the water distribution service.

(2) The old irrigation system.

(a) The canal system.

(b) The various irrigation areas.

(c) The disadvantages of non-regulated flow.

(d) Brush dam, bifurcations, and other structures of the old system.

(3) The new irrigation system.

(a) Regulated flow and its advantages.

(b) The new canal system.

(4) Reading maps and aerial photographs and calculation of the areas concerned from the map.

(5) Discharge measurements.

(a) The velocity-area method: The velocity to be measured by a float; the velocity to be measured by a current meter.

(b) Method of using a formed construction such as weirs, Parshall flumes and orifices.

(6) Rating curves.

(a) Factors influencing the rating curves.

(b) How to obtain a rating curve.

(c) Guage reading.

(d) How to use a rating curve.

(7) Irrigation.

(a) Definition and reason for irrigation.

(b) The application rate, frequency and time required.

(c) Irrigation efficiency.

(d) Irrigation methods: flooding, borders, furrow, corrugation, and basin.

The above subjects were taught in detail with the necessary field practices.

As a result of this training course, well trained staff members are at present carrying out the following functions:

(1) Regulation of water in the pilot project.

(2) Discharge measurements and preparation of provisional discharges of the old canals of Dez East, Dez West, Karkheh and Balarud (Greater Dez Project Area).

Regulation of the Dez Pilot Project canals is administered by the canal operation staff: watermaster, assistant watermaster and ditchriders. Each ditchrider is in charge of regulation of water for 3,500 hectares.

The staff of the hydrographic section has also attended the full training course and at present is engaged in the following duties:

(1) Discharge measurements of the old canals.

(2) Calibration of the structures of the new system (to find the most accurate discharge coefficient).

(3) Groundwater observation.

(4) Meteorological data of fifteen stations located in the Dez Irrigation Project.

Maintenance Training

The academic phase of the irrigation system maintenance training is normally of no consideration, with emphasis being placed on technical training.

Equipment operators spend three to seven days in the yard familiarizing themselves with the operating characteristics of their new equipment, its use, tempo and balance. They are then assigned to small, simple, fully supervised jobs for a short period and then to larger jobs with less and less supervision until they become full fledged operators. Labor foremen and key laborers are

Table 1 Irrigation Operation and Maintenance Organization Chart

1965

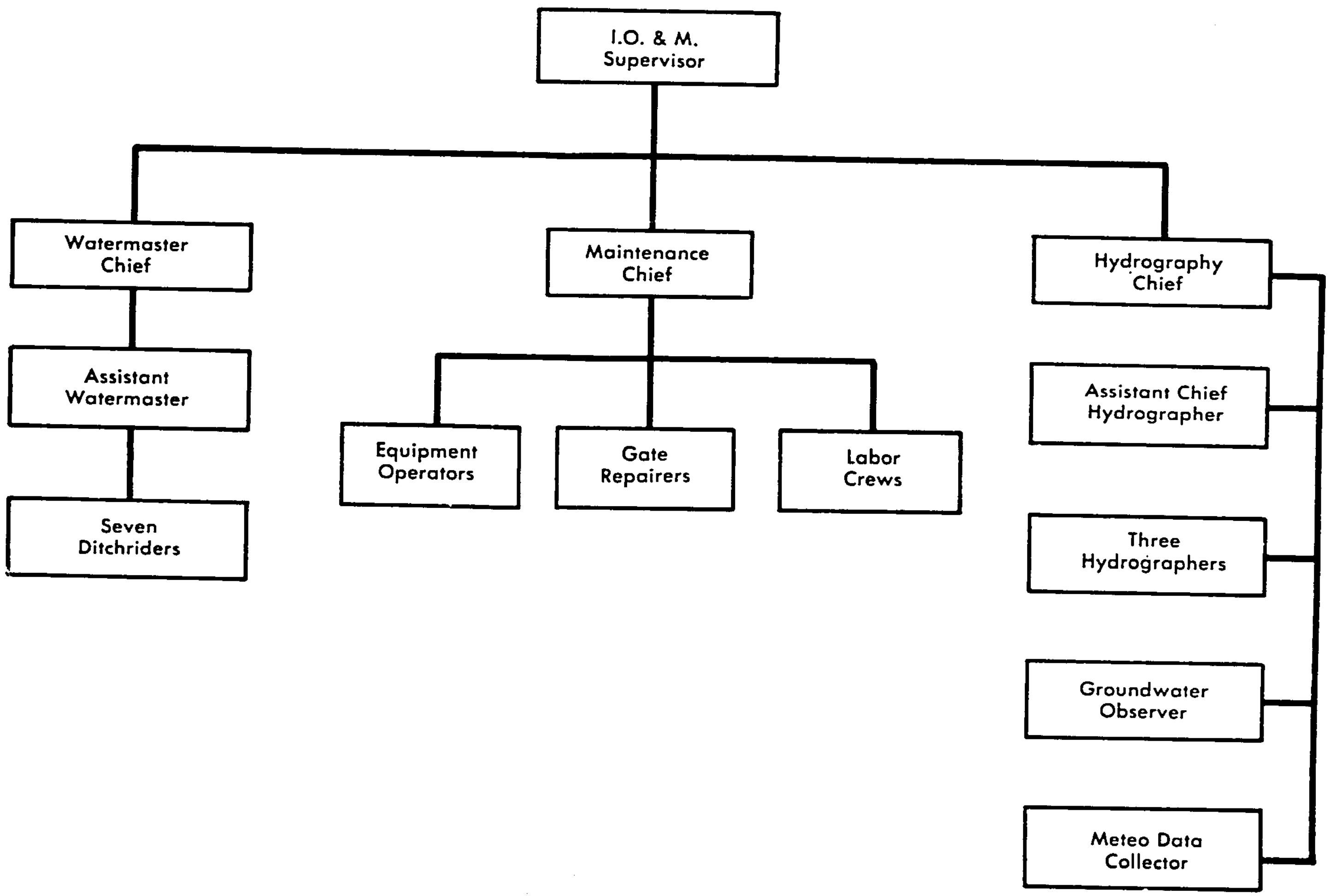
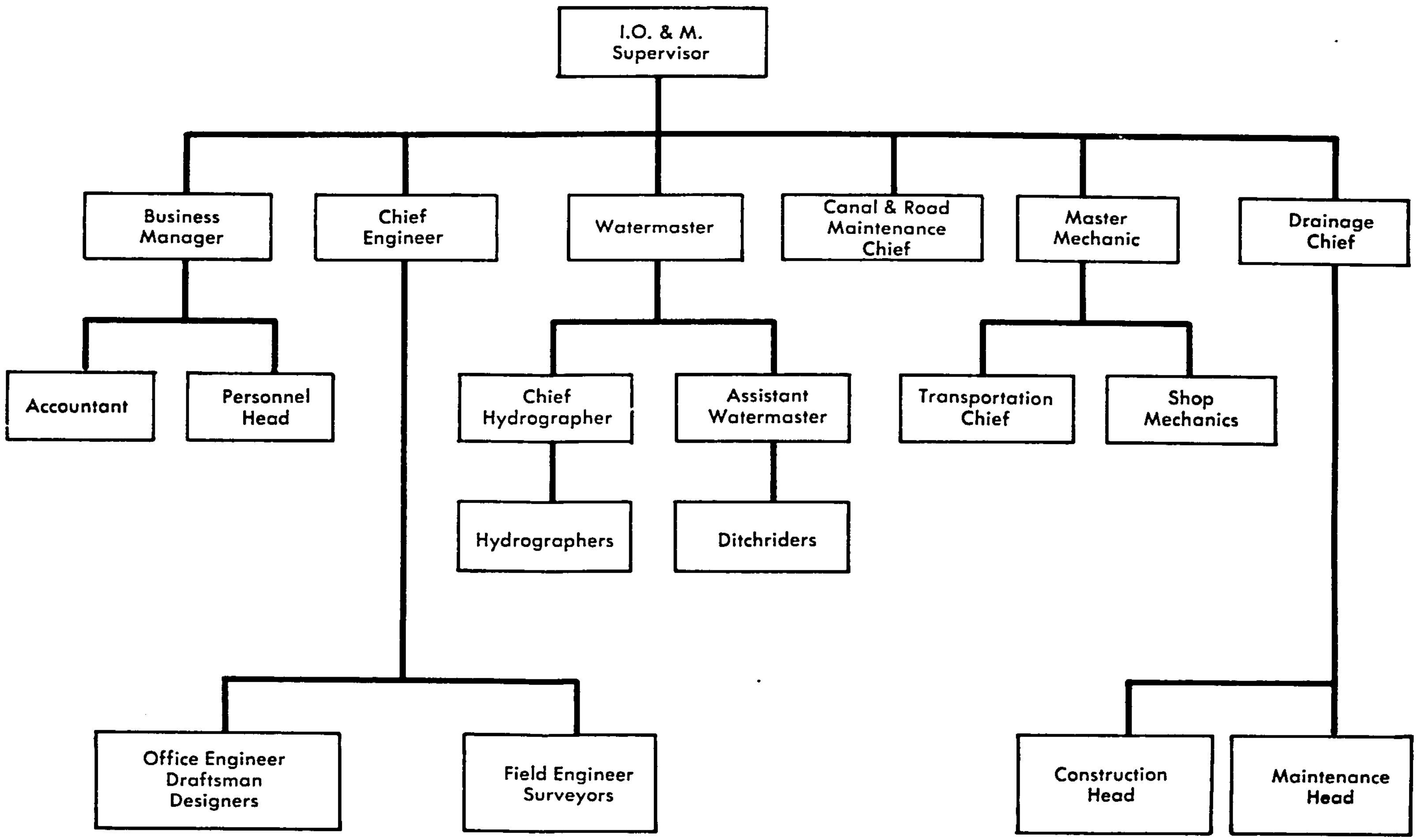


Table 2 Provisional Organization Chart of Irrigation Operation and Maintenance



carefully trained in the field in mixing and placing of concrete, forming, placing steel, determing the proper remedial steps required on small jobs and generally following in the training steps of the equipment operators, until only occasional direction as to the type of activity is required.

The organization chart in Table 1 indicates the personnel involved in the operation and maintenance of the Dez Pilot Project canals and roads. The hydrography section does not confine its services to the pilot area only, but devotes a major portion of its time to the accumulation of information concerning the Greater Dez Project. This chart will be revised to a typical irrigation operation and maintenance organization chart as shown in Table 2 when the Greater Dez Irrigation network is constructed.

Funds expended for training of the staff of the Canal Operation and Hydrography Section (two college graduates and fourteen high school graduates) were approximately 37,500 dollars. This figure includes the salaries of the staff, overseas and Iranian instructors, transportation, supplies, etc.

Maintenance section staff members have been selected from the construction inspectors, foremen, equipment operators and labor crews who were employed during the canal and road construction period. Therefore, the cost for on-the-job training of the maintenance section was negligible.

Agricultural Training

Another aspect of the program was the training of several village agent leaders in various fields of agriculture. These active members of the project, who are carrying out a considerable portion of the responsibilities for the execution of the development program, in turn teach and supervise the daily task of thirty-five village agents in the project.

The village agents are responsible for guiding and assisting the activities of the farmers in:

(1) Use of selected and reliable seed and new varieties of wheat, barley, blackeye beans and many different vegetables.

(2) Introduction of crops, new to the area, such as berseem clover, sudan grass, sorghum, sweet corn and alfalfa.

(3) Constant supervision and training in the use of simple implements, such as a cyclone seeder to obtain uniform seed planting.

(4) The efficient use of backpack sprayers for control of insects and plant diseases.

(5) The advantageous use of chemical fertilizer.

(6) Improvement of livestock feeding, etc.

(7) Introduction of poultry production.

The overall feasibility of this training program is reflected in Table 3, which indicates up to a threefold increase in crop production.

Table 3

Crop	Crop Yield Traditional Method (kilograms per hectare)	Crop Yield Improved Method (kilograms per hectare)
Barley	735	1800
Wheat	675	1600
Broadbeans	925	1690
Rice	1600	3000
Sesame	220	800

In conclusion, it is apparent that the entire outcome of the agricultural program depends to a large extent on the technical knowledge of the staff members and their ability to impart this to the farmers of the area for practical application.

Newly recruited personnel, to eventually occupy various positions in the expanded program of the Khuzestan Water and Power Authority, will be trained continuously along the same lines. In this manner this organization will at all times have at its disposal a working force, fully trained and willing to be of service to the farm population of the area.

CHAPTER XII

Field Trips

SIXTH NESA IRRIGATION PRACTICES SEMINAR

Sixth NESA Irrigation Practices Seminar field trips were taken on March 28 and 29. The trips afforded adequate time for a detailed study of the design, construction, operation and maintenance of farm equipment and of farm improvement activities utilized in development of the East Ghor Irrigation Project. The delegates were divided into two tour groups to visit and study separately, for one day each, the (1) East Ghor Irrigation Project in distribution and drainage; (2) East Ghor Irrigation Project in agricultural and rural development. Both sections met at Wadi Yabes camp in the center of the project each day for lunch and discussion. The following are highlights of each tour:

East Ghor Irrigation Project in Distribution and Drainage

(1) Visit to the planning and design office of the East Ghor Canal Authority to review and discuss the planning and design practices used for the distribution and drainage systems of the project.

(2) Visit to a lateral under construction, where construction priorities for the project facilities were discussed and observed.

(3) Visit to machine shops to observe and discuss the local manufacture of metal gates used for water control on the project distribution system.

(4) Visit the operation and maintenance headquarters to discuss operation and maintenance regulations and instructions as well as to observe actual water delivery to a project farm. Highlights of the discussion pointed up the following items of interest:

(a) Water is delivered to farms on a measured quantity basis according to the water regulations for the project, which state, "one fils (JD. 0.001 = $0.0028) per one cubic meter of water per donum shall be paid for the first 1800 cubic meters of water, and two fils per cubic meter shall be paid for any quantity of water in excess of that" (used each year).

(b) Regulations provide for licensing and regulation of bananas, citrus, rice, sugar cane, culturing of fish and perennial fodder crops, to limit the area planted to high water-use crops, as well as to provide insured water for crops requiring substantial long-term investments.

(c) The farmer is billed each month for the quantity of water used the previous month and then given one month after billing to make payment. In case payment is delinquent the farmer is denied delivery of water until his bill is paid.

(d) Annual formal inspections are made of the main canal, laterals and drains by top operation and maintenance personnel to provide the basic information for the continuous maintenance schedule. The project goal is to maintain the project as constructed and to prevent deterioration with its subsequent large rehabilitation cost.

(e) The delivery of water to a farm through an individual constant head orifice measuring structure was demonstrated.

(f) The duties and general instructions to official personnel and farmers were discussed.

East Ghor Irrigation Project in Agriculture and Rural Development

The Agricultural Extension Department, Agricultural Credit Corporation and the cooperatives' part of the program was designed to show how these services to the farmers of the Ghor contributed to development of individual farms in the valley.

The first stop on the field tour was made at the Deir Alla Research Station, where delegates were taken on an inspection of the station and shown the field work in progress. The station is doing variety work on cereal crops, wheat and barley. It has a program in growing sugar beets and determining sugar contents of various varieties suited to the valley. Inspection was also made of fields of safron, berseem and flowers, on which various research is being conducted. There are many other activities in livestock, soils, plant protection, seed variety, and other phases. But time did not permit seeing all these activities.

The second stop was made to inspect a farm that was developed and planted to citrus. The development was made possible through a loan to the farmer for financing the work on an irrigation system which the Extension Service recommended for the farm.

The third stop was made to inspect a farm unit on which a contour bench irrigation system has been installed. This system has been in operation for three years. The technical design and supervision of construction was done by the Agricultural Extension Department. An incentive payment of JD. 100 was given the farmer as an inducement to install the improved irrigation system on his farm. Plan of this farm was given to the delegates.

The fourth stop was made to inspect a field leveling job in progress. Here again, the technical design, layout and supervision of construction was done by the Agricultural Extension Department and an incentive loan of JD. 100 (maximum payment) was given by the cooperatives.

The fifth and final stop was made to inspect a farm that had been developed through a loan from the ACC. This farmer had developed his farm by first pumping water from the Jordan River, and later taking water from the East Ghor Canal Authority. The farm is producing excellent citrus, berseem, and field crops. The farmer gave a brief history of the development of his farm and the valley in general, which was of great interest to the delegates.

At each stop great interest was shown by the delegates, and such factors as costs, design, layout and construction procedures, payment of loans, research results, and other items were freely discussed.