SDSU-RSI-83-08

Land Classification/Soil Survey Project of the

SYRIAN ARAB REPUBLIC

VOLUME 7

Irrigation in Syria

October 1982

Prepared for

United States Agency for International Development
and the
Syrian Arab Republic

Prepared by

Louis Berger International, Inc.
East Orange, New Jersey, U.S.A.

Remote Sensing Institute
South Dakota State University
Brookings, South Dakota , U.S.A.

and the
Ministry of Agriculture and Agrarian Reform
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Irrigation in Syria

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1. Introduction, Summary and Recommendations
2. Reconnaissance Soil Survey, 1:500,00 scale
3. Soil Survey of the First Settlement Zone, 1:100,00 scale
4. Detailed Soil Survey of the Tartous Area, 1:25,000 scale
5. Reconnaissance Land Use Survey of Syria, 1:500,000 scale and Land Use Survey of the First Settlement Zone, 1:100,000 scale
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FOREWORD

The stated objective of the Land Classification/Soil Project is:

'To assist the Syrian Arab Republic Government (SARG) expand and accelerate its program of land classification and soils survey in order to facilitate the implementation of the Government's decision to intensify agricultural production in selected areas, thus increasing both agricultural output and income through more efficient and appropriate use of limited land and other productive resources.'

When reviewing publications, conducting project visits, conferring with Syrian professionals, and making other project related contact, the following items were noted:

1. There is a significant difference in the production yields currently being obtained and the potential yield of many crops. These differences for a few crops are shown in Table 7-2.1. The potential yields shown were determined after considering the yields reported in research publications, yield figures discussed at research centers and Ministry offices and in discussions with project personnel. It is recognized that the best yields obtained in research are normally higher than production yields because of the variety of conditions and management at the farm level. For this reason, the potential yields shown are below the research yields. For example, the sugar beet potential yield was set at 40000 kilograms per hectare even though some estimates of the yield potential were as high as 70,000 kilograms per hectare and yields approaching 60,000 kilograms per hectare have been reported by ACSAD. Similarly the maize potential yield was set at 6,300 kilograms per hectare even though the Homs Agricultural Research Center (Figure 7-2.1) personnel stated that their peak yields were 10,000 kilograms per hectare and their average yields were between 7,000 and 8,000.

2. The information needed to increase the production yields generally exists. The research yields are evidence of this fact. The practices used to produce these high yields may not be the most economical and may not in all cases be practical on a whole country basis but this was recognized in setting the lower potential yield figures. This statement is not intended to suggest that there is no longer a need for research. Instead, this publication recommends an increased research effort. The concern raised is whether the information already available is being presented in a format to maximize its benefit to the producers and ultimately to the country.

This publication which presents a set of recommendations related to irrigation water requirements and water management deals with one of the factors that is limiting production yields. Other factors such as varieties used, fertilization amounts and practices and general cultural practices are also obviously of importance in educational programs designed to increase yield levels. Water management is, however, considered to be a major limiting factor although no quantitative assessment of its effect was either available or made during the project.

OBJECTIVE

The objective of this portion of the project was:

To prepare irrigation water requirements and water management guidelines to assist the Syrian Arab Republic Government in meeting that part of the stated project objective that deals with intensifying agricultural production through more efficient and appropriate use of limited land and other productive resources.

Although the production from new irrigation projects currently being constructed or designed will benefit the agricultural production of the Syrian Arab Republic, the limited water resource available may soon limit further development. Future production increases will require the use of the water resources in the most efficient manner possible if the full agricultural potential is to be realized.

These guidelines were presented in a set of recommendations that deal with issues related to water requirements and water management. These issues were identified during project activities as those most important to the efficient and appropriate use of limited land and other productive resources.

volume 7

Irrigation in Syria

1.1 INTRODUCTION*

The soils information collected and described in this Land Classification/Soil Survey project is based on observed or measured characteristics of soils at specific locations selected to represent broader areas identified through remote sensing imagery or aerial photography. This is an objective approach which groups soils according to common characteristics.

Interpretive classifications are necessary to make practical applications of the technical soils information collected during this project. The land capability classification done as a part of the soils report is one example of an interpretive classification. This is a subjective approach where the values or standards used in classification are based on past experience, reported research information and judgement.

This report on the irrigation portion of the project presents an interpretive or subjective classification system for evaluating the soils of the Syrian Arab Republic for their irrigation suitability by three irrigation methods. It is designed to be interactive with the computer based soils information system. This will permit the production of thematic maps showing the irrigation suitability in five classes for each irrigation method.

The importance of irrigated agriculture to agricultural production in the Syrian Arab Republic can be documented in two ways. One way is to compare precipitation amounts and distribution with evapotranspiration requirements. Somy (1981) presents the precipitation information reproduced in Table 7-1.1.

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*Prepared by Fred Bergsrud and Said Sheikh Al Shabab. Mr. Bergsrud is an Agricultural Engineer (Irrigation) for the Remote Sensing Institute, South Dakota State University, Brookings, SD, USA. Mr. Shabab is a staff member with the Soils Department, Ministry of Agriculture, Syria.

Somy further states that in the second and third settlement zones, the relationship between evapotranspiration and precipitation is high, between five and twelve, which requires that water resources be developed to provide the water for even winter crops to achieve full development of the agricultural potential.

The second way in which the importance of irrigated agriculture is documented is from agricultural production statistics presented in the Annual Agricultural Statistics Abstract, 1978. Table 7-1.2 presents the yield per hectare for irrigated and non-irrigated production of the major field crops and vegetables and the ratio of that production for the period 1974-1978. The ratios of production range from 1.21 for grazing barley to 5.75 for cotton. That is, one hectare of irrigated cotton produced 5.75 times as much product as one hectare of non-irrigated cotton. Table 7-1.3 presents similar data for the major orchard and vineyard crops. Here the ratios range from 2.14 for grapes to 2.65 for apricots. In addition to these quantative comparisons, two other factors should be considered: the quality of the product produced and the stability of production. Stability of production refers to the small variation in per hectare yields from one year to the next year. This is vary important in governmental planning to meet the consumption needs of a crop like potatoes and the processing requirements of a crop like sugar beets. All of these factors such as quantity, quality and stability must be considered in the economic evaluation of irrigation projects and the projects cropping programs.

1.2 OBJECTIVE

The objective of the irrigation portion of the project was: to develop criteria and standards to evaluate the potential irrigability of the soils of the Syrian Arab Republic. The criteria to be used are limited to the measured, observed and laboratory determined characteristics obtained and reported by the project soil survey team.

As the project developed, the following points became apparent.

1. Although using the same criteria, different methods of irrigation require unique evaluation standards to assess potential irrigability of a particular area. For this reason, this report presents criteria standards for three irrigation methods and discusses the use of a fourth method.

2. The depth standards established for the 3 irrigation methods frequently exceed the one meter depth investigated by the soil survey team. The one meter depth is acceptable at the reconnaissance level and will be used in preparing the thematic maps. The standards set are for potential use at more detailed levels where greater depths must be investigated. In the criteria, standard tables for the depth to be used in detailed surveys is shown as the main value with the reconnaissance depth in parenthesis.

These criteria and standards were established in order to assist the Syrian Arab Republic Government (SARG) in:

1. Identifying the soils that have the greatest potential for irrigation development and in selecting the appropriate method of irrigation for these soils.

2. Identifying soils of intermediate, low, or limited potential for irrigation development and determining the limitations of these soils and the appropriate method for their development.

3. Demonstrating the practical use of the soil survey information system established by the project through the preparation of irrigation potential thematic maps based on the established criteria and standards.

1.3 METHOD USED

The method used in developing the criteria and standards was a step process. The steps involved were as follows:

STEP 1 - Review of the irrigation situation to identify soil related problems that are limiting yields or development potential.

STEP 2 - Review of previous irrigation suitability criteria used in the country to evaluate the methods, criteria and standards used.

STEP 3 - Familiarization with the data collection process and information system to be developed by the soil survey team.

STEP 4 - Preparation of the first draft of criteria and standards to illustrate the process and for review and comment by project and Directorate personnel.

STEP 5 - Office testing of first draft for compatibility with soil survey system by evaluating selected soils.

STEP 6 - Field testing of the results of step 5 by visits to the sites of the selected soils.

STEP 7 - Field visits to areas with specific identified problems to collect information needed to complete the criteria and standards.

STEP 8 - Review of literature obtained on field visits, at ACSAD seminar and through Directorate.

STEP 9 - Preparation of revised criteria and standards.

STEP 10 - Recheck of the compatibility of the expanded criteria and standards with the soil survey information system.

Step 11 - Preparation of the final report presenting the criteria and standards together with the reasons and considerations behind their development.

Two steps remain before the report is completed. These cannot be completed until the computer furnished by the project is in Syria and operational.

STEP 12 - Criteria and standards programmed into the computer by irrigation method.

STEP 13 - Computer prepared thematic maps provided showing the irrigation suitability potential by irrigation method.

1.4 CLASSIFICATION SYSTEM

The classification system used is based on the United States Bureau of Reclamation (USBR) Irrigation Suitability Classification System. The USBR system, however, in complete form considers both economic and engineering factors that are beyond the scope of this project. Each separate irrigation development considered by the SARG will require a detailed survey and analysis. The results of this system will assist in selecting priority areas for site specific studies and will identify soil related characteristics that require special attention.

Five irrigation suitability classes are identified in this report. The classes used are as follows:

CLASS I - ARABLE - Highest potential for irrigation development. No identified soil, drainage or topographic deficiencies. No salinity or alkalinity problems. Suitable for all crops otherwise adapted to the area.

CLASS II - ARABLE - Intermediate potential for irrigation development. Slight to moderate deficiencies in soil, drainage or topographic characteristics Slight rise in alkalinity or salinity level. Crop selection may be limited by depth, salts, gypsum content, etc.

CLASS III - ARABLE - Lowest potential for irrigation development. Moderate to severe limitations in soil, drainage or topographic characteristics. Alkalinity or salinity levels may significantly limit crop selection without reclamation.

CLASS IV - LIMITED USE OR SPECIAL STUDY - The USBR system separates these categories into two classes with Class IV being limited use and Class V being special study. There did not appear to be reasons to separate these classes in this project.

CLASS V. - NOT SUITABLE FOR IRRIGATION DEVELOPMENT BY THE METHOD BEING CONSIDERED.

1.5 CRITERIA USED

In planning an efficient conservation irrigation project or system, there are many factors to be considered such as the type of soils water quantity and quality method of water delivery, control and application; crops to be grown and, the cultural and agronomic practices used. The soil is, however, the foundation or base factor that influences all of the other factors.

The criteria used in this report were selected for the basic objective of evaluating the soils potential for irrigation development. Consideration was

also given to the manner in which the soils influence other planning factors as is pointed out at several places in the discussion.

Sixteen criteria standards have been established for each irrigation method. A brief discussion of the general criteria and their reason for inclusion follows.

1.5.1 DEPTH

Soil depth is considered in three ways: depth to an unconsolidated layer such as coarse sand, gravelly or stony material, etc.; depth to a consolidated layer such as bedrock, compacted layers, calcic or gypsic layers, etc; and depth to the water table.

Soil depth is important for the following reasons:

1. An adequate depth must be available to permit normal root development of the crop. Shallow soils limit crop selection.

2. The leveling of the shallow soils may expose undesirable subsoils or parent material. As a minimum this will greatly increase leveling costs and may, in some cases, prevent leveling.

3. Shallow soils over unconsolidated material may require lining or sealing of canals and field ditches to prevent excessive seepage losses.

4. Shallow soils over consolidated layers may have future drainage problems, may be difficult to drain and may, therefore, be difficult to reclaim if affected by salt.

5. Soils with a high water table may move salts upward into the root zone of the crop and may need future or immediate artificial drainage.

1.5.2 SURFACE TEXTURE

Surface texture is used in these criteria as an indicator of the intake rate of the soil. Intake rate affects both the selection of an irrigation method and the design of that method. For example, a surface texture of loam is suitable for surface irrigation method. If the land is flat and a row crop is to be grown level, furrows may be the preferred method. The intake rate is then used in determining the length of furrow, the flow rate into the furrow and the time of application.

Twenty-two surface texture classes were used by the soil survey team. These have been grouped into intake rate categories for use in this evaluation process. These categories are shown in Table 7-1.4

Intake rate as used in this report is a measure of the soils ability to absorb irrigation water and transmit it to succeeding layers in the soil profile. Water may enter the soil through pores, cracks, worm holes, decayed root holes and tillage created spaces. Salts, improper tillage and other practices may lead

to a surface sealing or crusting which will reduce the intake rate for a given surface texture.

The transmitting of water through the soil profile is governed by the hydraulic conductivity or permeability of the soil throughout the root zone. Permeability is considered separately in this report in a later section.

The categories shown, therefore, are based only on the surface texture and on the base intake rate expected for that textural designation. Base intake rate is a term used to describe the nearly constant intake rate that develops some time after irrigation has started.

1.5.3 AVAILABLE WATER HOLDING CAPACITY (AWHC)

The available water holding capacity (AWHC) of a soil is a measure of its capacity to store and release water for plant growth. It is the amount of water held in a soil between field capacity and permanent wilting point. The preferred method of calculating the AWHC is as follows:

$$AWHC = \frac{B.D. \times T \times Pw}{dw \times 100}$$

where:
- AWHC = Available water holding capacity in centimeters
- B.D. = Bulk density
- T = Thickness of soil being considered in centimeters
- Pw = Moisture content between field capacity and permanent wilting point in percentage by weight.
- dw = Density of water (taken as 1.0)
- 100 = Constant to convert percentage into a decimal

Example:

Silt Loam Soil
Bulk Density = 1.35
Thickness = 100 centimeters
Field Capacity by Weight - 26.0 percent
Wilting Point by Weight - 11.0 percent
Therefore: Pw = 26.0 - 11.0 = 15.0 percent

$$AWHC \frac{1.35 \times 100 \times 15.0}{1 \times 100} = 20.2 \text{ centimeters}$$

Once areas have been identified that appear to have potential for development, on-site samples should be collected for bulk density determinations in the laboratory or determination may be made in the field using the equipment provided by the project. At the same time, samples should be collected to make field capacity and wilting point determinations using the laboratory equipment furnished by the project. On-site sampling is required because of the spatial variability of soils. The project scale of mapping precluded the inclusion of

these parameters. Therefore, an alternative method of calculating AWHC had to be selected.

The method used by the soil survey team in making the land use capability classification was selected in order to maintain consistency throughout the report. The source of the method and its complete description is contained in the soils report so it is not repeated here. The method uses the laboratory determined proportions of sand, silt and clay in a sample to calculate the moisture equivalent. Moisture equivalent is defined as the moisture retained in an air-dried, screened sample of soil which has been wetted and drained in a standard manner and centrifuged for 30 minutes in a centrifugal field equal to 1000 times gravity. The moisture equivalent can then be used to calculate the field capacity and wilting point through the following formulas:

$$M.E. = (0.027 \times S) + (0.187 \times Si) + (0.555 \times C)$$

where: M.E. = Moisture Equivalent, percentage dry weight basis
S = Percentage of Sand in the sample
Si = Percentage of Silt in the sample
C = Percentage of Clay in the sample

Field capacity is then calculated as follows:

$$F.C. = (0.904 \times M.E.) + 1.3$$

where: F.C. = Field Capacity, percentage dry weight basis
M.E. = Moisture Equivalent, percentage dry weight basis

Wilting point is then calculated as follows:

where: $W.P. = (0.473 \times M.E.) - 1.22$

where: W.P. = Wilting Point, percentage dry weight basis
M.E. = Moisture Equivalent, dry weight basis

Using these formulas, the available water holding capacity (AWHC) of a silt loam with laboratory determined proportions of 5 percent sand, 70 percent silt and 25 percent clay can be calculated as follows:

$$M.E. = (0.027 \times 5) + (0.187 \times 70) + (0.555 \times 25)$$
= 27.1 percent dry weight basis
$$F.C. = (0.904 \times 27.1) + 1.3$$
= 25.8 percent dry weight basis
$$W.P. = (0.473 \times 27.1) - 1.22$$
= 11.6 percent dry weight basis

and therefore: $Pw = F.C. - W.P. = 25.8 - 11.6 = 14.2$ percent dry weight basis.

Using the same bulk density of 1.35 as used in the previous example, the AWHC is:

$$AWHC = \frac{1.35 \times 100 \times 14.2}{1 \times 100} = 19.2 \text{ Centimeters}$$

The AWHC of a soil limits the amount of water that can be applied in a single irrigation and when combined with crop use figures is used to determine the frequency of irrigations. These factors affect irrigation method selection and the management required.

1.5.4 SURFACE FRAGMENTS

Surface fragments considered are stones and rocks. Stones are defined as material in the size range of 7.5 to 25 centimeters and rocks are greater than 25 centimeters. Surface fragments are considered because of their effect on the workability of a soil, mechanization potential and ease of land leveling. Soils with a high amount of surface fragments are common (see Figure 7-1.1).

1.5.5 PROFILE FRAGMENTS

Profile fragments consider the percentage of the total volume of a soil that is occupied by gravel, stones or rocks. Size designations for stones and rocks are the same as in the previous section with gravel being less than 7.5 centimeters. Profile fragments are considered in two depth categories: in the surface layer, 0 to 30 centimeters, where they have a similar effect to surface fragments; and in the total depth studied, 0 to 100 centimeters where they may cause problems with the installation of water delivery systems or may make drainage installations difficult and expensive.

1.5.6 SALINITY

The salinity of a soil is a measure of the soluble salts contained. Principally these salts are various proportions of the cations sodium, calcium and magnesium and the anions chloride and sulfate. Saline soils are soils which contain large enough amounts of these salts to reduce the value or productivity of the soil or to put limits on crop selection. The standard definition of a saline soil is one in which a solution extracted from a saturated soil paste has an electrical conductivity of 4 millimhos per centimeter (mmhos/cm) or more at 25 °C. Saline soils normally occur where the pH is less than 8.5.

Saline soils are very common in arid and semi-arid areas. Any salts carried to the soil by rainwater or irrigation water are left behind when the water is evaporated or transpired and there is not enough rainfall to leach the salts from the soil profile. Upward movement of water from a shallow water table or poor quality irrigation water may result in a greatly increased rate of salt build up in the profile.

Saline soils with good natural internal drainage may be reclaimed by leaching if the irrigation water supply has a low salt current. In reclaiming saline soils, it is important to apply the water uniformly and to use the minimum

amount of leaching water both to conserve water resources and to avoid raising the water table.

Saline soils that have been artificially drained either to remove excess ground water or for the purpose of reclamation need similar attention to the uniformity of application of the leaching water. Attention must also be given to the disposal of the leached water (or drainage water) so it will not have a detrimental effect on the receiving waters which may be used downstream as an irrigation water supply.

1.5.7 ALKALINITY

The alkalinity of a soil is a measure of the exchangeable sodium present. Sodium is the predominant cation, but large amounts of potassium may also be present. The cations calcium and magnesium are easily precipitated at a high pH and in the presence of carbonate soils. An increase in the exchangeable sodium percentage results in a deterioration of soil structure, a decrease in permeability and specific harmful effects on crops. These effects may be nutritional imbalances or sodium toxicity. Citrus, for example, has been shown to be sensitive to an exchangeable sodium percentage as low as 5. The standard definition of an alkali soil is one in which the exchangeable sodium percentage (ESP) is greater than 15. Alkali soils normally occur where the pH is between 8.5 and 10.

In general, fine textured soils are more adversely affected at a given ESP level than are coarse textured soils. Organic matter in the soils tends to reduce the unfavorable effects of a high ESP.

The reclamation of alkali soils requires the replacement of exchangeable sodium. The addition of calcium or magnesium salts to irrigation water reduces the sodium hazard, but increases the salinity hazard. This should be practiced only where other factors indicate a very low salinity hazard. Three of the chemicals used in reducing high exchangeable sodium levels are calcium carbonate, sulphur and gypsum. Calcium carbonate is effective only in low pH soils which is unusual in alkali soils. Sulphur is most effective in high pH soils containing free carbonates but takes time to react. If used, there must be a time delay before leaching. Gypsum which supplies soluble calcium is effective and can be added directly to an irrigation water supply. Since the reduction in exchangeable sodium content is dependant on a replacement process, the replaced sodium must be leached from the soil to eliminate the possibility of reabsorption. The leaching principles discussed in the salinity section should be observed.

1.5.8 GYPSUM

Gypsum is found in many of the soils of arid regions and is a major problem in the middle Euphrates region of Syria. Gypsum occurs because of a high gypsum content in the sedimentary rocks from which the soil is formed, from being transported into an area by wind and water erosion, or by being formed by the precipitation of calcium and sulphate during salinization processes.

Gypsum may have a beneficial effect in an alkali soil and also may permit the use of a high sodium content irrigation water. The detrimental effects of gypsum are reduced yields, reduced crop selection and the problems associated with constructing irrigation canals, ditches and dikes in high gypsum content soils.

1.5.9 SLOPE

Slope is a major factor in determining the feasibility of irrigation, in selecting an irrigation method and in designing the irrigation canal and control network or pipelines. It is one of the topographic features that needs to be evaluated in a detailed survey before the final project or system design.

1.5.10 SOIL DRAINAGE CLASS

Adequate surface and internal drainage are essential to a successful irrigation project. The need for artificial drainage in an area may result from a natural high water table, excessive precipitation in a an area or run-off from adjacent areas, excessive irrigation applications, seepage from reservoirs, canals and ditches, or from leaching water applied to control or remove salts from the soil.

The soil drainage class is one of the factors used in evaluating current or potential drainage problems in a soil. The soil drainage class assigned by the soil survey team considers the internal condition and the depth to water table. The internal condition considers primarily the presence of mottling or a gleyed horizon. A complete description of the soil drainage classes is contained in the soils section of the report.

1.5.11 PERMEABILITY

The rate at which water enters and moves in a soils is of major concern in evaluating a soil for irrigation purposes. Part of this, the intake rate, was considered and discussed earlier. Permeability, a measure of the rate at which water moves through a soil, is important both to irrigation method determination and identification of potential drainage problems. Soils of low permeability may cause temporary waterlogging of the root zone resulting in crop damage, may make the installation of artificial drainage costly and difficult, and may make the leaching of salts from saline soils difficult to accomplish. High permeability rates result in too rapid a rate of water movement and may be unsatisfactory for surface-method irrigation.

1.5.12 FLOODING

Surface flooding of soils is an obvious problem that can carry undesirable deposits; interferes with planting and other field operations; does direct crop damage; and in general, reduces the cropping potential of soils. Flooding can also be beneficial in leaching soils, but the benefits are usually small compared to the problems.

1.6 CRITERIA STANDARDS BY IRRIGATION METHODS

This section presents the criteria standards for classifying soils for irrigation suitability for three irrigation methods and discusses a fourth irrigation method. For systems not currently in wide use in Syria, there is a brief discussion of the method, its advantages and limitations.

1.6.1 SURFACE METHODS

Surface methods of irrigation predominate in Syria currently and are expected to remain as the main method. Surface methods can be highly efficient if properly designed, constructed and managed to control seepage losses and waste.

Table 7-1.5 summarizes the criteria standards established for surface methods of irrigation. In preparing these standards, the following methods of surface irrigation were considered: basin, level border, level furrow, graded border, graded furrow, corrugations, contour border, contour furrow and contour ditch.

The factors considered in setting the standards for each of the criteria were as follows:

1.6.1.1 DEPTH

The depth standards set, particularly in class I, considered all crops of economic importance to Syria including fruit and olive production. Although a small part of either of these crops is currently irrigated, both are known to respond to properly managed irrigations. The production information in the introduction shows irrigated fruit trees producing three times the amount of non-irrigated fruit trees in the period 1974-78. Olives, because of their characteristics of good production under drought conditions, are not as important a consideration to these standards but can be economically irrigated. Water management is, however, very important when irrigating olives because better quality normally results when the soil is low in moisture as the crop matures.

1.6.1.2 SURFACE TEXTURE

Most surface irrigation methods require a moderate to slow intake rate to achieve optimum design and high water use efficiency. For this reason, a narrow range of soil textural classes was placed in class I. The slightly coarser textured soils placed in class II can be successfully irrigated with surface methods but require smaller basins, shorter lengths of run, etc.; thus resulting in the need for an expanded delivery system which on these coarser textured soils may result in greatly increased seepage losses. The finer textured soils placed in class II require a higher level of management to achieve uniformity of application except on completely leveled land because of their low intake rates. Similar analysis can be used on the expanded range of surface texture placed in

class III or IV but the management problems increase in each class.

1.6.1.3 AVAILABLE WATER HOLDING CAPACITY (AWHC)

The AWHC standards were set at levels consistent with the surface texture and permeability standards while considering the frequency and amount of irrigation. A class I soil such as loam with low organic matter might hold as little as 16 centimeters of available water in a one meter profile. Fifteen centimeters per meter was therefore selected as the standard for class I. If fifty percent of the available water is used between irrigations, a soil meeting the minimum standards would accept a net irrigation of 750 m^3 per hectare. At 75% efficiency, this is a gross or total application of 1000 m^3 per hectare. At a daily use rate of 7 millimeters per day, irrigation would be required every 10 days on this soil.

A value of 10 centimeters per meter of depth was selected as the standard for both classes II and III because net irrigation applications of less than five centimeters (50% of TOTAL) are not practical with some methods of surface irrigation. The standard set for class IV of five centimeters per meter is marginally low but was felt justified for this limited-use special study class.

1.6.1.4 SURFACE FRAGMENTS

The standards set for surface fragments are the same for both classes I and II. This is a level that is considered to cause minimum interference with workability or mechanization and where fragment removal can be accomplished. The class III and IV standards are set in a manner where they are considered in combination. That is class III may have up to 10% rockiness if the stoniness percentage is less than 3% but may have only 2% rockiness if the stoniness is between 3 and 15%. The percentages used are the percentage categories used in data collection by the soil survey team.

1.6.1.5 PROFILE FRAGMENTS

The profile fragment standards are set for two depths: 0-30 centimeters and 0-100 centimeters. The shallower depth represents 30% of the total and the standards are set similarly. This may make a split seem unnecessary but it was done to separate out those situations where the fragments are not evenly distributed throughout the profile.

1.6.1.6 SALINITY

Because of the salinity problem in Syria, particularly in parts of the Euphrates basin, (see Figure 7-1.2) considerable attention was given to these standards. Some systems for irrigation suitability separate the salinity standards according to soil texture with the coarser textured soils being given higher values. There is justification for this approach. However, the arrangement of the surface textural classes in these standards did not seem to fit that approach. The standards selected for classes I, II and III are the

normal standards used in irrigation classification systems. Since class IV as used in this report includes special study, consideration was given to setting that standards unlimited but studies must show that the soils can be easily leached. Because of the difficulty and cost associated with reclaiming very highly saline soils, an upper limit of 40 mmhos/cm was set for this class. All of these values for salinity should be considered average values in one meter of depth.

1.6.1.7 ALKALINITY

The alkalinity standards established recognize both crop and soil differences. An ESP value of 5 was used for class I because some crops have been shown to be sensitive at that level. The class II standards were set at the break point between alkali and non-alkali soils. Class IV was set an an ESP of 50 because of the different effect of a given ESP level on the physical properties of soils of different textures. For example, the hydraulic conductivity of a coarse textured soil may not be more adversely affected by an ESP of 50 than a fine soil would be at an ESP of 15. The class III standard was set on an intermediate level between classes II and IV.

1.6.1.8 GYPSUM

The gypsum standards were set based on work done at the Granada Station reported by Mardoud (1979) and on a private discussion with Matar (1981). The class I standard was set at 5% because this was the level at which first yield reductions were experienced by Matar. The class II standard was set at 10% as an upper limit for minimizing canal and field ditch construction problems. Estimates of this value ranged from 3 to 10% with the higher value being selected. The class III standard of 25% is a compromise value between Matar's work which shows 20% at the Granada Station where selected crops showed possibilities for economical production in soils with 25% gypsum at the surface, 25-35% in the middle layer and 50% at the bottom of the root zone. The class IV standard was set at 45%, the level above which crop selection is severely limited. Figure 7-1.3 shows an example of a high gypsum content soil.

1.6.1.9 SLOPE

The slope standards recognize the categories used for slope by the soil survey team. They generally fit well with various methods of surface irrigation. Basins, level borders and level furrows, for example, should be completely level or on a very slight grade to fit slopes less than 2% in class I. Graded furrow and graded border methods are well adapted to class II slopes of 2 to 5% although graded borders on the steeper slopes should be used only for close growing or sod crops. Contour borders, contour furrows and corrugations are adaptable to slopes up to 9% placed in class III. Contour furrows should not be used on soils that crack when dry because of the danger of water flow through the cracks to the adjacent furrow. Corrugations are generally not recommended on saline soils. Contour ditches are the only method of surface application considered acceptable on class IV slopes of up to 15% and then only for close growing crops.

These slope method recommendations are general and must consider the specific site. All furrow methods should be used with caution on saline soils or with saline irrigation water because of the tendency for the salts to occur in the ridges between furrows. Level basins and level borders are preferred on saline soils requiring reclamation because the methods can be easily used with no change in layout or operation.

1.6.1.10 DEPTH TO WATER TABLE

The depth to water table standards consider the depth at which appreciable amounts of salts may be carried upward into the crop root zone and also the need for artificial drainage (see Figure 7-1.4). Class I is set at 300 centimeters, a depth which should not contribute salts due to upward movement and should not lead to future drainage problems with proper water management throughout an irrigation project. The class III standard was set at 100 centimeters, the minimum depth acceptable for a controlled water table. Crop selection may be limited at this depth but that is consistent with the class III definition. Class II was set at a intermediate depth between class I and class III. The class IV designation of at or near the surface represents those situations needing special study to determine if drainage is practical and economically feasible.

1.6.1.11 SOIL DRAINAGE CLASS

The soil drainage class categories reported by the soil survey team are based on observations as discussed in the criteria used section. A class I soil has a standard of being well drained with each class expanding to include a broader range of soil drainage classes.

1.6.1.12 PERMEABILITY

The moderate permeability rate category of 2 to 6.25 centimeters per hour was selected as the class I standard. This category is most desirable because it will neither restrict water movement greatly nor transmit in excessively fast where surface conditions result in uneven intake. Classes II and III expand the standards towards both more and less permeable soils. The class IV standard is the same as class III placing the extremes of permeability in class VI for surface methods.

1.6.1.13 FLOODING

The flooding categories used in the soil survey are: none, rare, expected, frequent-regular and frequent-irregular. The category assigned is based on profile evidence such as surface alluvial deposits and on knowledge of the area. This may not be adequate to completely describe the flooding potential of an area. Therefore, areas known to have flooding problems such as portions of the Akkar plain (see Figure 7-1.5), Sinn Basin and Ghab depression may require special consideration in producing the computer thematic maps.

1.6.2 LOW APPLICATION RATE SPRINKLER SYSTEMS

Low application rate sprinkler systems are defined for these criteria standards as those with an application rate of less than 1.5. centimeters per hour. The calculation of the application rate of a sprinkler system uses the following formula:

$$A.R. = \frac{360 \times Q}{S \times L}$$

where: A.R.= Application rate in centimeters per hour
360 = Constant to cover units
Q = The discharge or flow rate of a single sprinkler in liters per second
S = Spacing of sprinklers in one direction normally along a lateral line in meters
L = Spacing in the other direction normally between lateral lines in meters

As an example, when using small sprinklers, the discharge may be 0.7 liters per second and the spacing 20 meters by 20 meters. The application rate in this example would be:

$$A.R. = \frac{360 \times 0.7}{20 \times 20} = 0.63 \text{ centimeters per hour}$$

The sprinkler systems most adapted to low application rates are small volume sprinklers spaced along lateral lines. The lateral lines may be moved by hand, mounted on wheels or skids for mechanical moving, placed in a permanent location in a field for an entire season, or permanently installed underground in a field (see Figure 7-1.6). The sprinklers and laterals must be spaced in a manner that gives uniformity of water application based on the sprinkler characteristics and expected wind conditions. Proper sprinkler pressure (recommended pressure ranges are supplied by the manufacturers) must be maintained in order to get uniformity of water application.

Sprinkler systems are often criticized for having excessive evaporative losses when operated in a hot, dry climate. Although these conditions are conducive to evaporative losses, the magnitude of these losses is frequently overstated. Frost and Schwalen (1956) at the University of Arizona ran extensive tests on sprinkler evaporative losses. A summary of their works is quoted in Sprinkler Irrigation (1975) as follows:

> "Individual test points indicate that losses as low as 3% may be expected at lower vapor pressure deficits with nearly zero wind movement and comparable losses on a hot day may run up to 10%.

Near the saturation point or at a very low vapor pressure deficit, the losses were about 3% at 30 psi and noticeably greater at 50 psi with the differences increasing with the vapor pressure deficit.

Losses were considerably higher at high wind velocities as much of the fine spray was carried out of the collecting area and therefore failed to reach the ground in measurable quantities. As this drift did not moisten the ground, it was assumed that it was a complete loss for irrigation purposes. Doubling the wind velocity approximately doubled the loss for all weather conditions for the nozzles used in these tests.

Evaporation and spray losses from sprinklers are dependent both on climate factors and operating conditions. The following general conclusions are based upon some 700 test runs unders a variety of climatic conditions. Losses increase with temperature, wind movement, operating pressure and degree of breaking of spray, and decrease with increase in humidity and nozzle diameter. They are most directly related to the vapor pressure deficit in the atmosphere which is dependent upon the temperature and relative humidity.

Sprinkler systems likely will not have any higher water losses than surface methods. This is particularly true on coarser textured soils where the losses in the field delivery system may be high and uniformity of application with surface methods may be difficult to achieve.

Sprinkler systems are generally considered to have advantages where the land has excessive slope, where leveling is difficult or costly, or where the soil is coarse textured, shallow or highly erodible. The disadvantages are the initial cost, the energy required to provide pressure, difficulty of achieving uniformity of application under high wind conditions and for some crops, the possibility of increased disease problems due to increased wetting of the leaves.

Proper water management in terms of applying a determined amount of water to a field is easily accomplished with sprinkler systems. Once an application rate has been calculated, it is simply a matter of operating the system for a certain amount of time. As the irrigator gains experience, some adjustments can be made for climatic conditions at the time of irrigation, but these are minor."

The criteria standards for low application rate sprinkler systems are presented in Table 7-1.6. A discussion of the standards follows with frequent comparisons to the more common surface methods.

1.6.2.1 DEPTH

As mentioned in the preceding general discussion, sprinkler systems are better adapted to shallower soils than surface methods. The depth standards set are between 60 and 75% of the standards for surface methods. The controlled depth of water application that can be achieved with sprinkler systems plus the fact that pipe systems are used instead of field ditches, greatly reduces the potential percolation and seepage losses. This reduces the danger of a temporary

water table being built as well as reducing the possibility of long-term drainage problems over consolidated layers. A shallower depth to unconsolidated material is acceptable because there is little or no need for leveling.

1.6.2.2 SURFACE TEXTURE

The surface texture standards include some of the coarser textured soils in class I that were not included for surface methods because of the possibility of seepage and percolation losses. Similarly, the class II standards include a greater range of coarse textured soils with no change in the textural limit on fine textured soils when compared to surface methods. In class III, all of the coarse textured soils are included although some may be eliminated by other criteria standards as AWHC. The silty clay and clay loam soils included in class III for surface methods are not included here because of their low intake rate. Sprinklers designed to match these intake rates have such small droplet sizes that they are subject to excessive evaporative and wind drift losses. These soils are included in class III for limited use where special provisions may be made to reduce these losses (limited operating times, windbreaks, etc.). Heavy clay was not considered acceptable for sprinkler irrigation so was placed in class VI.

1.6.2.3 Available Water Holding Capacity (AWHC)

The available water holding capacity standards were set using a similar process to that used for surface irrigation. All classes have lower standards than for surface irrigation. The class I standard is at a level that is expected to require irrigation every 5 to 7 days during peak use periods. Class II might require irrigations every 4 to 6 days at the minimum level and class III every 3 to 4 days. Class IV might require daily irrigations during critical periods because of the high losses associated with these light applications. However, some high value crops that might also benefit from the crop cooling associated with daily irrigations may make daily irrigations feasible.

1.6.2.4 SURFACE FRAGMENTS AND PROFILE FRAGMENTS

Since the main consideration in setting these standards is workability and mechanization potential, no reason was seen to change these standards by irrigation method. All classes were, therefore, left the same as in surface irrigation.

1.6.2.5 SALINITY

The salinity standards for low application rate sprinkler systems are the same as for surface methods in classes I, II and III. Higher values were considered because of the inclusion of some coarser textured soils. However, the tendency of many sprinkler irrigators to slightly under-irrigate is believed to counteract that benefit. The class IV and VI standards were set at levels considerably lower than for surface irrigation methods because of the cost and difficulty of leaching salts with sprinkler systems.

1.6.2.6 ALKALINITY

The alkalinity standards for classes I, II and III remain the same as for surface irrigation. The class III standard may be excessive for the finer textured soils that meet class III standards but should be acceptable for the coarser textured soils. Class IV and VI standards are again lower than for surface methods for the same reason as the salinity standards.

1.6.2.7 GYPSUM

The same information was used in developing the sprinkler irrigation standards for gypsum content as were used in surface irrigation. The construction difficulties with surface irrigation methods were not considered to be a factor in this case. The class II standard, therefore, which was based primarily on this problem has been raised to the level of class III in the surface irrigation standards and class III to the same level as class IV. Economic crop selection remains the major consideration.

1.6.2.8 SLOPE

Low application rate sprinkler systems do not require standards as close on slope as do surface methods. The elevation differences resulting from long slopes or steep slopes must be considered in design to maintain satisfactory pressure throughout the system. This is easily accomplished through proper equipment selection including where necessary pressure regulators or flow control devices. The cost of installing sprinkler equipment on steeper slopes may increase because of these design requirements. Operating costs may also be higher on steeper slopes if the water is at the base of the slope, but irrigation can be practiced efficiently.

Because of the possibility of these increased costs, slopes of 15 to 30% were placed in class IV for special study and slopes greater than 30% were considered non-irrigable and placed in class VI.

1.6.2.9 DEPTH TO WATER TABLE

No change was made in the depth to water table standards from those used in surface irrigation.

1.6.2.10 SOIL DRAINAGE CLASS

The soil drainage class standards established for sprinkler irrigation are set to accept more of the moderately excessively and excessively drained soils. Class I has been expanded to include the moderately excessively drained soils. Class II has not been changed from surface methods. Class III eliminates the imperfectly drained soils and includes the excessively drained category. Class IV includes all categories in order to be consistent with the depth to water

table standards which is one of the factors in setting soil drainage class. Very poorly or poorly drained soils are still not considered as desirable for sprinkler irrigation purposes.

1.6.2.11 PERMEABILITY

In general, a more permeable soil can be sprinkler irrigated without the concern of percolation or deep seepage losses that occurs with surface methods. For this reason, all of the classes have been expanded to include soils of greater permeability than for surface methods. Soils of excessive permeability may be excluded because of their AWHC, but should not be identified as limited by their permeability. On the low side, the permeability standards for classes I and II are the same as for surface methods. Class III is more restrictive for sprinklers than surface methods with classes IV and VI the same as surface methods.

1.6.2.12 FLOODING

No change in the flooding criteria standards was made from those used in the surface irrigation methods.

1.6.3 HIGH APPLICATION RATE SPRINKLER SYSTEMS

High application rate sprinkler systems are defined for these criteria standards as those with an application rate or precipitation rate greater than 1.5. centimeters per hour. Two major types of sprinkler equipment are considered here: the center pivot and the traveling gun. No center pivots were seen in Syria, but several traveling guns were seen. Since these are not common systems in Syria, a brief description of each system is included.

The center pivot gets its name from its operation where a pivot point at which the water is supplied is located near the center of a field and the system rotates about that pivot point as it applies the water. Water is conveyed from the pivot point through a lateral pipe, 12 to 20 centimeters in diameter, mounted on wheels spaced every 30 to 60 meters along the pipe. The lateral pipe is supported on these wheels by towers and suspension cables or by bridge type trusses. Each the towers has a power source to drive the wheels. This power can be supplied by water or oil hydraulics, or electricity. The speed of rotation is normally controlled by the outer tower with all other towers following that tower through a series of alignment devices. Sprinklers are spaced along the entire length of the lateral pipe in a manner to provide uniform water distribution. Several combinations are used including: sprinklers at fixed spacings with sprinkler size increasing from the pivot to the outer end, sprinklers at variable spacings with no change in sprinkler size but the distance between sprinklers decreasing from pivot to the outer end, or in combinations of these two arrangements.

The speed of rotation of a center pivot system is variable. Normally a full circle is completed in 72 to 96 hours, but may range from 12 hours to 120 hours. The most common length of lateral pipe is 400 meters. The area covered in one

irrigation by the system is, therefore, the area within a circle of that radius which for 400 meters is approximately 50 hectares. The flow rate of water required to irrigate this amount of land is substantial and is a function of the peak daily use rate of the crop, the application efficiency of this system and the area being irrigated. As an example, assume a peak daily use rate of 8 millimeters per day, and an application efficiency of 80 percent for the 50 hectare system.

$$Q = \frac{11.6 \times Etp \times A}{Ef}$$

where:
- Q = Flow rate required in liters per second
- 11.6 = Constant to convert units
- Etp = Peak daily use rate in millimeters per day
- A = Area in Hectares
- Ef = Application Efficiency

$$Q = \frac{11.6 \times 8 \times 50}{80} = 58 \text{ liters per second}$$

This calculation assumes the system will operate continuously for 24 hours per day through the peak use period. To allow for some time to service the equipment, make repairs, etc., a 10 to 15% increase in flow rate is normally added. The design flow rate, Qd, would then be:

$$Qd = Q \times 1.15 = 58 \times 1.15 = 66.7 \text{ liters per second.}$$

The application rate of center pivots is greatest at the outer end where a unit length covers a larger area than a similar length closer to the pivot. The formula for calculating the precipitation rate at this outer end is as follows:

$$A.R. = \frac{438 \times Qd}{R \times r}$$

where:
- A.R. = Application rate in centimeters per hour
- 438 = Constant to convert units
- Qd = Design flow rate in liters per second
- R = Distance from pivot point to the outer end of the lateral line in meters
- r = Radius of area wetted by a sprinkler at the outer end of the lateral line in meters

Continuing with the previous example where Qd = 66.7 liters per second and R = 400 meters we need one more value, the radius of the sprinkler. This value varies with the type of sprinkler arrangement between about 5 meters for low pressure spray type systems to 30 meters for high pressure sprinkler systems. The range of application rates using these values would be:

$$A.R. = \frac{438 \times 66.7}{400 \times 5} = 14.6 \text{ centimeters per hour}$$

$$A.R. = \frac{438 \times 66.7}{400 \times 30} = 2.4 \text{ centimeters per hour}$$

This example has considered a standard sized center pivot, and obviously other lengths can be used. Shorter lengths would have a smaller flow rate and a smaller application rate, and longer systems would increase in both cases. The investment cost for center pivots is high and increases greatly with shorter lengths because of the length to area ratio. A system of one half the standard length, 200 meters, covers only 12.5 hectares or one fourth of the area with an investment of 60 to 70% of the standard system. This great increase in cost per hectare may make the shorter systems economically impractical. Longer systems decrease the investment cost per hectare, but may have such high flow rates and application rates that their use is limited.

Travelling guns also get their name from their operation. The term 'gun' refers to a large volume sprinkler delivering between 20 and 60 liters per second. The 'traveling' part of the name comes from the fact that the gun is mounted on a framework on wheels or skids that travels across the field as it applies water. The traveling is normally accomplished through a cable and winch arrangement located at the field edge or mounted on the framework with the gun. Some systems use the water supplying hose as a cable. Power to drive the winch is supplied either by water hydraulics or by a small gasoline or diesel engine. Water is supplied to the gun through a hose ranging in diameter from about 5 to 15 centimeters. The standard length of hose is 200 meters with a normal range of 60 to 400 meters. The path traveled by the system across the field is called a travel lane. The length of the travel lane is normally either equal to the hose length or twice the hose length. The spacing between lanes is dependent on the diameter wetted by the sprinkler, the wind velocity expected during irrigations and on the dimensions of the total area to be irrigated. Travel speeds are adjusted to apply the required amount of water, but a common operating speed is 60 centimeters per minute.

The water flow rate requirement for a traveling gun can be calculated using the same formula as a center pivot. Traveling guns, however, should never be assumed to operate 24 hours per day because of the time required to move the system from one travel lane to another travel lane. Also some time may be needed to move the pipe bringing water from the main water source to the hose supplying the gun. The recommended practice is to assume the system can operate 20 hours per day which requires increasing the calculated flow rate by a factor of 1.2. The area covered by a traveling gun varies with the crop and soil being irrigated, but 35 hectares is a reasonable average figure.

As an example, assume 35 hectares of a crop with a peak daily use rate of 8 millimeters per day is to be irrigated. Assume a design application efficiency of 75%

$$Q = \frac{11.6 \times Etp \times A}{Ef}$$

$$= \frac{11.6 \times 8 \times 35}{75} = 43.3 \text{ liters per second}$$

But this rate must be increased by a factor of 1.2 to account for operating 20 hours per day

$$Qd = Q \times 1.2 = 43.3 \times 1.2 = 52.0 \text{ liters per second.}$$

The average application rate for a traveling gun is calculated as follows:

$$A.R. = \frac{360 \times Q}{\pi r^2}$$

where: A.R. = Application rate in centimeters per hour
360 = Constant to convert units
π = Constant in area calculation
r = The wetted radius of the gun sprinkler

Using the design flow rate, Qd, to irrigate 35 hectares and assuming a wetted radius of 75 meters which is consistent with the flow rate, the average application rate would be:

$$A.R. = \frac{360 \times 52}{\pi(75)^2} = 1.06 \text{ centimeters per hour}$$

This is the average application rate over the entire wetted area. The peak application rate varies with sprinkler design but is approximately 1.5 times the average application rate. In this case, the peak application rate would be:

$$A.R.\ (PEAK) = A.R.\ (AVE.) \times 1.5$$
$$= 1.06 \times 1.5 = 1.6 \text{ centimeters per hour}$$

Different designs or design assumptions may give peak application rates for travelling guns slightly below the 1.5 centimeters per hour of high application rate sprinkler systems. It is recommended, however, that travelling guns be considered high application rate systems with respect to these criteria standards.

The criteria standards for high application rate sprinkler systems, presented in Table 7-1.7, are identical to the standards for low application rate systems with four important exceptions. The exceptions and the reasons for the

changes are as follows:

1.6.3.1 DEPTH TO UNCONSOLIDATED LAYER

The acceptable depth to an unconsolidated layer has been lowered slightly for class I soils. These low labor systems with precise water applications can be used on very shallow soils and still provide a broad range in crop selection. Center pivots are not adaptable to orchards, but travelling guns can be with special adaptation. The depth for class IV soils has been raised in these standards compared to the low application rate sprinklers. The very shallow soils which might require daily irrigations are not suitable - this is discussed further in the AWHC section.

1.6.3.2 SURFACE TEXTURE

Because of the high application rate of these systems, they are most adapted to the coarser textured soils. The class I standard for these systems includes some of the class I for surface methods. In class II, two textured standards are included by slope group. The coarser textured soils are acceptable only up to 2% slope. Some surface ponding of water during irrigation may occur on these finer textured soils so the lesser slopes are necessary to prevent runoff or water movement in the field. A similar texture-slope relationship is used in class III with a slight expansion of textural classes. Silt is the finest texture considered suitable for this method as reflected in the class IV and VI standards.

1.6.3.3 Available Water Holding Capacity (AWHC)

The class I AWHC standard is lower for this method than for the other methods. As mentioned earlier, the low labor requirement makes these systems particularly suited to soils which require frequent irrigation. The class III and IV standards are, however, higher than for the low application rate sprinkler systems because a minimum 3 day irrigation interval was considered desirable. Daily irrigations are possible with these systems and are practiced with center pivots on some crops in part of the United States but are not recommended. Even where used, the soils should have some reserve to sustain the crop for a short period should these mechanical systems fail.

1.6.3.4 SLOPE

The slope standards set for this irrigation method are more restricted than for the other methods. The systems considered have the capacity of operating on much greater slopes than the standard allows without mechanical problems. Center pivots, for example, are designed for slopes of 15 to 20%. The reason for the restricted slopes is related to the water hydraulics of the systems rather than their mechanical capabilities. For example, on a uniform slope of 2%, the elevation change from the pivot point to the outer end of a 400 meter system is 8 meters. If this is up in one direction and down in the opposite direction, this is a total difference of 16 meters. This elevation difference reflects directly

on the pressure available for the sprinklers and causes substantial problems in water application uniformity. Short slopes that exceed these standards should not cause problems for this method of irrigation. Since the slope characterization used by the soil survey team reflects the general slope, the standards were set at these low values expecting some steeper slopes within the area. In detailed design surveys within the general areas identified by these criteria standards, particular attention should be given to slope length and elevation variations resulting.

1.6.4 DRIP (TRICKLE) IRRIGATION METHOD

Specific standards have not been developed for the drip (trickle) method of irrigation. The reasons for this are:

1. The investment cost of drip systems is still very high. Therefore, the use of drip systems is recommended only on specialized production such as orchards, vineyards or very high value crops, where water supplies are limited, or where conditions are not favorable for use of one of the other systems discussed in this report.

2. Drip irrigation is still relatively new and developments in both equipment and techniques are rapidly occuring. These developments may make standards developed now obsolete in a short period of time. Drip irrigation is characterized by the application of water at low pressure through emitters placed near the ground at each plant. Water is released from the emitters in drops or a weak spray and moves downward and outward from the point of application. In coarse textured soils, the water movement is greater in the downward direction with relatively little outward movement. In medium textured soils, the outward movement increases and in fine textured soils, the downward and outward movement are about equal. When determining the number and placement of emitters, designing a drip system the shape of the wetted area and shape of the root zone of the plant being irrigated needs to be considered. to be considered together with the shape of the root zone of the plant being irrigated in designing drip systems to determine the number and placement of the emitters.

The advantages of drip irrigation are:

1. Water savings - since a small portion of the surface area is wetted by this method, evaporation losses are low compared to other methods. Also, water is applied directly into the active root zone of the crop eliminating water lost in non-productive areas. With careful water management, deep percolation losses can almost be eliminated. Early studies with drip irrigation reported water savings as high as 80%. This figure has since been shown to be excessively high for most applications. Savings of 15-25% are far more common and realistic if compared to highly efficient sprinkler or surface methods using the best delivery and management techniques.

2. Operation Costs - compared to high pressure sprinkle systems which have very high energy requirements, the energy costs of operating a drip system are very low. Lowered labor costs reduce the operating costs of drip systems below most surface methods. In both cases, the decreased quantity

of water used lowers the operating costs where either direct or indirect costs are associated with the water supply.

3. Use of Saline Water - several factors contribute to the increased success of using saline water in drip irrigation systems. One, the soil moisture can easily be maintained at a high level so the salts are diluted at any given time. Two, the salts tend to accumulate at the wetted front which can be controlled just outside the rooting zone. Three, the decreased water requirements mean that less total salts are deposited in a year.

Removal of the salts accumulated over a period of years remains a concern where drip irrigation is used. It may be necessary to leach the soil profile occasionally with some other method of irrigation where there is insufficient rainfall to remove these accumulated salts.

4. Decreased Use of Fertilizer - like the water savings, decreased fertilizer use can result if it is applied with the water and, therefore, placed only in the active root zone of the crop.

The major limitations of drip irrigation are:

1. Investment Cost - the investment cost of a drip irrigation system is normally considered to be the highest of commonly used systems.

2. Emitter Plugging - emitter plugging has been a major problem due to insufficient filtering of the water, mineral content of the water, algae growth, etc. Techniques and equipment to deal with these problems have been and are being developed, but they continue to be problems.

3. Unequal Pressure Distribution - since these systems operate at very low pressure, friction losses and elevation changes can easily result in pressure variations large enough to cause changes in emitter discharge. Design procedures incorporating proper equipment can handle these variations, but they require careful attention.

The anticipated use of drip irrigation systems in Syria is most likely in orchards (see Figure 7-1.7) and vineyards, and on high value vegetable crops in areas with limited water supply. The soil and topographic areas most suited are the rocky or stoney soils not easily adapted to other methods and the steeper slopes.

In comparing these requirements to the standards established for the other methods, some general recommendations can be made. 1. Soils placed in class IV, surface irrigation methods, for reasons of depth, rockiness or stoniness either on the surface or in the profile, or slope may be better adapted to drip irrigation than to surface methods. 2. Soils placed in class VI, surface irrigation method, for reasons of rockiness or stoniness or slope may be irrigable using drip irrigation methods. 3. Similar statements apply to class IV and VI soils for the Low Application Rate Sprinkler System and to class VI for the High Application Rate Sprinkler Systems.

1.7 SUMMARY

This report has described the irrigation suitability classifications, criteria used and the standards established to evaluate the potential of the soils of the Syrian Arab Republic for irrigation development. The initial application of these standards will be the preparation of thematic maps showing the irrigation suitability by irrigation method. It must be recognized that on a whole country basis, the soils information system contains information collected on a 1:500,000 scale. At this scale, rather large inclusions of soils with varying characteristics may be present. Scales of 1:100,000 and 1:25,000 are used for the first settlement zone and the arable areas within the first settlement zone, respectively. The additional detail in these zones will decrease the soil variability substantially. Detailed surveys will always be required, however, for final planning and design of areas identified by these standards.

Soils are the key factor in irrigation planning, but the importance of water quantity and quality cannot be over-emphasized. Combining the results of this project effort with a water resources assessment is highly recommended. The combination of soils and water information will provide an excellent basis for the Syrian Arab Republic to make proper decisions regarding the development and efficient use of these vital natural resources.

2 RECOMMENDATIONS FOR FUTURE ACTIVITIES

2.1 RECOMMENDATIONS

2.1.1 RECOMMENDATION NO. 1

Increased resources should be made available for the research effort to determine directly crop consumptive use requirements and to determine crop coefficients used in calculating crop consumptive use.

The research effort to determine those values has been stated by the Irrigation, Drainage and Reclamation Section of the Soils Directorate in accordance with their 1981-1985 work plan as shown in Figure 7-2.2. This work is of major importance because of the use of crop consumptive use values in project design, project management and field water management. The increased resources recommended are to obtain additional equipment and to expand the scope of the research.

Two items, in particular, were noted that indicated a strong need for this information. The first was the lack of a consistent method used in project reports and other publications reviewed. The second was the design information obtained on existing irrigation projects which showed great variation in maximum canal flow rates. This variation may be justified because of climatic differences, cropping differences and leaching requirements, but appears to be excessive.

2.1.2 RECOMMENDATION NO. 2

The major empirical,theoretical and correlative methods of crop consumptive use should be compared and a method (or methods) be recommended for use until the field research determinations are completed.

This recommendation is very closely related to Recommendation No. 1 and is based on the same identified needs. Although one method would be preferred, more than one method may be required because of differences in climatic data available. A method utilizing solar radiation may be preferred, for example, for locations where that information is available while a method using only temperatures may be required at other locations. The comparison of the methods involves using experience and engineering judgments together with research data available from within the country and other areas of similar climate.

Some comparative calculations were made during the project. The method selected for use was the modified Blaney-Criddle method. The modifications were made by the U.S. Soil Conservation Service for use of the formula in arid and semi-arid areas. Two modifications were made. One was the use of a climatic coefficient related to mean air temperature and the other was the use of a crop growth stage coefficient.

The basic Blaney-Criddle Formula is as follows:

$$U = K \times F = k \times f$$

where:

U = Estimated consumptive use in millimeters for the entire growing season
K = Empirical consumptive use coefficient
F = The sum of the monthly consumptive use factors
k = Monthly consumptive use coefficients
f = Monthly consumptive use factors based on mean monthly air temperatures and mean monthly percent of annual daytime hours as follows:

$$f = p\ (0.457\ t + 8.13)$$

where:

p = Mean monthly percent of annual daytime hours. This is latitude dependent and the information for latitudes pertinent to Syria are reproduced in Table 7-2.2.
t = Mean monthly air temperature in °C.

The modifications apply to the 'k' values. The modified k is as follows:

$$k = kt \times kc$$

where:

kt = 0.03114 t = 0.2396 (t in °C)
kc = A crop growth stage coefficient obtained from curves. Three examples are reproduced as Figures 7-2.3, 7-2.4, 7-2.5, 7-2.6, 7-2.7 and 7-2.8.

This modified Blaney-Criddle method was used to calculate crop consumptive use for three crops at five locations. The planting dates and length of growing season used were the same as those used in Publication 167, Water Requirements of Some Crops, Ministry of Agriculture and Agrarian Reform, 1979. The mean monthly air temperature data used was for the period 1955-1978. The principal sources were the Agroclimatological Reference book for the Syrian Arab Republic and Monthly Climatological Data both published by the Meteorological Department, Ministry of Defense, Syrian Arab Republic. The results of those calculations are shown in Tables 7-2.3, 7-2.4, and 7-2.5. These values were than compared to those in Publication 167. The following items were noted:

1. The Penman method of Publication 167, consistently provides higher total seasonal consumptive use values.

2. The major reason for these high seasonal totals by the Penman method is the very high use estimated for early in the growth period (almost twice as high as the average of the other two methods).

3. The Penman method does not reflect crop differences. The monthly use values for May, June, July and August are the same for all crops at each of the locations.

4. The Blaney-Criddle method in general agreed more closely with the modified Blaney-Criddle as expected since they are variations of the same basic formula.

5. The Blaney-Criddle method calculations showed in some cases (Sugar beets at Aleppo and Lattakia and corn at Aleppo) a higher water use in two non-consecutive months than in the intermediate month. This is not an expected pattern and would occur only under very unusual conditions. This may be an error in reproduction, but is noted for consideration.

6. The Blaney-Criddle method resulted in lower than expected average daily water use. In this respect, there was better agreement between the Penman and the modified Blaney-Criddle than with the standard Blaney-Criddle.

For these reasons, the modified Blaney-Criddle is recommended as one of the methods to be considered in this method comparison.

Some additional calculations were made with the modified Blaney-Criddle method to show some of the limitations and the need for accurate input to the formula. The crop selected was maize at Damascus. The following situations and results were obtained.

1. The growing season was moved one month earlier to be April through July instead of May through August. The water requirement for this growing season was 89.3 percent of the standard growing season used.

2. Since longer maturing varieties normally have a higher yield potential, a five month growing season, April through August, was compared to the standard. This resulted in a 16.7% increase in water use.

3. All temperatures used were decreased by 1.5 °C. to represent a cooler than normal growing season. This resulted in a water use requirement of 92.8% of the standard.

These variations are significant when planning long term projects because they illustrate the effect that changes in production practices and climate may cause. The variations also suggest ways in which project water requirements may be decreased when water supplies are limited.

2.1.3 RECOMMENDATION NO. 3

An effort should be made to improve water use efficiency in existing projects through a land leveling program and/or improved irrigation method selection.

The basin method of irrigation is being widely used. The basins are not, however, sufficiently level to achieve the potential efficiency of this method. The small size of the basins provides a reasonable degree of water application uniformity but requires an extensive water delivery system which leads to high evaporative and seepage losses. A high percentage of the land observed where basins are being used is on low enough slopes that leveling costs would not be expected to be excessive. With leveling, the basin size could be increased or

the level border system used. The more sloping land which basins are currently being used appear better adapted to one of the graded type irrigation methods or possibly to low application rate sprinkler systems (see Recommendation No. 7).

2.1.4 RECOMMENDATION NO. 4

A joint study of the management and control of project water delivery systems should be made by the Government agencies involved.

Effective water resources utilization on a project basis requires close coordination of the project water delivery system with the project cropping program. Part 1 of the report 'Agricultural Development of the Akkar Plain' prepared by Tipton and Kalmbach-Schick International, March 1979 presents in Chapter IV on future cropping program for the project. For this cropping program, August is identified as the month of maximum crop irrigation requirements. This is the key point for project design. From a project management point of view, the distribution of irrigation requirements must also be considered. Using the data presented in Table IV-1 and IV-2 of that report, the relative water requirements for the period May through September were calculated. Neglecting effective precipitation (which the report indicates may partially satisfy crop requirements during May and September) the results of those calculations were:

MONTH	PERCENTAGE OF MAXIMUM REQUIREMENT
May	85.4
June	53.4
July	62.0
August	100.0
September	76.7

Therefore, if this project were implemented as projected in this report, the water delivery during May should be 85.4 percent of the August design maximum, then cut back sharply for the months of June and July, increased to a maximum for the month of August and reduced to 76.7 percent in September. Further analysis of the water to be delivered into secondary canals from the main canal is based on the cropping program in each sector of the project.

When project water supplies are limited so that full requirements cannot be provided, the water delivery should consider the critical growth stage of the crops involved. The critical growth stages of some crops are identified in Table 7-2.6.

Delivering the proper amount of irrigation water to a project is a major step towards effective water resource utilization as shown in Figure 7-2.9. An efficient field ditch system shown in Figure 7-2.10 and efficient application of the right amount of water at the right time (see Recommendation No. 5) by properly selected irrigation methods is necessary to fully reach a project's efficiency potential.

2.1.5 RECOMMENDATION NO. 5

A field water management educational program should be started based on a moisture accounting approach.

Field water management consists of applying the right amount of water at the right time to satisfy crop consumptive use requirements. The use of proper irrigation methods to enable this to be done efficiently is assumed.

Several methods of managing or scheduling irrigation water are available. Included are: methods using instruments to monitor soil moisture such as tensiometers (as shown in Figure 7-2.11) or gypsum blocks, methods based on the feel and appearance of the soil; methods correlated to the evaporation from open pans, and methods based on moisture accounting. The latter method is recommended because of its simplicity, low cost and ease of implementing.

Moisture accounting methods require:

1. A knowledge of the soil being irrigated particularly its field capacity or available water holding capacity.

2. A knowledge of the rooting depth of the crop in order to know the depth of the soil supplying the moisture and selecting an irrigation depth. Rooting depths and recommended irrigation depths for some crops are presented in Table 7-2.7.

3. The amount of depletion of soil water that a crop can tolerate without significant yield reduction. This can be expressed either as a percentage of field capacity or of available water holding capacity.

4. Tables of consumptive use for the crop being grown. These must be based on the conditions (planting date, length of growing season, etc.) expected in the area. The method or methods used to prepare the tables should be selected as a result of Recommendation No. 2.

As an example, assume the following situation. A silty clay loam soil with an average field capacity by volume of 32.6 percent in 1 meter of depth is to be used for tomato production near Latakia.

From Table 7-2.7, a recommended irrigation depth of 120 centimeters is determined. The depletion recommendation is assumed to be 25 percent of the field capacity (75 percent remaining at the time of irrigation). The consumptive use information used is that presented in Table 7-2.3, but presented in Table 7-2.8 by 1/3 month intervals.

The field capacity is known only for 1 meter, but is assumed to remain the same to the recommended irrigation depth of 120 centimeters. The total water stored in that depth is:

$$d_1 = \frac{F\ C\ \%\ x\ Depth}{100} = \frac{32.6\ x\ 120}{100} = 39.12 \text{ centimeters}$$

If 25 percent can be depleted (or used) before irrigating, that amount is:

$$d_2 = \frac{39.12 \times 25}{100} = 9.78 \text{ centimeters or } 97.8 \text{ millimeters}$$

This is the soil moisture depletion amount used in the system. With this information, the dates for each irrigation can be determined by subtracting the water used from the soil moisture depletion amount.

Date	Crop Use Since Previous Date From Table 8	Soil Moisture Depletion Amount in Millimeters
May 1	0	97.8
May 10	20	77.8
May 20	22	55.8
May 31	26	29.8
June 10	27	2.8

At this point it should be noted that the remaining soil moisture is less than the daily use rate in the next period so irrigation is needed. If several days are needed to irrigate, the entire field irrigation should have been started earlier. In a similar manner, the other irrigation dates can be determined. These would be: July 7, July 24, Aug. 8, Aug. 31, Sept.16, Oct. 9. No credit has been given to effective rainfall in this analysis. It would be expected to make a contribution eliminating one or two of these irrigations. Rainfall should be measured in the field and added to the soil moisture up to the maximum of 97.8 millimeters that the soil can store.

The net amount of water to be applied in each irrigation is the amount needed to raise the soil moisture to field capacity. An irrigation applied on June 10 in the example would need to provide 95 millimeters (97.8-2.8). This is the equivalent of 950 cubic meters per hectare. The total (or gross) amount applied should be the net amount divided by the application efficiency. With a level basin or level border type of system, application efficiencies of 60 percent to 80 percent are common. Using the average of these values, 70 percent, the gross irrigation requirements are:

$$\text{Gross Irrigation Requirements} = \frac{\text{Net Irrigation Requirements}}{\text{Application Efficiency}}$$

$$G\ I\ R = \frac{950\ m^3/\text{Hectare}}{0.70} = 1357\ m^3/\text{Hectare}$$

The amount of water diverted from project storage would need to be larger than this amount to account for evaporation and seepage losses in the delivery system.

As research data becomes available, improvements in this basic system should be made. For example, crop water use could be correlated with mean or maximum daily temperatures in addition to stage of growth and more precise application efficiencies could be determined on a demonstration basis at one or several locations in each project.

Increased production with improved water use efficiency is the objective of this recommendation. Several educational methods might be used, but the demonstration method is strongly recommended.

2.1.6 RECOMMENDATION NO. 6

A research program should be started on the use of a limited water supply in irrigation projects.

Irrigation projects are not always capable of fully meeting crop consumptive use requirements. Some projects are designed to meet only a set percentage of crop needs in a normal year or to fully meet crop needs in a certain percentage of years. Others, due to a change in cropping programs to more high water use crops are no longer capable of meeting crop needs immediately.

Several options are available to optimize production in this situation including: designating a certain area to receive no irrigation water each year, revising cropping plans to include more low water use crops, changing planting dates or using shorter season crop varieties, accepting reduced yields due to insufficient water supplies, or supplementing the water supply from an alternative source such as supplementing surface sources with wells (Figure 7-2.12). This last option may not be available, but where it is, the cost should be considered compared to the other options.

The research program would be concentrated on the options of a change in planting dates, shorter season crops and reduced yields. The effects of these options on total production needs to be documented so that the Government has the information needed to make the right decision.

The implementation of these options requires control over the use of the irrigation waters available. Without a workable control program, some users will practice full irrigation further reducing the already limited supply available for other users.

2.1.7 RECOMMENDATION NO. 7

A research study should be made of the evaporative and wind drift losses in sprinkler irrigation.

Currently there is very little use of sprinkler irrigation in the country. The major objection to the use of sprinkler-irrigation that was expressed was the high losses expected to occur under Syrian climatic conditions. No published information documenting these losses was found. Since the greatest potential appears to exist for sprinkler systems with application rates in the range of 0.5 to 1.5 centimeters per hour, it is recommended that these be studied first.

The higher investment cost and energy requirements of sprinkler systems also needs to be considered, but the research on losses should precede this. If the losses prove excessive, no further investigations would be justified. The higher investment cost would be partially offset by the elimination of land leveling cost, in most cases. The energy requirements could be primarily supplied by electricity, which is currently in a very favorable supply situation.

The nature of sprinkler systems provides excellent opportunities for precise measurement and control of water applications. This promotes good water management leading to increased yields and effective water utilization.

2.2 SUMMARY

The seven recommendations presented in this report were selected from more than 12 items noted during field visits. They were felt to be most important to the future of efficient use of the country's limited land and water resources. Among those not included here was a concern about the salt effected lands in the Lower Euphrates. This area is known to be under study and the importance of prompt action before further degradation occurs seems to be adequately understood. A great deal of concern was also noted for the water supply, water quality and industrial encroachment in the Ghouta. The drainage and water supply problems in the Ghab Depression were also noted for possible inclusion, but insufficient time was spent in that area to make recommendations.

The personnel and resources required to deal with these recommendations are already available except as noted under Recommendation No. 1. Work on these recommendations should be considered with other high priority projects and a timetable established for their completion.

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TABLE 7-1.1.
PRECIPITATION RANGE BY LAND AREA

PRECIPITATION RANGE-mm	LAND AREA -Km	PERCENT OF TOTAL LAND AREA
1000	9,250	5
500 - 1000	37,000	20
250 - 500	46,000	25
100 - 250	74,000	40
100	18,500	10

TABLE 7-1.2.
PRODUCTION YIELDS AND YIELD RATIOS
MAJOR FIELD CROPS AND VEGETABLES
1974 - 1978

CROP[1]	YIELD IN KILOGRAM PER HECTARE IRRIGATED	NON-IRRIGATED	YIELD RATIOS IRRIGATED TO NON-IRRIGATED
Total Wheat	2127	848	2.51
Cotton	2226	387	5.75
Maize	2113	791	2.67
Tomatoes	20532	4453	4.61
Grazing			
Barley	12291	10126	1.21
Barley	1665	678	2.46
Sesame	822	268	3.07
Sugar			
Beets	22714	16452	1.38
Potatoes	13837	9180	1.51
Snake			
Cucumbers	15576	4977	3.13

1- Crops are listed in order by the number of hectares irrigated in 1978. That is, total wheat had the most hectares irrigated, followed by cotton, etc.

TABLE 7-1.3

PRODUCTION YIELDS AND YIELD RATIOS
MAJOR ORCHARD AND VINEYARD CROPS
1974 - 1978

CROP[1]	YIELD IN TONNES PER HECTARE IRRIGATED	NON-IRRIGATED	YIELD RATIO IRRIGATED TO NON-IRRIGATED
Apricot	4.13	1.56	2.65
Apple	4.58	2.06	2.22
Grapes	6.95	3.25	2.14
Citrus	7.22	None Reported	----
Olives	2.50	1.00	2.50

1- Crops are listed in order by the number of hectares irrigated in 1978 as in previous table.

TABLE 7-1.4.
SOILS LISTED BY INTAKE RATE CATEGORY
DECREASING SEQUENCE

TEXTURE CLASS	MODIFIER	COMPUTER CODE DESIGNATION	INTAKE RATE CATEGORY
SAND	COARSE	01-3	>6.25 cm/HR
SAND		01	
SAND	FINE	01-2	
LOAMY SAND	COARSE	02-3	4-6.25 cm/HR
LOAMY SAND		02	
LOAMY SAND	FINE	02-2	
SAND	VERY FINE	01-1	
LOAMY SAND	VERY FINE	02-1	
SANDY LOAM	COARSE	03-3	
SANDY LOAM		03	2-4 cm/HR
SANDY LOAM	FINE	03-2	
SANDY LOAM	VERY FINE	03-1	
LOAM		04	
SANDY CLAY LOAM		08	
SILT LOAM		05	1-2 cm/HR
SILT		06	
SANDY CLAY		10	
SILTY CLAY LOAM		09	0.5-1 cm/HR
CLAY LOAM		07	
SILTY CLAY		11	0.125-0.5 cm/HR
CLAY		12	
HEAVY CLAY		13	<0.125 cm/HR

TABLE 7-1.5.
SURFACE IRRIGATION METHODS

	I	II	III		IV		VI
DEPTH TO UNCONSOLIDATED LAYER - CM	>150 (>100)	>100	>60		>30		<30
DEPTH TO CONSOLIDATED LAYER - CM	>200 (>100)	>120 (>100)	>90		>60		<60
SURFACE TEXTURE	LOAM TO SILT 13 to 16	VERY FINE SAND TO CLAY LOAM 7 to 19	FINE SAND TO CLAY 3 - 21		COARSE SAND TO HEAVY CLAY 1 - 22		COARSE SAND TO HEAVY CLAY 1 - 22
AWHC CM/METER	>15	>10	>10		>5		<5
SURFACE FRAGMENTS STONINESS %	<3	<3	<3	<15	<15	<60	>60
SURFACE FRAGMENTS ROCKINESS %	<2	<2	<10	<2	<10	<2	>10
PROFILE FRAGMENTS % 0 - 30 CENTIMETERS	<2	<5	<10		<20		>20
PROFILE FRAGMENTS % 0 - 100 CENTIMETERS	<5	<15	<35		<60		>60
SALINITY EC_e - mmhos/CM	<4	<8	<16		<40		>40
ALKALINITY ESP	<5	<15	<30		<50		>50

TABLE 7-1.5. (cont'd)

GYPSUM %	<5	<10	<25	<45	>45
SLOPE %	<2	<5	<9	<15	>15
DEPTH TO WATER TABLE -CM	>300 (>100)	>200 (>100)	>100	AT OR NEAR THE SURFACE	
SOIL DRAINAGE CLASS	WELL DRAINED	MOD. WELL DRAINED TO MOD. EXC. DRA.	EMP. DRAINED TO MOD. EXC. DRA.	VERY POORLY DRAINED TO EXC. DRAINED	
PERMEABILITY CM/HR	2-6.25	0.5-12.5	0.125-25	0.125-25	0.125 or 25
FLOODING	NONE	RARE	RARE	EXPECTED OR FREQUENT	

TABLE 7-1.6.
LOW APPLICATION RATE SPRINKLER SYSTEMS

	I	II	III	IV	VI
DEPTH TO UNCONSOLI-DATED LAYER - Cm	>100	>60	>45	>20	<20
DEPTH TO CONSOLI-DATED LAYER - Cm	>120 (>100)	>90	>60	>45	<45
SURFACE TEXTURE	SANDY LOAM TO SILT 10 - 16	FINE SAND TO CLAY LOAM 3-19	COARSE SAND TO CLAY LOAM 1-19	COARSE SAND TO CLAY 1 - 21	COARSE SAND TO HEAVY CLAY 1-22
AWHC Cm/METER	>10	>8	>6	>3	<3
SURFACE FRANGMENTS STONINESS %	<3	<3	<3 <15	<15 <60	>60
SURFACE FRAGMENTS ROCKNESS %	<2	<2	<10 <2	<10 <2	>10
PROFILE FRAGMENTS 0 - 30 CM %	<2	<5	<10	<20	>20
PROFILE FRAGMENTS 0-100 Cm %	<5	<15	<35	<60	>60
SALINITY ECe mmhos/cm	<4	<8	<16	<16	>16
ALKALINITY ESP	<5	<15	<30	<30	<30
GYPSUM %	<5	<25	<40	<40	>40
SLOPE %	<5	<9	<15	<30	>30
DEPTH TO WATER TABLE - Cm	>300 (>100)	>200 (>100)	>100	AT OR NEAR THE SURFACE	

TABLE 7-1.6 (cont'd)

SOIL DRAINAGE CLASS	WELL DRAINED MODE +C DRAINED	MOD WELL DRAIN TO MODE+C DRAINED	MOD WELL DRAIN TO ED	VPD TO ETC. ETC. DRAINED	
PERMEABILITY Cm/AR	2 - 12.5	0.5 - 25	0.5	125	0.125
FLOODING	NONE	RARE	RARE	EXPECTED OR FREQUENT	

TABLE 7-1.7.
HIGH APPLICATION RATE SPRINKLER SYSTEMS

	I	II		III		IV		VI
DEPTH TO UNCONSOLIDATED LAYER - Cm	>90	>60		>45		>45		<45
DEPTH TO CONSOLIDATED LAYER - Cm	>102 (>100)	>90		>60		>45		<45
SURFACE TEXTURE	very fine sand to fine sandy - loam 7 - 12	fine sand to VFSL 3 - 12	loam to silt 13-16	coarse sand to 1-14	silt loam to silt 15-16	coarse sand to silt 1 - 16		coarse sand to heavy clay 1 - 22
AWHC Cm/METER	>8	>6		>5		>5		<5
SURFACE FRAGMENTS STONINESS %	<3	<3		<3	<15	<15	<60	>60
SURFACE FRAGMENTS ROCKINESS %	<2	<2		<10	<2	<10	<2	>10
PROFILE FRAGMENTS 0 - 30 Cm %	<2	<5		<10		<20		>20
PROFILE FRAGMENTS 0 - 100 Cm %	<5	<15		<35		<60		>60
SALINITY ECe - mmhos/cm	<4	<8		<16		<16		>16
ALKALINITY ESP	<5	<15		<30		<30		>30
GYPSUM %	<5	<25		<40		<40		>40
SLOPE %	<2	<5	<2	<5	<2	<9		<9
DEPTH TO WATER TABLE - cm	>300 (>100)	>200 (>100)		>100		AT OR NEAR SURFACE		

TABLE 7-1.7. (cont'd)

SOIL DRAINAGE CLASS	WELL DRAINED TO MOD EXC DRAINED	NOT WELL DRAINED TO MOD EXC DRAINED	MWD TO E D	V P D TO E D	
PERMEABILITY	2 - 12.5	0.5 - 25	0.5	.125	.125
FLOODING	NONE	RARE	RARE	EXPECTED OR FREQUENT	

TABLE 7-2.1.
PRODUCTION YIELDS AND POTENTIAL YIELDS
OF SELECTED CROPS

CROP	PRODUCTION YIELD 1974-1978[1] KILOGRAMS PER HECTARE	POTENTIAL YIELD KILOGRAMS PER HECTARE
WHEAT	2,127	3.400
SUGAR BEETS	22,714	40,000
MAIZE	2,113	6,300
POTATOES	13,837	20,000
COTTON	2,226	3,000
CUCUMBERS	15,576	20,000

[1] From Annual Agricultural Statistics Abstract, 1978.

TABLE 7-2.2
MONTLY PERCENTAGE OF DAYTIME HOURS

LATITUDE NORTH	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
37°	6.92	6.82	8.34	8.87	9.85	9.89	10.05	9.44	8.37	7.83	6.88	6.74
36°	6.98	6.85	8.35	8.85	9.80	9.82	9.99	9.41	8.36	7.85	6.93	6.81
35°	7.04	6.88	8.35	8.82	9.76	9.76	9.93	9.37	8.36	7.88	6.98	6.87
43°	7.10	6.91	8.35	8.80	9.71	9.71	9.88	9.34	8.35	7.90	7.02	6.93
33°	7.15	6.94	8.36	8.77	9.67	9.65	9.83	9.31	8.35	7.92	7.06	6.99
32°	7.20	6.97	8.36	8.75	9.62	9.60	9.77	9.28	8.34	7.95	7.11	7.05

TABLE 7-2.3.
MONTHLY, SEASONAL AND PEAK CROP USE
CALCULATED BY THE
MODIFIED BLANEY-CRIDDLE METHOD

TOMATOES

LOCATION	ALEPPO	HAMA	LATTAKIA	DAMASCUS	DEIR AZ ZOUR
Month	(All values in millimeters)				
May	71	72	68	68	84
June	101	104	93	98	124
July	186	187	168	171	227
Aug	223	227	210	205	269
Sept	160	161	159	145	178
Oct	90	93	106	87	97
Total	831	844	804	774	979
Peak Month	Aug	Aug	Aug	Aug	Aug
Average Daily Use In Peak Month	7.2	7.3	6.8	6.6	8.7

TABLE 7-2.4.
MONTHLY, SEASONAL AND PEAK CROP USE
CALCULATED BY THE
MODIFIED BLANEY-CRIDDLE METHOD

CORN

LOCATION	ALEPPO	HAMA	LATTAKIA	DAMASCUS	DEIR AZ ZOUR
Month		(All values in millimeters)			
May	80	82	76	78	95
June	174	176	156	163	211
July	250	250	224	226	304
Aug	205	208	191	186	246
Total	709	716	647	653	856
Peak Month	July	July	July	July	July
Average Daily Use In Peak Month	8.1	8.1	7.2	7.3	9.8

TABLE 7-2.5.
MONTHLY, SEASONAL AND PEAK CROP USE
CALCULATED BY THE
MODIFIED BLANEY-CRIDDLE METHOD

SUGAR BEETS

LOCATION	ALEPPO	HAMA	LATTAKIA	DAMASCUS	DEIR AZ ZOUR
Month	(All values in millimeters)				
April	47	50	53	47	57
May	104	109	100	100	125
June	199	202	178	186	240
July	277	271	250	252	338
Aug	272	277	254	247	322
Sept	184	188	187	170	210
Total	1,083	1,097	1,022	1,002	1,292
Peak Month	July	Aug	Aug	July	July
Average Daily Use In Peak Month	8.9	8.9	8.2	8.1	10.9

TABLE 7-2.6.
CRITICAL GROWTH PERIODS

CROP	STAGE OF GROWTH
Potatoes	Blossom to Harvest
Cotton	First Bloom Through Boll-Maturing Stage
Maize	Pollination Period-Tasseling Through Silking
Sugar Beets	3 to 5 Weeks After Emergence
Wheat	Boot to Heading Stage
Alfalfa	Start of Flowering-After Cutting For Quick Regrowth
Orchards	Fruit Development
Vineyards	Fruit Development
Cucumbers	Blossom to Harvest
Tomatoes	Fruit Ripening

TABLE 7-2.7.
RECOMMENDED MANAGEMENT DEPTH

CROP	ACTIVE ROOT ZONE IN CENTIMETERS	RECOMMENDED IRRIGATION MANAGEMENT DEPTH IN CENTIMETERS (NO ROOT PENETRATION LIMITATIONS)
Alfalfa	90-180	120
Cotton	90-180	120
Cucumbers	45-120	60
Maize	90-180	90
Orchards	90-180	150
Potatoes	60-90	60
Sugar Beets	60-120	90
Tomatoes	120-180	120
Vineyards	90-180	150
Wheat	90-200	120

TABLE 7-2.8.
TOTAL AND DAILY CROP USE BY ONE-THIRD MONTH PERIODS

Periods	Total Use Millimeters	Daily Use Millimeters
May 1-10	20	2.0
May 11-20	22	2.2
May 21-31	26	2.4
June 1-10	27	2.7
June 11-20	30	3.0
June 21-30	36	3.6
July 1-10	46	4.6
July 11-20	56	5.6
July 21-31	66	6.0
Aug 1-10	69	6.9
Aug 11-20	71	7.1
Aug 21-31	70	6.4
Sept 1-10	62	6.2
Sept 11-20	54	5.4
Sept 21-30	43	4.3
Oct 1-10	37	3.7
Oct 11-20	35	3.5
Oct 21-31	33	3.0

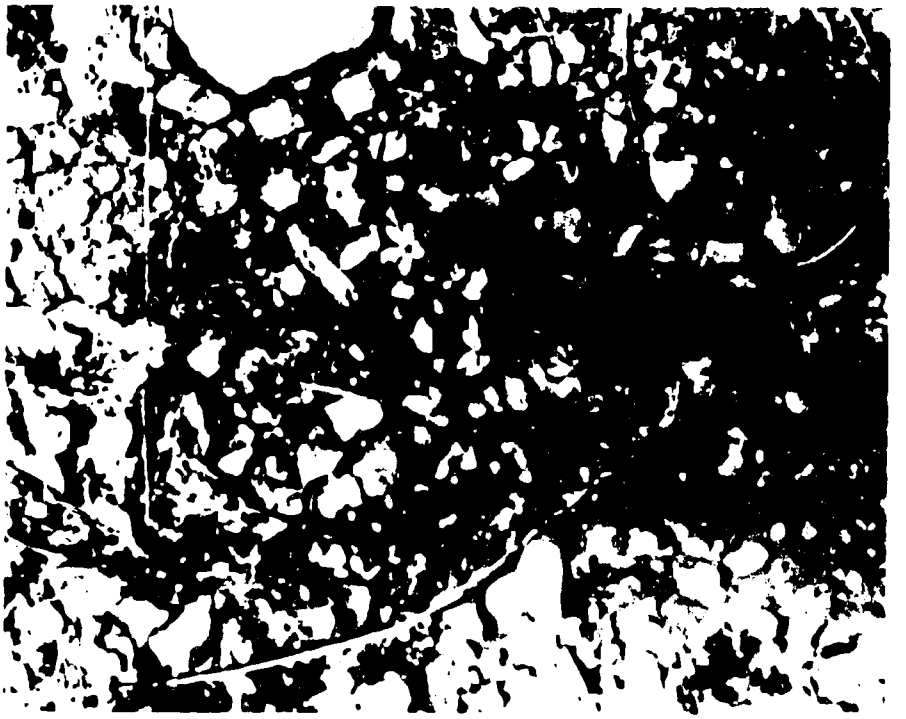

Figure 7-1.1.
Rocks and stones both on the surface and in the profile limit both crop and irrigation methods in large areas of the country.

Figure 7-1.2.
Large areas along the lower Euphrates are salt affected. Improved drainage systems are needed to reclaim these areas which have been irrigated for many centuries. The quality of Euphrates waters appears to be acceptable to irrigate these soils, once reclaimed, if proper irrigation management is used.

Figure 7-1.3.

This soil profile is from the Raqqa area where the gypsum content of the soil is very high. Special cropping, management and irrigation methods will be required to successfully irrigate these soils.

Figure 7-1.4.

The GHAB Depression requires an improved drainage system both to control water table and salinity to realize its full potential.

Figure 7-1.5.

Vegetable production on the Akkar Plain south of Tartous suffers from periodic flooding and insufficient drainage. This relatively high area shows maize or sorghum being used as a windbrreak to protect the sensitive vegetable crops from Mediterranean winds.

Figure 7-1.6.

The forestry research station near Homs uses sprinkler irrigation effectively. Research on sprinkler irrigation is recommended in order to utilize this method more fully on soils not well suited to surface irrigation.

Figure 7-1.7.

Orchards such as these in the Ghouta near Damascus provide the best opportunity for the use of drip or trickle irrigation. Orchards or vineyards on rocky or sloping ground would benefit greatly from the use of this method.

Figure 7-2.1.

Maize offers an excellent opportunity to increase grain production under irrigation.

Figure 7-2.2.

The research being conducted in the country by SARG and by other agencies such as this ACSAD station near Deir Al Zour are rapidly increasing the information required to properly manage irrigated agricultural development.

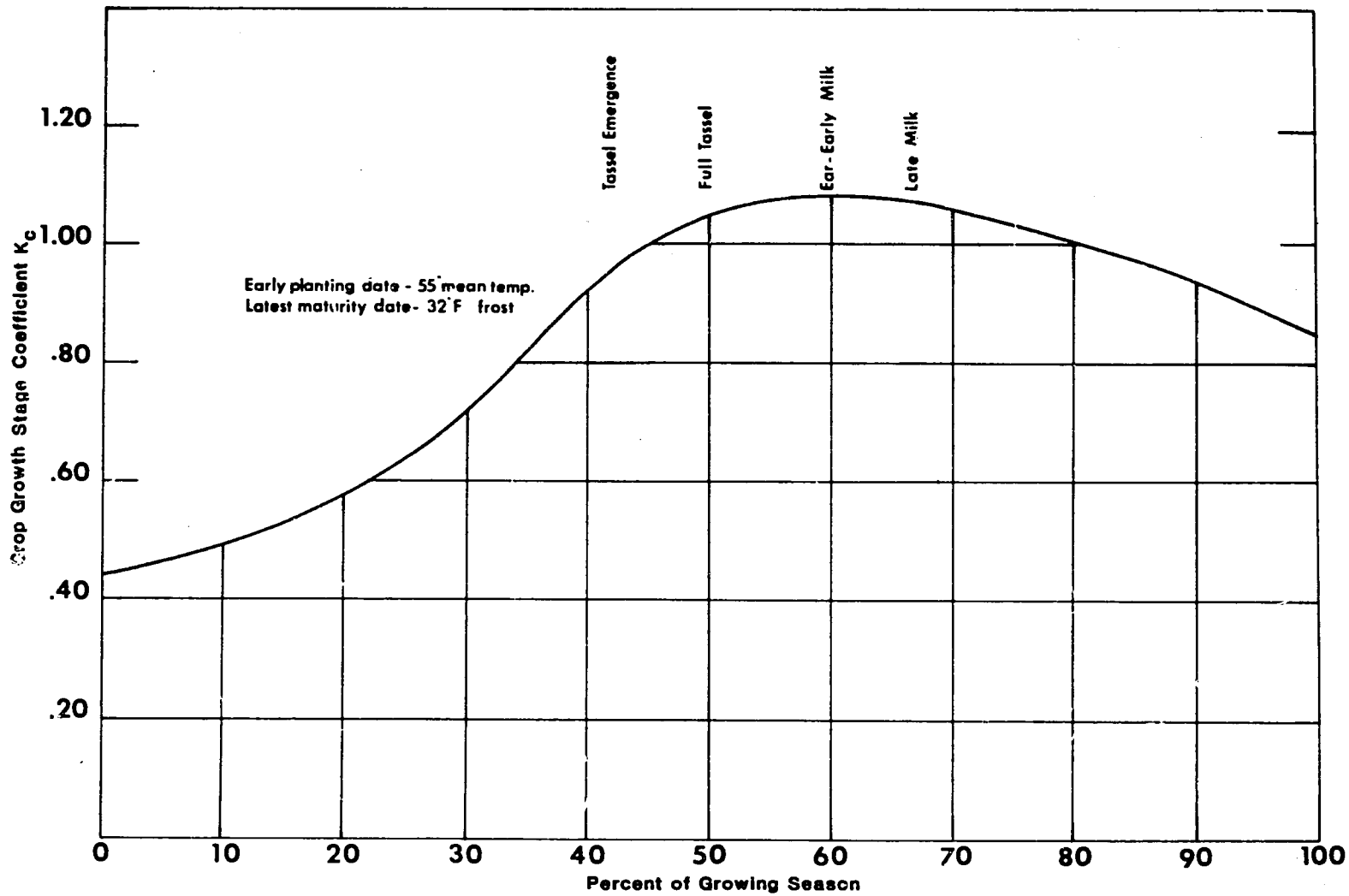

Figure 7-2.3.Crop Growth Stage Coefficient Curve For Corn (Grain)

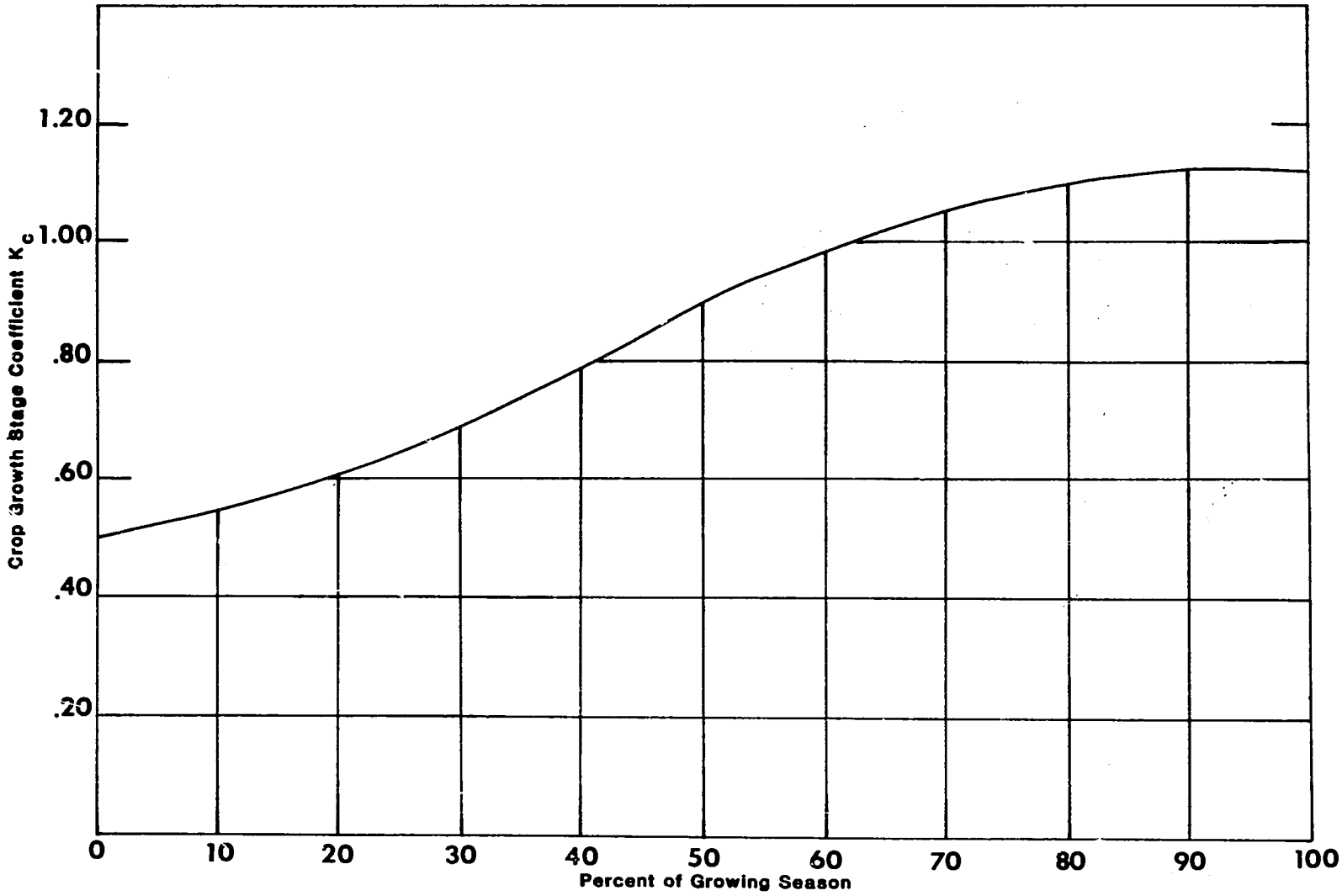

Figure 7-2.4. **Crop Growth Stage Coefficient Curve For Snap Beans**

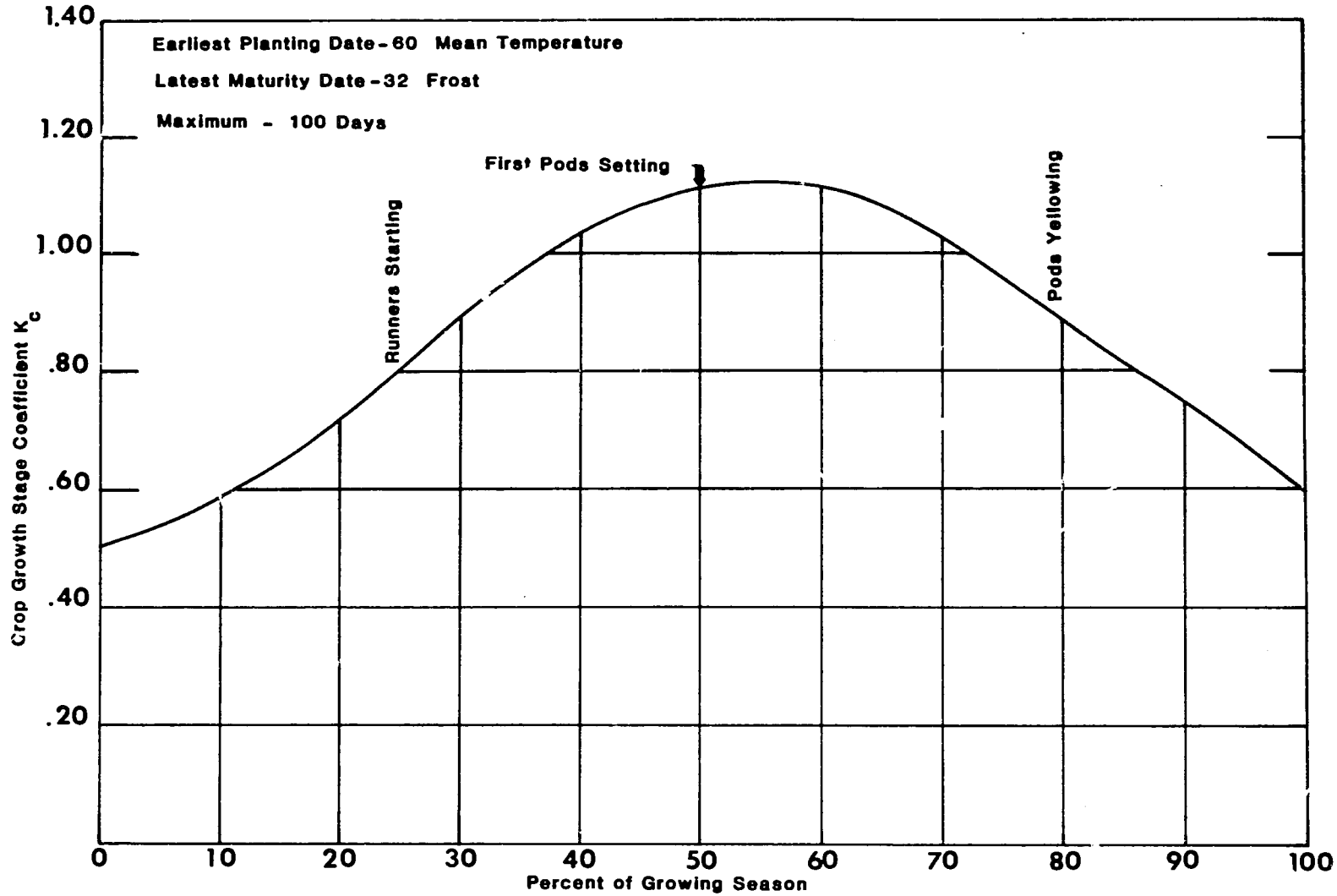

Figure 7-2.5. Crop Growth Stage Coefficient Curve For Dry Beans

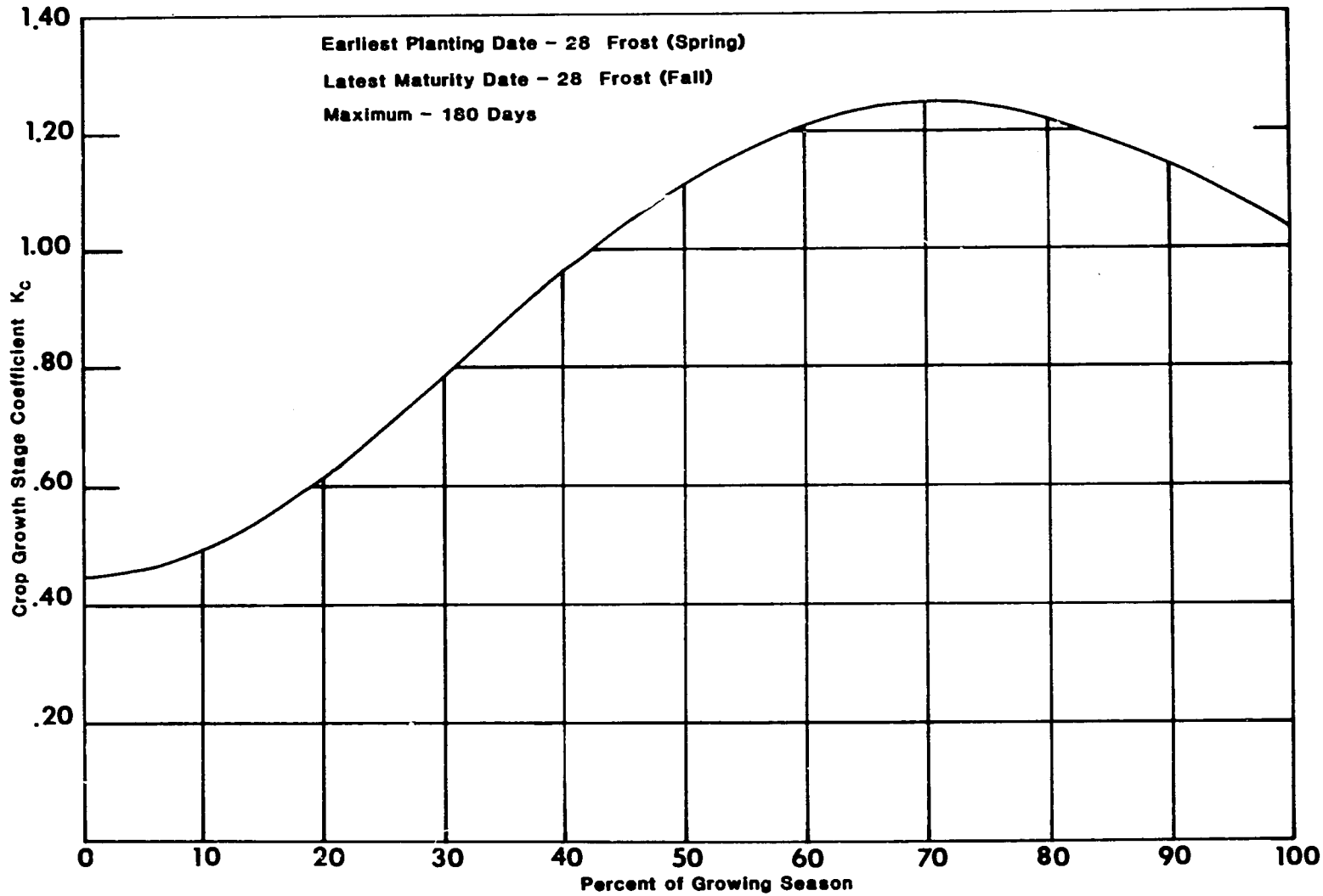

Figure 7-2.6. **Crop Growth Stage Coefficient Curve For Sugar Beets**

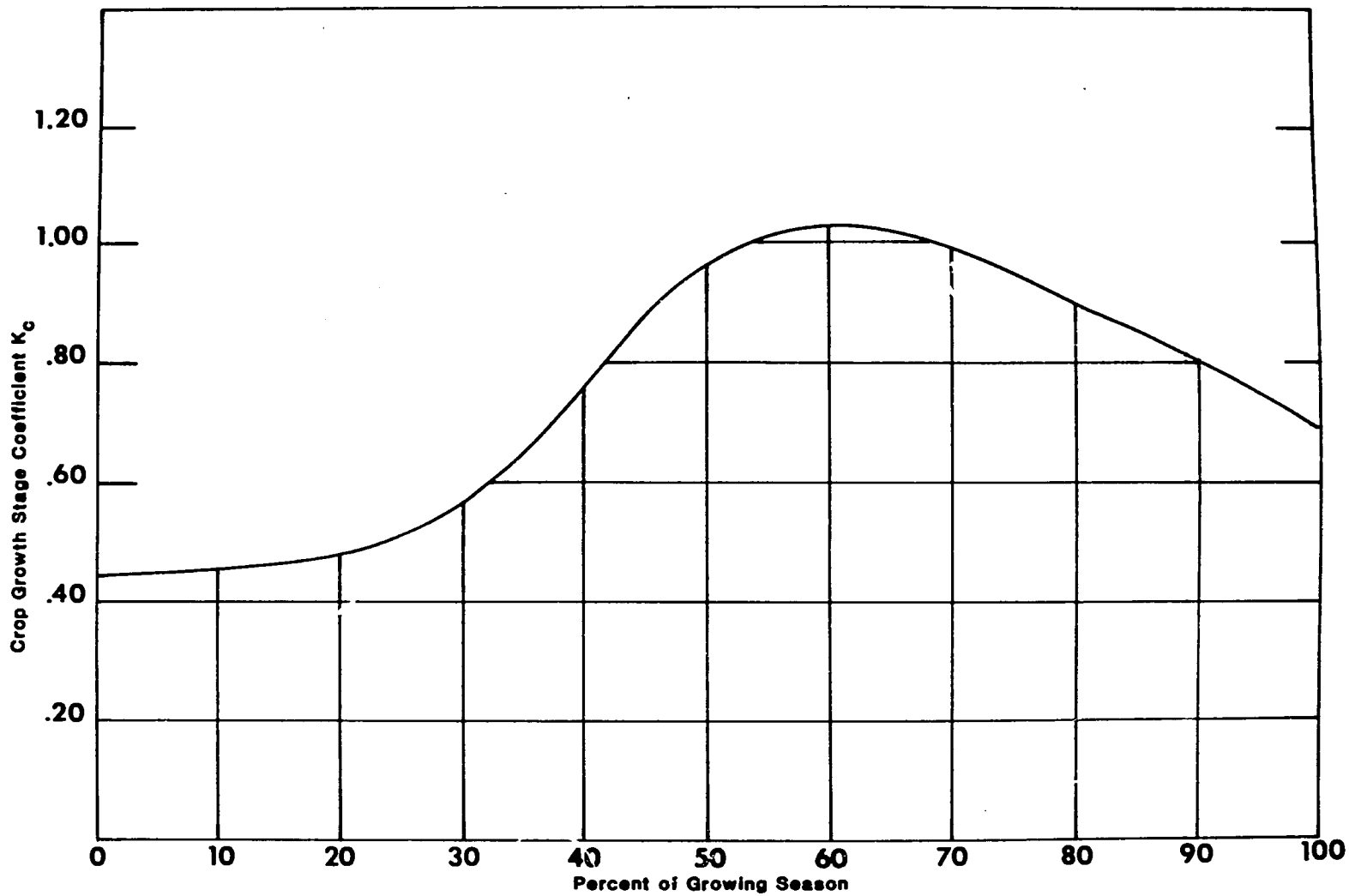

Figure 7-2.7. **Crop Growth Stage Coefficient Curve For Tomatoes**

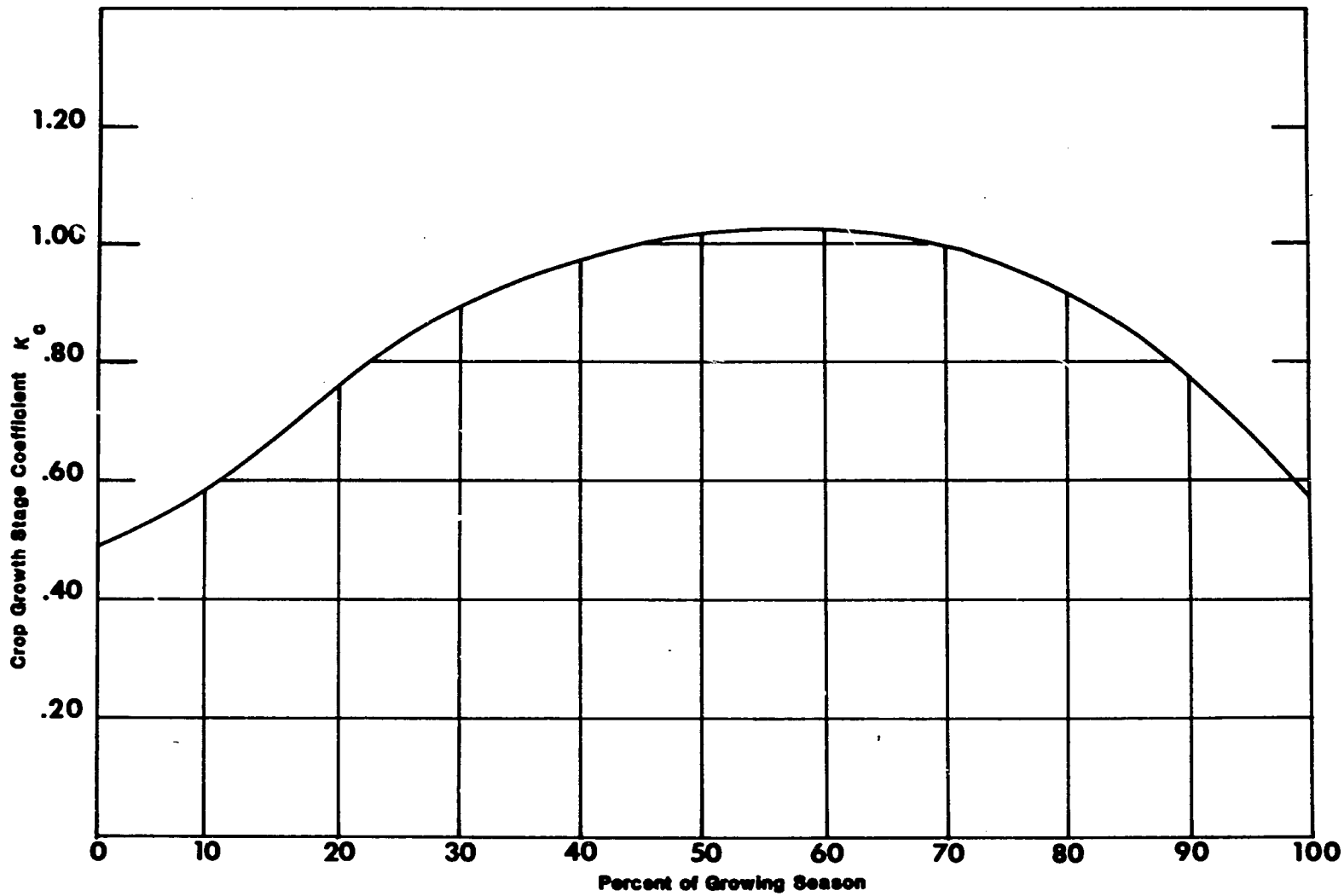

Figure 7-2.8. **Crop Growth Stage Coefficient Curve For Small Vegetables**

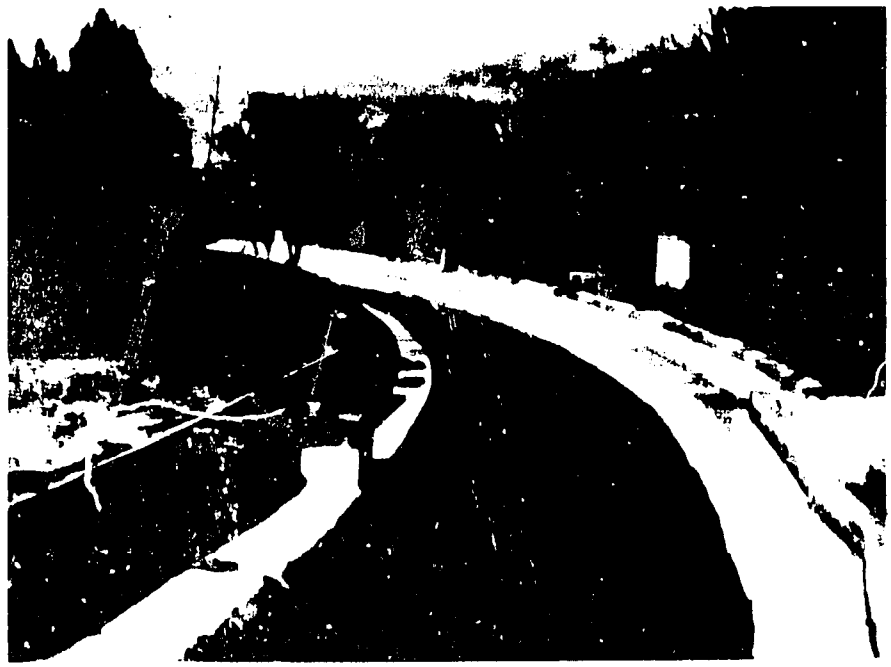

Figure 7-2.9. Large concrete line canal near Homs for efficient delivery of water to secondary canals of surrounding fields.

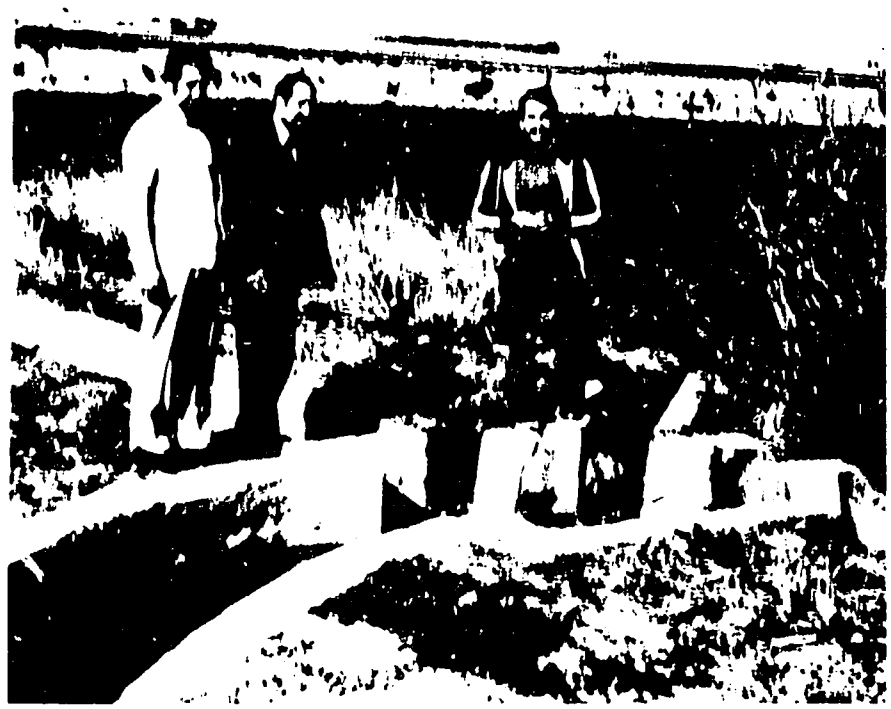

Figure 7-2.10. The physical facilities in this existing project near Homs appears well-designed and maintained. An integrated planning, management and operation program provides opportunities for increased utilization of soil and water resources involved.

Figure 7-2.11.

Research projects like this one near Khrabo will assist in development of improved water management methods and improved crop water utilization values. Note tensionmeters in use in upper center of picture.

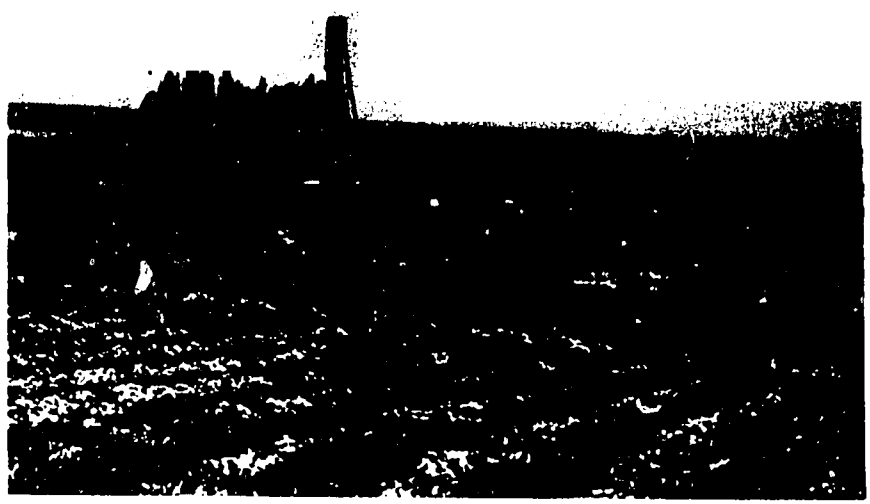

Figure 7-2.12.

This well drilling rig was in the coastal area. Ground water development must be carefully regulated to avoid overuse and use of low quality water.