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AGRICULTURAL DEVELOPMENT OF THE AKKAR PLAIN

PART II - APPENDICES

VOLUME 1

TIPTON AND KALMBACH-SCHICK INTERNATIONAL
DENVER SALT LAKE CITY

MARCH, 1979

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

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APPENDIX AI

SOILS AND LAND CAPABILITY CLASSIFICATION

Soil Characteristics

The Akkar Plain, located on the coastal plains of Syria, reflects the Mediterranean-type climate of arid summers and high precipitation during the winter. A general World Soil Map places the Akkar Plain in the two dominant soil orders of aridisols and vertisols. Aridisols are soils without horizons of clay accumulation that are low in organic matter and generally arid for six or more months of the year. Aridisols are especially responsive to irrigation and make up much of the irrigated lands throughout the world. Vertisols (previously called grumosols) are characterized by a high content of swelling-type clay. The clay in vertisols swells when moist and shrinks when dry. Deep, wide cracks develop in these soils during the dry season from May to November on the Akkar Plain. Inadequate drainage and poor physical soils conditions are constraints limiting crop production on the vertisols.

Bottomlands bordering the major streams are formed by alluvial deposits and are deep, medium-textured soils of excellent structure and fertility. Alluvial bottomlands are capable of being very productive soils where they are well-drained and not subject to flooding.

Large undulating land areas have lacustrine deposits over sandy limestone and basalt bedrock. These deposits form productive soils except where they are shallow over rock. Rolling hills and steeper areas have residual soils formed principally from decomposed basalt and to some extent from decomposed limestone. These residual soils are well drained and are generally used for

olive groves.

Bedrock

Basalt, limestone, and sandy limestone are the predominant rock materials, although much of the arable lands are of transported soils of alluvial or lacustrine origin. Limestone or sandy limestone are the predominant underlying rock in the western portion of the Plain. The eastern portion of the Plain is largely underlain by basalt.

Detailed Soils Investigation

Soil examinations were made by boring to depths of 160 centimeters or more, to barriers preventing auger penetration. Occasionally, the presence of rock or dense clay layers limited borings to shallower depths; but roads, railroads, surface wells, and drainage cuts frequently made deep observations of soil conditions possible. One to five soil examinations were made in each square kilometer in the project area. At each boring, observations were made of the land use, slope, relief, and subsurface drainage. Soils were examined in the field or laboratory for texture, depth to gravel or to fractured rock, presence of bedrock, reaction (pH), salinity, soil structure, compaction, and fertility of the soil material.

During the progress of the survey, samples of representative soil profiles were collected throughout the project area. Samples were sent for laboratory analysis to confirm the field determinations. Numerous mechanical analyses were made at Latakia Soil Laboratory to check the field estimate of soil texture. Soil pH was determined for the same samples. Results of the mechanical analyses and pH were tabulated for some representative profiles, Table AI-1. The pH values show the soils to be near neutral or slightly basic.

TABLE A1-1. Textural Analyses and pH from Latakia Soils Laboratory, Syria

Sample Number		Depth	Silt	Clay	Sand	Textural Class	pH	Land Class
		cm	%	%	%			
B4	#1	0-20	31	41	28	clay loam	7.8	2sd
		20-50	31	38	31	clay loam	8.0	
		50-100	25	38	27	clay loam	7.7	
C4	#1	0-30	25	38	37	clay loam	7.9	3d
D3	#1	0-90	27	52	21	clay	7.5	3sd
		90-110	30	48	22	clay	7.3	
E11	#1	0-15	31	37	32	clay loam	7.9	5d
		15-60	31	38	31	clay	7.8	
E12	#1	0-20	15	31	54	sandy clay loam	7.5	2d
		20-30	11	33	56	sandy clay loam	7.2	
		30-80	7	40	53	sandy clay loam	7.5	
E13	#1	0-30	33	45	22	clay	7.7	2sd
		30-70	27	52	21	clay	7.5	
G5	#1	0-35	32	18	50	loam	7.2	2rs
		35-50	27	41	32	clay loam	7.2	
G9	#3	0-20	27	49	24	clay loam	7.2	3sd
		20-60	27	46	27	clay	7.4	
G12	#2	0-15	14	34	52	sandy clay loam	7.5	3sd
		15-60	23	35	42	clay loam	7.7	
I8	#1	0-20	24	51	25	clay	7.8	3sd
		20-50	47	48	25	clay	8.0	
I15	#1	0-30	51	26	23	clay loam	7.6	2sd
		30-70	43	37	20	clay loam	7.6	
J6	#1	0-60	37	23	40	loam	7.5	2d
		60-90	33	32	35	clay loam	7.5	
J12	#1	0-50	21	46	33	clay	7.5	3sd
		50-70	25	26	49	sandy clay loam	7.8	

TABLE AI-1, continued. Textural Analyses and pH from Latakia Soils Laboratory, Syria.

Sample Number	Depth	Silt	Clay	Sand	Textural Class	pH	Land Class
	cm	%	%	%			
K15 #3	0-30	20	30	50	sandy clay loam	6.5	2rs
	30-60	16	42	42	clay	6.8	
K16 #1	0-30	38	34	28	clay loam	7.7	1
	30-80	34	34	32	clay loam	7.7	
	80-110	40	24	36	loam	8.6	
L13 #2	0-50	23	48	29	clay	7.5	2s
	50-80	23	50	27	clay	7.3	
M12 #2	0-70	27	48	25	clay	7.0	3sd
	70-90	30	48	22	clay	7.4	
M15 #1	0-30	30	48	22	clay	7.3	2rs
	30-100	27	50	23	clay	7.4	
M16 #1	0-60	36	18	46	loam	7.7	1
	60-120	23	22	55	sandy clay loam	7.8	
N10 #2	0-20	29	46	25	clay	6.9	3sd
	20-50	27	46	27	clay	6.9	
O15 #1	0-20	35	44	21	clay	7.8	3s
	20-50	37	40	23	clay loam	7.9	
Q12 #2	0-60	28	46	26	clay	7.4	2s
	60-80	26	42	23	clay	7.6	
R9 #1	0-40	31	38	31	clay loam	7.4	2rs
	40+	24	26	50	sandy clay loam	7.5	
R9 #3	0-30	24	48	28	clay	7.0	2s
	30-80	25	44	31	clay	7.2	

Textural analyses indicate the Akkar Plain soils to be predominantly fine-textured with the clay percentage exceptionally high. The exceptional granular structure of the clay, after the saturated soils dry to field moisture capacity and less, is an unusual characteristic. This granulating of the dry clay permits drainage to be more effective than usually expected in heavy soils. An exception to the above characteristic is found in the heavy bottomland soils on the west side of the Plain. These soils consist of clays with compact massive structure that expand when wet and shrink when dry to form wide cracks in the surface.

Soil Laboratory Analyses

Tests were made for organic matter, cation exchange capacity, electronic conductivity, and pH (soil reaction) in the Damascus Soil Laboratory. The results presented in Table AI-2 are compared with two soils in the United States. The organic matter is low, compared with a fertile irrigated Utah soil, but compares favorably with soils from the Southern Great Plains of the United States. The cation exchange capacity (sum total of exchangeable cations that a soil can adsorb) is very high in comparison with normal United States soils and is a result of the high clay content of Akkar Plain soils. This means that the soil has the ability to retain nutrients for plant growth.

No evidence of saline or alkali soils was discernible in the Akkar Plain. A thin white coating was occasionally observed on the surface, but apparently this was residual silt left on soil particles after seepage of surface moisture or residue from high fertilizer applications. The tests from both the Damascus and the U.S. Soil Laboratories indicated little or no

Table AI-2. Soil Analyses at Damascus Laboratory

Sample Number	Land Class	Organic Matter %	Cation Exchange Capacity Meq/100 gr	Electrical Conductivity Of Saturation Extract $EC_e \times 10^3$
G 9	3sd	1.94	47	0.36
J15	1	1.62	50	0.57
Q11	3s	1.30	77	0.60
F 7	3rs	1.81	37	0.22
J13	2sd	1.78	39	0.55
M14	2sd	1.53	67	0.30
P15	3sd	1.21	55	0.24
L12	2s	1.24	57	0.28
I 7	3sd	2.04	77	0.39
J11	3sd	1.69	52	0.34
R14	2s	1.24	45	0.24
N10	3sd	1.88	60	0.32
Normal Soils in U.S.A.		2.69 1/	20. 3/	0.60 3/
		1.55 2/	29	1.68
			17	0.84

1/ Utah, U.S.A.

2/ Southern Great Plains.

3/ Agriculture Handbook No. 60, USDA, 1969.

salinity in the samples submitted. The electrical conductivity of a saturated extract (ECe) less than 4 millimhos/cm represents a concentration of soluble soils that is not considered harmful for most plants. Conductivity measurements of soil samples made by the Damascus and the U.S. Laboratories were all less than one millimho/cm.

Laboratory measurements of pH and alkalinity for nearly all the samples submitted indicated alkalinity (sodic soils) was not present in amounts harmful to plants. Measurements of alkalinity made by the U.S. Laboratory is expressed as an alkalinity index as shown in Table AI-3. Results of the twelve samples submitted indicate ten had an alkalinity index of 2 or less which is considered non-sodic. The other two had an alkalinity index of 4 and 6, respectively. Soils with an alkalinity index of 4 or less are considered satisfactory for plant growth, but for the soil with an alkalinity index of 6, 18 kg of elemental sulfur per hectare was recommended by the laboratory. Most of the samples submitted to both laboratories had pH values less than 7.5. Soils having pH values of less than 7.5 contain no alkaline earth carbonates.

Tests for elements essential for plant growth were made by the U.S. Soil Laboratory of samples collected from representative soil areas. Fertilizer recommendations were made for production of high yields of maize, sorghum, onions, cabbage, and citrus trees, Table AI-4. The laboratory results indicate the soils are very deficient in the major plant nutrients of nitrogen, phosphorus, and potassium. Likewise, deficiencies in the minor plant nutrients were indicated, particularly of sulfate sulfur and zinc. Large amounts of fertilizer were recommended by the laboratory to meet the plant requirements for

Table AI-3 Soil Analyses of Akkar Plain Soils , sampled from 0-30 cm.

Item	Unit	Sample Number											
		F-7-2	I-7-2	G-9-4	J-11-2	J-13-1	J-15-1	L-12-1	N-10-1	M-14-1	P-15-1	Q-11-1	R-14-1
Reaction	pH	7.5	7.8	7.9	7.4	7.4	8.1	7.3	7.1	6.7	7.7	6.9	7.7
Soluble Salts	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alkalinity	index	1	6	2	2	1	4	2	2	0	2	0	1
Organic Mat.	%	1.4	3.2	1.8	1.2	0.9	1.5	0.6	0.6	0.8	0.7	0.5	0.5
Organic Nit.	kg/ha	55.	70.7	59.5	52.7	46	57.3	29.2	29.2	38.2	33.6	24.7	24.7
Nitrate Nit.	kg/ha	nil	11.2	11.2	11.2	33.7	33.7	nil	nil	nil	nil	nil	nil
Avail. P	kg/ha	33.6	26.9	48.2	40.3	67.2	82.9	38.1	33.6	35.8	38.1	35.8	29.2
Avail. K	kg/ha	190.4	101.	112.3	101.	89.8	123.5	56.1	78.6	67.4	78.6	67.4	89.8
Sulfate Sulfur	kg/ha	39.3	46.	39.3	46.	39.3	112.3	52.8	46.	52.8	32.6	39.3	39.3
Zinc	kg/ha	.16	.54	.53	.26	.22	.34	.17	.12	.13	.18	.17	.13
Manganese	kg/ha	6.2	2.7	3.1	9.2	4.1	4.1	4.0	7.9	9.3	5.0	6.2	7.6
Copper	kg/ha	2.1	2.6	3.1	3.4	3.1	3.1	3.4	3.1	3.5	3.7	3.5	4.6
Boron	kg/ha	.67	.11	.56	.56	.90	.67	.34	.79	.45	1.12	.45	.67
Iron	kg/ha	16.2	2.1	6.4	12.2	13.9	7.6	13.5	13.0	13.9	10.5	14.4	17.7
Magnesium	kg/ha	707	662	448	640	763	2077	2436	2436	2762	2156	2717	2324
Calcium	kg/ha	5726	19760	12799	8196	6624	12125	5726	6175	6400	7298	5614	5052
Sodium	kg/ha	157	121	98.8	151.6	198.7	206.6	217.8	229.0	223.4	184.	196.5	174.
Chlorine	kg/ha	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4

Table AI-4. Fertilizer Recommendations for Akkar Plain Soils (Method application may vary this recommendation)

Item	Sample Number											
	F-7-2 1/	I-7-2 1/	G-9-4 1/	J-11-2 2/	J-13-1 3/	J-15-1 3/	L-12-1 1/	N-10-1 2/4/	M-14-1 5/	P-15-1 5/	Q-11-1 5/	R-14-1 5/
	(kg available per hectare)											
Total Nitrogen	247	191	247	213	180	157	258	168	79	90	123	123
Phosphate	101	135	101	112	191	191	101	191	112	135	112	135
Potash	157	236	213	202	224	213	224	247	213	202	213	191
Sulfate Sulfur	67	11	67	67	79	0	56	45	11	34	34	34
Zinc	11	6	6	9	9	9	11	9	9	9	9	9
Manganese	3.4	3.4	9	0	6	6	6	0	0	3.4	3.4	0
Copper	1.1	.6	0	0	0	0	0	0	0	0	0	0
Boron	1.1	1.7	1.1	1.1	1.1	1.1	1.7	1.1	1.7	1.1	1.7	1.7
Iron	0	0	0	0	0	0	0	0	0	0	0	0
Magnesium	0	0	0	0	0	0	0	0	0	0	0	0
Gypsum	0	0	0	0	0	0	0	0	0	0	0	0
Elemental Sulfur	0	45	0	0	0	0	0	0	0	0	0	0

1/ Recommendation for high yield maize.
2/ Recommendation for high yield sorghum.
3/ Recommendation for high yield onions.
4/ Recommendation for high yield cabbage.
5/ Recommendation for young orange trees.

nitrogen, phosphorus, and potash necessary to attain maximum crop yields. The quantities of nutrients recommended are those necessary to be applied if soil deficiencies are to be completely overcome. However, in practice it is the aim to fertilize only that portion of the soil in which the roots are concentrated. Band placement of fertilizer for row crops, placement of fertilizer in a ring around trees, and small applications at intervals throughout the season for close growing crops can cut fertilizer amounts to as much as one-fourth and still achieve optimum yields. Severe foliage burning may occur if the full amount of the recommended fertilizer was applied in limited areas or without adequate mixing in the surface soil. In practice the average farmer usually uses less fertilizer than the laboratory recommends. However, some overfertilization with nitrogen and phosphate was observed on the Akkar Plain during the 1978 growing season.

The use of complete fertilizers containing the major plant nutrients appears to be widespread and their benefits well known in the Akkar Plain. However, trace element deficiencies are not as well known, even though their deficiency can be equally as restricting to crop yields. As little as 0.6 kg per hectare per year of boron can maintain the boron level for maximum crop yields in boron deficient soils. Similarly, the other minor elements, zinc, manganese, and copper indicated as deficient in the soil tests, can be maintained at an optimum level with small amounts of the element being added each crop year.

A deficiency of boron and zinc is indicated for all the soils tested, and 6 to 11 kg per hectare of zinc and from 1.1 to 1.7 kg per hectare of boron are recommended for all soils. Sulfate sulfur and manganese were found to

be deficient in most of the soils. Sulfate sulfur could be supplied most economically by using a sulfate fertilizer such as ammonium sulfate. All fertilizer recommendations should be tested at research locations prior to full distribution to farmers on the Akkar Plain, inasmuch as laboratory recommendations are frequently affected by outside factors, including cultural methods used by the individual farmers and varieties selected.

Land Classification

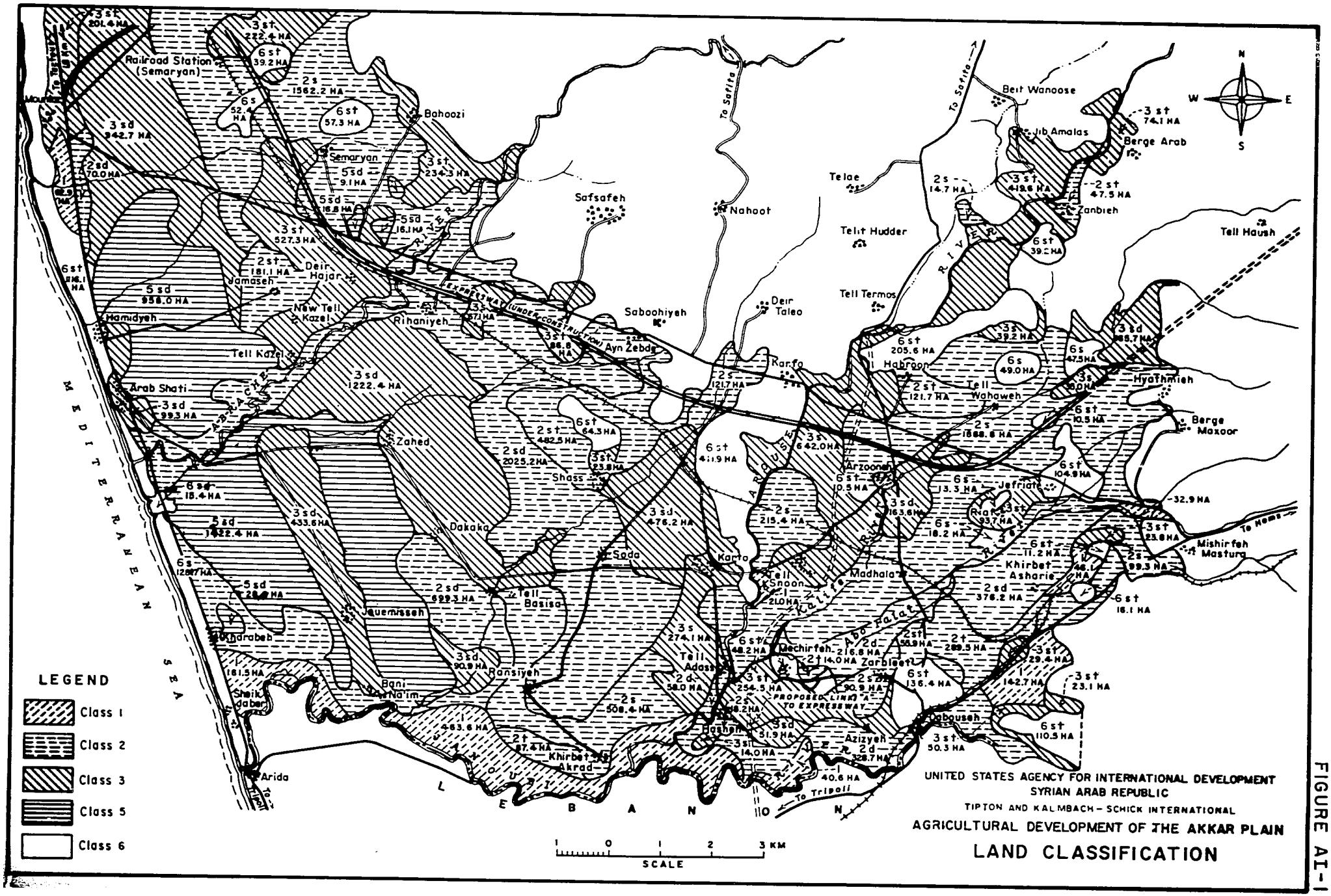
Characteristics of land resources include soils, topography, and drainage as they are related to the productivity of the complete landscape. The characteristics of the soils alone are not fully indicative of the economic productivity of the area. For example, land having topographic deficiencies, even though the soil appears to be highly productive, must be classified showing the crop constraint. Also, land has a drainage requirement regardless of micro-area productivity if the surface or subsurface water is a limiting constraint to crop production. These limiting characteristics of soil, topography, and drainage were considered in the land classification survey.

Specifications of soil, relief, and drainage characteristics determining each class of land are defined in Table AI-5. The location and extent of each class of land is shown on the Land Classification Map AI-1, and the area in each class and subclass is summarized in Table AI-6. Five land classes are shown on the map. Land Class I soils have good depth, texture, and structure, no drainage or topographic deficiencies, and no alkali or salinity problems. Class 2 may have slight to moderate deficiencies in soil, topographic, or drainage conditions. Class 3 lands have moderate to severe

Table AI-5. Land Classification Criteria for Irrigable Soils

Characteristics	Class 1	Class 2	Class 3	Class 5
Texture	Fine sandy loam to friable clay loam.	Sandy loam to clay loam.	Loamy sand to friable clay.	Clay loam to massive clay.
Depth				
To alluvial fractured rock	>75 cm	> 45 cm	> 30 cm	>30 cm
To permeable bedrock	>2.0 m	>1.5 m	>1.0 m	>1.0 m
Exchangeable sodium percentage	< 10 percent	< 20 percent	< 30 percent	< 30 percent
Reaction	pH <8.0 0-1 m	pH <8.0 0-70 cm	pH <8.0 0-35 cm	pH < 8.0 0-35 cm
Salinity or electrical conductivity	Conductivity of saturation extract 4 millimhos/cm	Conductivity of saturation extract 8 millimhos/cm	Conductivity of saturation extract 12 millimhos/cm	Conduc. of sat. extract 12 millimhos/cm
Slope	0-3 percent	0-5 percent	0-10 percent	0-10 percent
Relief	Gently undulating	Moderately undulating	Rolling	Gently undulating to rolling.
Surface and Subsurface Drainage	Little or no surface drainage requirements anticipated. No subsurface drainage required.	Some surface drainage anticipated. No subsurface drainage anticipated.	Major surface drainage is anticipated. Limited subsurface drainage anticipated.	Major surface drainage will be required. Subsurface drainage not feasible.

Class 6- Lands not meeting standards of irrigable classes.


LEGEND
Class 1
Class 2
Class 3
Class 5
Class 6
SCALE
1 0 1 2 3 KM
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
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TIPTON AND KALMBACH – SCHICK INTERNATIONAL
AGRICULTURAL DEVELOPMENT OF THE AKKAR PLAIN
LAND CLASSIFICATION
MEDITERRANEAN SEA
LEBANON
Railroad Station (Semaryan)
Bahoozi
Semaryan
Safsafeh
Nahoot
Telae
Telit Hudder
Tell Termos
Deir Taleo
Saboohiyeh
Ayn Zebda
Karfa
Habroon
Tell Wahaweh
Arzooneh
Jefriate
Riaf
Madhala
Khirbet Asharie
Mechirfeh
Zarbiset
Tell Snoon
Tell Adass
Hosneh
Azizyeh
Tabouseh
Mishirfeh Masturq
Hyathmieh
Berge Maxoor
Berge Arab
Jib Amalas
Zanbieh
Beit Wanoose
Tell Hausb
Deir Hajar
Jamaseh
New Tell Kazel
Rihaniyeh
Tell Kazel
Hamidyeh
Arab Shati
Zahed
Shass
Dakaka
Soda
Tell Basisa
Jouemisseh
Kharabeb
Sheikh Jaber
Bani Na'im
Ransiyeh
Khirbet Akrad
Arida
To Tripoli
To Safita
To Homs
EXPRESSWAY (UNDER CONSTRUCTION)
PROPOSED LINK TO EXPRESSWAY
ARQUESTE RIVER
ABU FALAT RIVER
AKKAR RIVER
N
S
W
E

FIGURE AI-1

Table AI-6. Akkar Plain Land Classification by Class and Subclass.

Land Class	Subclass	Class
	ha	ha
1		971
2t	391	
2d	603	
2s	4520	
2sd	3171	
2st	889	
Subtotal		9574
3s	1071	
3sd	3646	
3st	2264	
Subtotal		6981
5sd		2450
6s	309	
6sd	15	
6st	2383	
Subtotal		2707
Grand Total		22683

limitations in the above conditions. Lands with massive clay soils and flat topography that restrict effective drainage are in Class 5. Class 6 lands are not suitable for irrigation development. Subclasses are used to indicate the reason land is placed in a class lower than Class 1. This is shown by adding letters "s" for soil, "t" for topography, and "d" for drainage deficiencies to the right of the land class numbers 2, 3, 5 and 6. The subclasses used are st, sd, and std.

Typical soil profiles for Land Classes 1, 2, 3 and 5 are shown in Figure AI-2. Texture of soil horizons, presence of rock, depth of bedrock if encountered, textural analyses if made of a particular profile, and present land use are shown on four typical soil profiles for each major class of land.

Land Capability

Land capability, present and potential, is directly related to soil, topography, and drainage conditions, as is land classification; but is further restricted by climate and other land use limitations. With the land classification serving as a basis, the crops best adapted for each land class can be assessed in determining land use recommendations. Land capability is a combination of the physical factors expressed in the land classification considered together with the appropriate land use.

Eight classes are set up under the land capability classification. Lands having the greatest capabilities in response to good management and use and which have the least limitations are in Capability Class 1. Those lands with the least capabilities and greatest limitations are in Class VIII.

Six capability classes were recognized in the Akkar Plain classification,

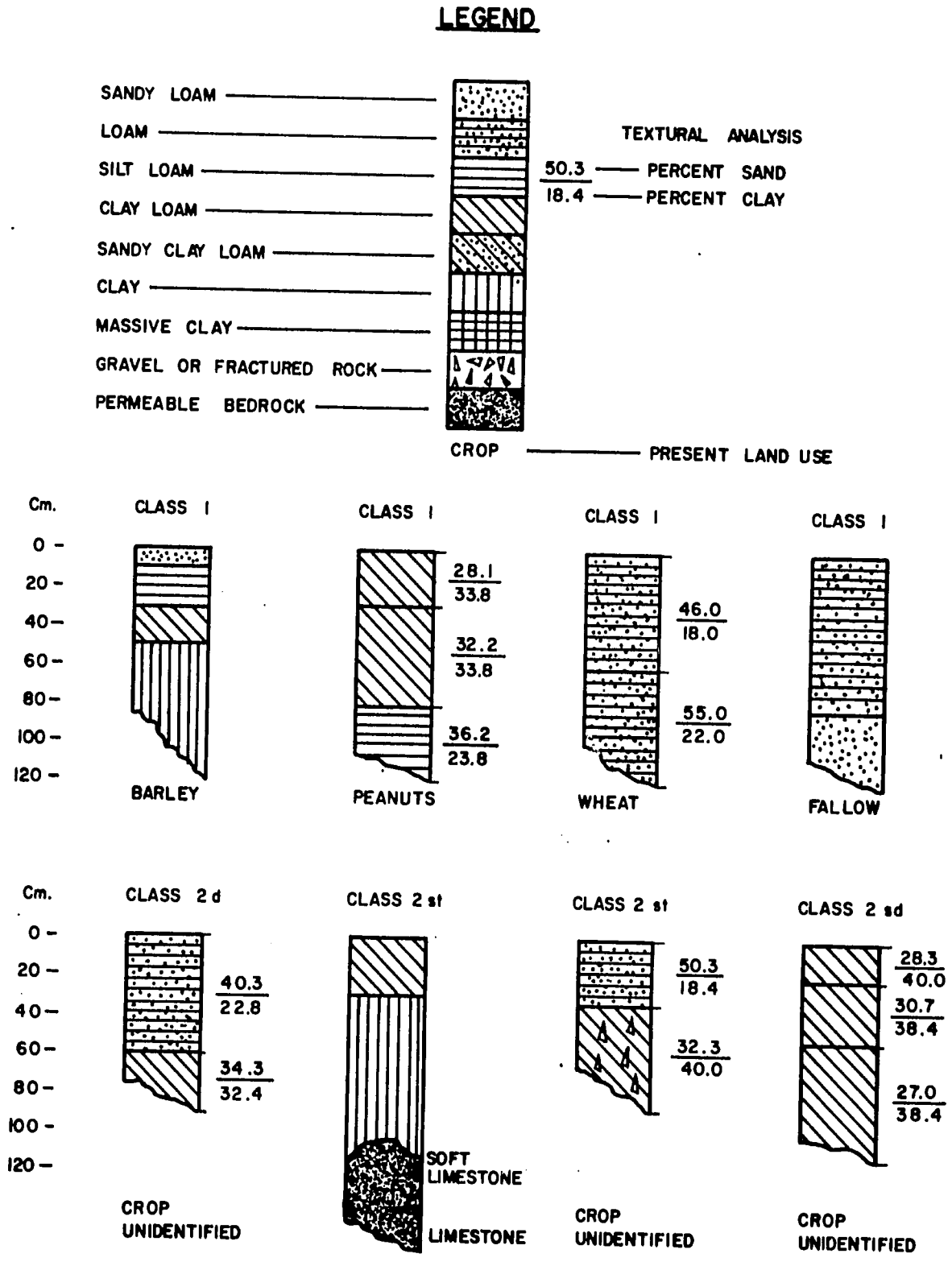


FIGURE AI-2 TYPICAL SOIL PROFILES

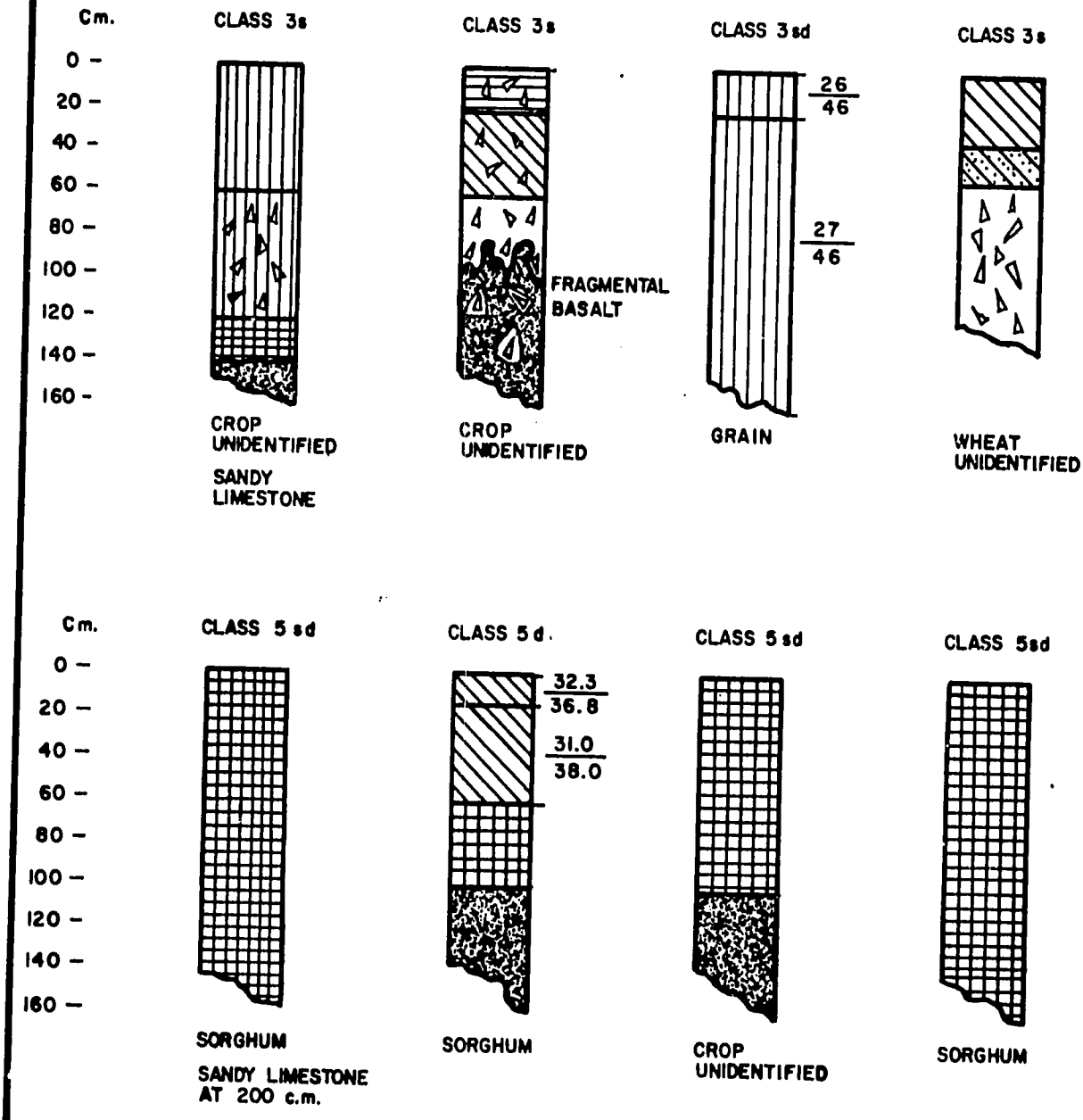


FIGURE AI-2 (CONTINUED)

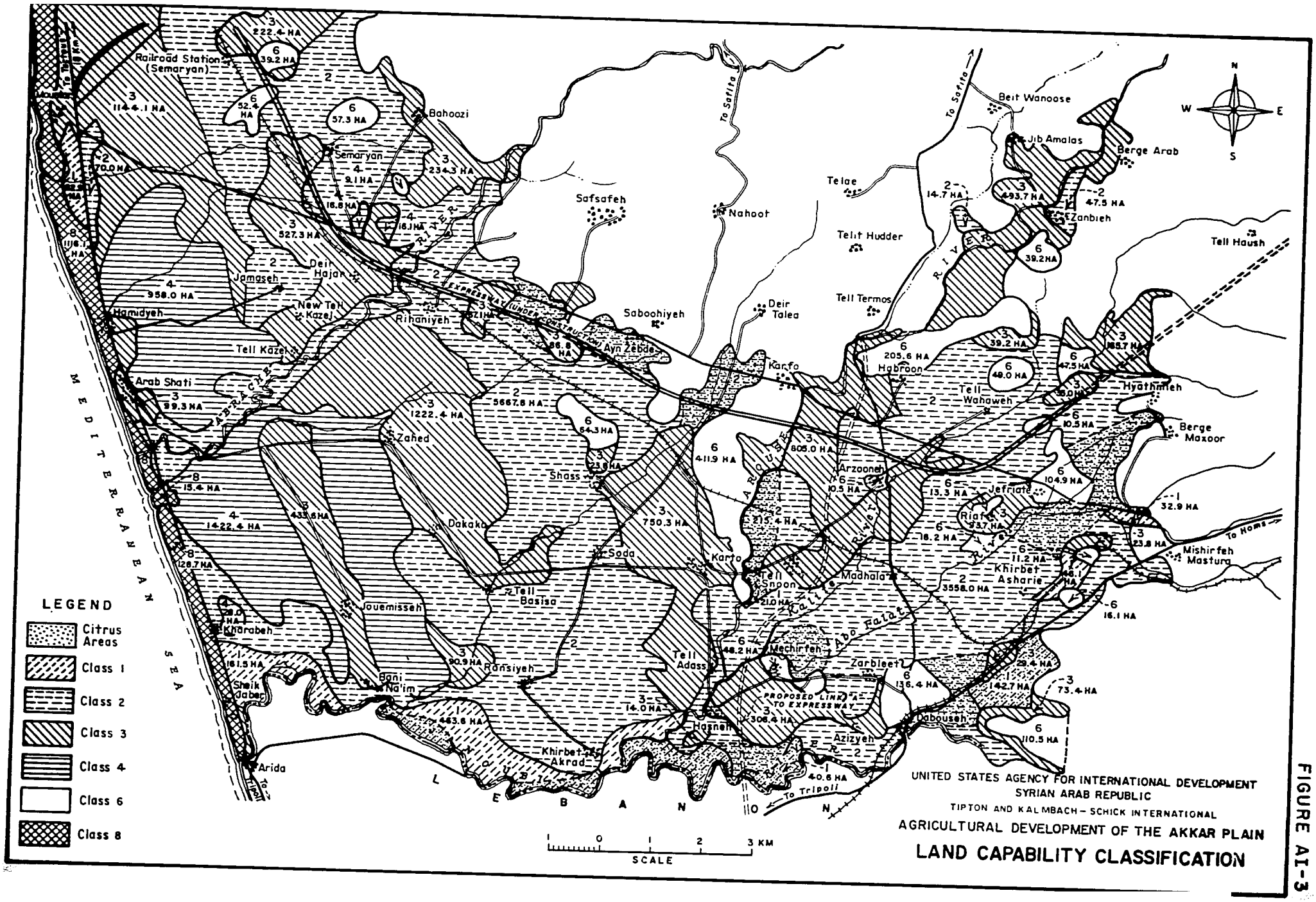
Figure AI-3. Land area in each category is summarized in Table AI-7. Forty-two percent of the Akkar Plain is in Capability Class II. Class III land is the next largest area with 31 percent of the total area. Class I has only 4 percent of the land.

Lands in Class I have few limitations that restrict their use. The soils are deep and well-drained, with high natural fertility or the soils respond well to fertilizers, and the topography is nearly level. The capacity to retain and yield available moisture for plant use is favorable, and the lands need only the usual cultural practices to maintain productivity.

Vegetable crops are presently grown over a wide range of soils with the availability of water being the main consideration. With development of the Akkar Plain, vegetables will continue to be dispersed over a wide range of soils, but the Class I soils will have the greatest advantage under full irrigation development. Improved drainage would allow the vegetables to be planted earlier, which would result in greater utilization of the spring and early summer rains. The principal benefit would come from greater yields with very little change in land area used for crops.

Class II lands have a wide choice of crops but are limited by one or more factors such as gentle slopes, a moderate erosion hazard, a few rocks in the plow zone, or inadequate soil depth with somewhat restricted drainage. Physical limitations in this capability class prevent the land from being as economically productive with the intensive vegetable crops suited to Class I lands.

Lands in Class III have severe limitations which reduce the choice of crops or require special cultural practices, or both. Limitations in use


LEGEND
Citrus Areas
Class 1
Class 2
Class 3
Class 4
Class 6
Class 8
MEDITERRANEAN SEA
LEBANON
SCALE
0 1 2 3 KM
N
S
E
W
Railroad Station (Semaryan)
Bahoozi
Semaryan
Deir Hajar
Jamaseh
New Teh Kazel
Hamidyeh
Tell Kazel
Arab Shati
Rihaniyeh
Ayn Zebde
Saboohiyeh
Safsafeh
Nahoot
Telae
Telit Hudder
Tell Termos
Deir Talea
Karfa
Habroon
Tell Wahaweh
Beit Wanoose
Jib Amalas
Berge Arab
Zanbieh
Tell Haush
Hyathmieh
Berge Maxoor
Mishirfeh Mastura
Khirbet Asharie
Jefriate
Riat
Madhala
Arzooneh
Zahed
Shass
Dakaka
Soda
Tell Basisa
Jouemisseh
Khirbet Akrad
Tell Adass
Mechirfeh
Zarbleet
Dabousieh
Azizyeh
Hasneh
Ransiyeh
Bani Na'im
Sheik Daber
Khirbet
Arida
To Tripoli
To Safita
To Homs
PROPOSED LINK TO EXPRESSWAY
EXPRESSWAY UNDER CONSTRUCTION
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
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AGRICULTURAL DEVELOPMENT OF THE AKKAR PLAIN
LAND CAPABILITY CLASSIFICATION

FIGURE AI-3

Table AI-7. Land Area by Capability Class

Capability Class	Land Area	Percent of Akkar Plain
	hectares	
I	971	4
II	9,574	42
III	6,981	31
IV	2,450	11
VI	1,447	6
VIII	1,260	6
TOTAL	22,683	100
Special Capability Class -		
Citrus (This area duplicates portions of Class I and II above).	1,400	13

result from such factors as moderately steep slopes, high erosion hazards, very slow permeability, shallow or restricted root depth, low water holding capacity, and low fertility.

Class IV lands can be used for cultivation but have a very severe drainage limitation and a poor physical soil structure. Very few crops are suitable to the severe constraints of these lands. Except for micro-areas, these soils are suited only for shallow rooted forage and cereal crops.

Classes V to VIII lands are generally not suited for cultivation. Class V was not used in the Akkar Plain classification. Class VI lands have severe limitations in soil depth, presence of rock outcrops, or steep slopes that restrict their use largely to pasture or olive trees. Class VIII are lands not capable of productive agricultural use and consist of the tidal flats, sandy beaches, and dunes along the coast.

Land Use by Capability Classes

In the land capability classification, lands are delineated as to suitability for irrigated crop production. Suggested crops and recommended land use practices are determined for each capability class. Figure AI-4 is an outline of suggested cropping patterns for the wet and dry season with future development of the surface irrigation system.

From the standpoint of land quality, Capability Class I lands are adapted to all the principal crops grown in the Akkar Plain. Citrus trees are suited to these soils where there is natural wind protection or where windbreaks can be provided. Drainage is adequate for citrus on these soils.

Suggested crops for the wet season in Class II lands include wheat, barley, vetch, beans, and cole crops. The growing season for grains

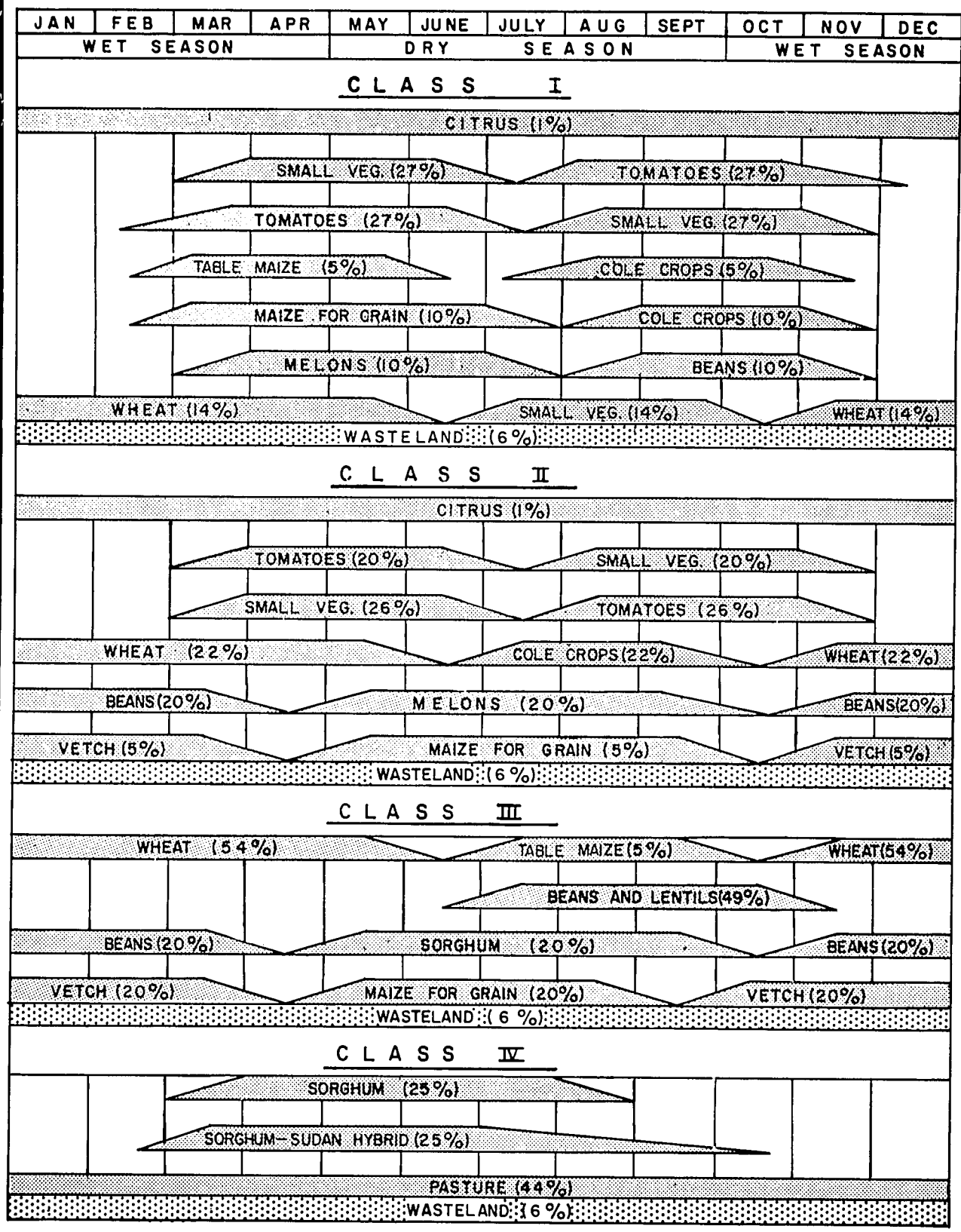

FIGURE AI-4 FUTURE CROPPING PATTERN AND LAND USE WITH IRRIGATION BY LAND CAPABILITY CLASS

and vetch carry over into the summer dry season. Principal crops suggested for dry season are tomatoes, eggplants, beans, lentils, melons, squash, and maize. Citrus is also adapted to Capability Class II lands where protection from heavy winds is present or can be provided and where surface drainage is not a constraint.

For sustained cropping, Capability Class II lands require special management practices. Land conditions common to Capability Class II are moderate topographic limitations of slope and relief, limited soil depth, and a higher percentage of clay than Class I. The topographic deficiency would curtail irrigation practices under gravity irrigation methods. The heavier soil restricts land tillage, water penetration, and adequate drainage through the soil profile. Under these restrictions, root development is inhibited and nutrients are less available to the plant.

Capability Class III lands have severe limitations that reduce the choice of crops because they are heavy, shallow, or low in fertility, drainage is impeded, or topographic conditions are not favorable for citrus crops. Likewise, the above limitations are not favorable for growing tubers, root vegetables, tomatoes, melons, squash, and cole crops. The slopes of Capability Class III lands require strict control of irrigation water to control erosion. Restricted surface drainage is more severe because of heavier soils and less favorable topography. Those crops requiring friable fertile soils and intensive tillage practices are not adapted to Class III lands. Shallow-rooted cereal and forage crops are best suited to utilize these lands.

Lands in Capability Class IV are subject to inadequate drainage that

limits their use to sorghum, forage, and pasture which receive water by capillary action from the high water table. Tillage is difficult on these soils of massive, heavy clays, except for a limited time when moisture conditions are precisely favorable. It is difficult to till and prepare seed beds in these soils because if the moisture content is not precisely right, a change in structure creates large blocks or clods. Due to the impermeable nature of the massive clay, the penetration of irrigation water is extremely restricted and root development is very poor. However, cultivated crops are successfully grown at the present time in mirco-areas where water is pumped from shallow wells for irrigation.

Irrigation was not recommended on Class IV land because of the restricted drainage in the massive surface clay soils. Irrigation on the entire area would increase the water regime in the upper one to two meters of the soil profile. It is also expected that any additional surface or subsurface water from irrigation of higher project lands will be intercepted by the drainage system planned for the project area. Therefore, no significant increase in drainage problems on low-lying lands is anticipated.

Capability Class VI lands have one or more severe limitations that make them unsuited for cultivation or irrigation. Land use is limited to pasture and olive groves utilizing natural precipitation. The land is generally rough, steep, and hilly with soils that are shallow, rocky, and usually excessively drained. Olives are suited to well-drained soils, and they tolerate shallow, rocky soils without severely limiting production. Vegetation used for pasture is limited by the availability of natural precipitation for which olives and forage plants compete.

Citrus production is very important, and SARG is interested in developing as many groves as possible on the Akkar Plain. Physical characteristics such as strong winds and shallow soils with restricted drainage make most of the Akkar Plain unsuitable as prime land for citrus groves. Several groves have already been planted on the Plain, and some of them are old enough to be in production. Windbreaks are planted on all sides of the citrus groves to protect them from the strong winds.

A special capability class was formed to facilitate locating the areas best suited for citrus production. Some areas, mostly in Class II lands, have natural windbreaks provided by hills or sharp drops in topography. Where the natural windbreak areas also have reasonably well-drained soils, it is conceivable that citrus could be produced with less land wasted for windbreaks and with less chance of fruit damage; these lands were put in the citrus capability class. Some Capability Class I soils were included in this subclass because of its soil characteristic advantages; it was assumed that windbreak would have to be grown to protect the groves. Availability of irrigation water was not included as a criterion for the citrus subclass. Approximately 1,400 hectares are reasonably well-suited for citrus production, assuming water is available for irrigation.

Nematodes are present in all classes of soil. Yields are expected to be reduced by at least 5 percent due to the damage to the roots even with the application of insecticides. This problem could be more acute if adequate treatment is not applied prior to planting.

AKKAR PLAIN AGRICULTURAL DEVELOPMENT PROJECT

APPENDIX AII

DRAINAGE AND FLOOD CONTROL

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APPENDIX AII

LAND DRAINAGE AND FLOOD CONTROL

INTRODUCTION

Inadequate surface drainage is a major problem on most of the Akkar Plain. Heavy precipitation occurring throughout the winter season coupled with inadequate surface drainage is the cause of the problem. The greatest intensity of waterlogged conditions is found on the low flat lands located on the west side of the Plain. Above normal precipitation occurring in 1977 and 1978, while field investigations were conducted, provided specialists with a good visual study of the existing drainage problems and possible corrective measures.

In addition to the Janoubi and Abrache River there are eight major and minor drainages which currently channel the floodwaters from the Akkar Plain to the Mediterranean Sea. During heavy storm runoff each of these channels overflows its banks and creates considerable flood damage on the adjacent farmlands. The degree of flooding is dependent upon the severity of the storm. The maximum accumulated flow from the eight drainages, during the above normal precipitation in the winter of 1977-78, was estimated to be approximately 31 m^3/s. The largest of these is the Ramit Laha drain which flows approximately 16 m^3/s. When the Janoubi River was also flooding the Ramit Laha drain increased in flow to about 68 m^3/s.

Because of inadequate drainage, the lands are subject to various degrees of temporary inundation. As a result, the soil remains saturated for an extended period of time which limits root development of winter crops and

delays planting of spring crops.

DRAINAGE INVESTIGATIONS

General Statement

The drainage field work conducted on the Akkar Plain covered the period November 10, 1977 to February 2, 1978. Because of the occurrence of heavy storms of approximately 70% above normal, this period of field investigations proved to be an excellent time for a visual study of the surface drainage problems and proposed corrective measures.

The drainage fieldwork consisted of (1) water table investigations; (2) subsurface explorations; (3) permeability tests; (4) surface drainage problem reviews; and (5) existing surface drainage system review. The details for each phase of the investigations follow:

Water Table Investigations

The water table investigations consisted of monitoring the depth to the water table on 52 dug wells scattered throughout the low lying areas. The depth to groundwater was also monitored in 56 drilled wells throughout the project area concentrating more on higher lands. All of these observations were made during the latter part of November and the early part of December, 1977, before the winter storms begin. A concentrated effort was also made in obtaining depth to water table readings, on a monthly basis, on 9 dug wells and 6 drilled wells located on three model farm areas selected for concentrated study. It is recognized that the water level in the drilled wells does not represent the true water table conditions, but information obtained was helpful in evaluating general water conditions.

Subsurface Investigations

Subsurface investigations are an important part of any drainage study. On the Akkar Plain it was possible to observe the depth to soft bedrock materials in 56 dug wells, numerous railroad and road cuts, and many deep vertical banks of rivers and streams. To supplement this information deep hand auger holes were drilled as deep as possible to soft bedrock, fractured rock, or gravelly materials. The lack of proper vehicles, equipment, and bad weather conditions limited the amount of augering in representative locations. However, enough subsurface information was obtained to make a fair appraisal of the subsurface drainage conditions and requirements.

Permeability Tests

The unavailability of a backhoe to dig test pits coupled with bad weather conditions limited the number of test pits that could be dug for testing the permeability of the subsurface materials. In general, the water tables were not high enough to attempt to conduct standard auger hole bailout permeability tests. As a result, the open-type pit test was selected as the most applicable and practical type permeability test for the area. These tests were limited to one test pit each for the three model farm areas. A total of 4 permeability tests were conducted. The pits were dug to a depth of one meter by the local villagers on a negotiated basis. The different type materials encountered were then tested in accordance with standard U.S. Bureau of Reclamation procedures for pit-type permeability determination of subsurface materials above a water table. These tests were successful and are evaluated in the drainage characteristics section of this appendix.

In addition to the pit-type tests, three conventional bailout

permeability tests were attempted in selected areas of high water table following heavy storms. These tests were conducted in semi-confining materials and the results are questionable but the total information obtained was helpful in gaining an understanding of the drainage conditions. The details are explained later under drainage characteristics.

The recharge rate of the dug wells, as obtained from a few farmers, was also very informative in determining the approximate permeability of the soft sandy limestone subsurface materials.

Surface Drainage Problems

Surface drainage is a major problem on the Akkar Plain and, as previously indicated, is a result of heavy storms occurring during the winter season. As most of the field investigations were conducted during the stormy season, a good visual study was possible to evaluate the impact of large amounts of surface flow and possible corrective measures.

From Local Precipitation:

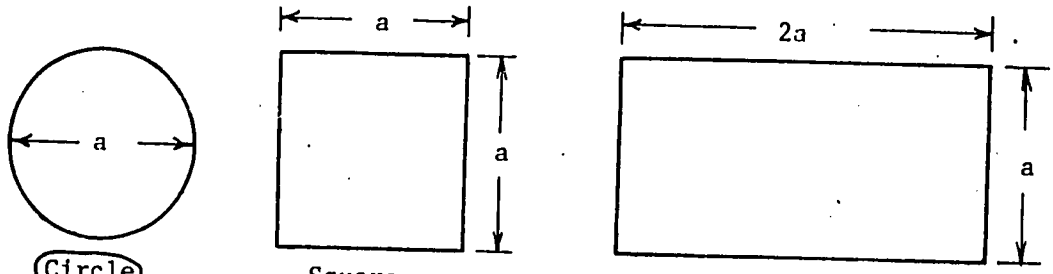
Investigations of surface drainage problems occurring as direct project area runoff from precipitation included 2 months of observations from December 1977 thru January 1978. During this period there were eight separate storms of varying intensity lasting from 2 to 8 days. The higher intensity storms were of shorter duration lasting only 2 to 3 days. During these storms daily observations were made on a portion of the project area of ponding conditions and the magnitude of flow in drainage channels, streams, borrow pits and road culverts. These observations were used as a basis for estimating the additional surface drainage requirements of the area. Manning's formula for determining flow of water in open channels was applied

HYDRAULIC CONDUCTIVITY DETERMINED BY
TEST PIT METHOD

Test Pit No. (I-II) #1
TPP No. 2
Crew CHRISTENSEN
KHALED

Project AKKAR PLAIN
Area DAKAKA – MODEL FARM
Location (I-II)

Date 12/27/77



Circle Square Rectangle

Depth of water in test pit. D = 0.23 m.

Dia. of circular pit or site a = 0.33 m.

$\frac{D}{a} = \frac{0.23}{0.33} = 0.69$

Dimensions of square pit

Conductivity Coefficient "C"

$\frac{D}{a}$	Circular test pit of Diameter a	Square test pit of dimensions a x a	Rectangular test pit of dimensions a x 2a
0.69	4.20 (extrapolated)		
1	4.92	5.49	7.35
2	6.92	7.68	9.89
3	8.78	9.70	12.18
4	10.65	11.63	14.44
5	12.39	13.54	16.59
6	14.09	15.33	18.62
7	15.87	17.15	20.68
8	17.52	18.95	22.81
9	19.22	20.74	24.82
10	20.72	22.51	26.87

$$K = \frac{1440\ Q}{C\ a\ D} = \frac{1440 \times .00132}{4.2 \times 0.33 \times 0.23} = 6.0 \text{ M./Day}$$

Conductivity Coefficient C = 0.69 EXTRAPOLATED

Quantity of flow per unit of time Q = .00132 m^3/min

K = Permeability m. per day
C = From above table
a = Explained above
D = Explained above
Q = Computed from accumulated volume curve

Test Depth From 60 to 83 cms. K = 6.0 m/day

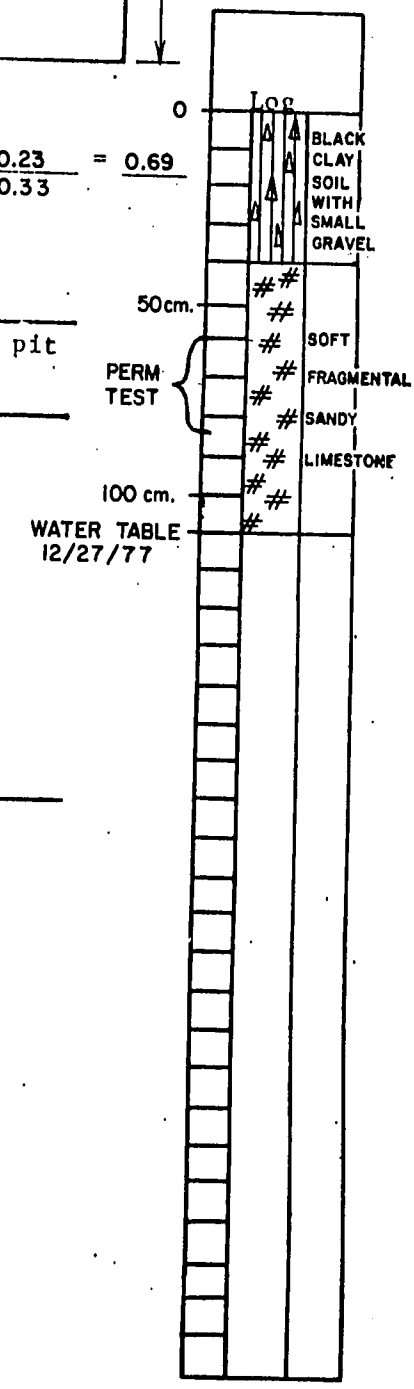


FIGURE AII-4

in estimating the tentative drainage channel design and cost estimates.

From Janoubi River Flooding:

Investigations of the Janoubi River flooding problems were conducted on a continuing basis during the stormy season. Most of the storms did not create a flooding problem from the Janoubi River but there were three major storms of high intensity and extended duration which caused the Janoubi River to overflow its banks. During the periods of flooding it was impossible to actually inspect the overflow along the river banks, but the evidence of such overflow was observed in the form of a much greater flow of water thru Ramit Laha and under the two Coast Road Bridges during the three referenced storms. Flooding was also observed in the form of driftwood occurrence in many places along the Janoubi River. Also, several landowners along the river were interviewed to determine the extent of flooding. In the absence of engineering surveys, information gained from the landowners was of extreme importance in analyzing the degree and lateral extent of the bank flooding problem.

During June 1978 additional flood investigations were conducted on the Janoubi River and Ramit Laha with respect to the required feasibility flood control designs. Brief preliminary surveys were conducted. Seven cross sections were taken of the lower 700 meters of the Ramit Laha channel; also, an observation was made of the outlet problems to the sea as well as a preliminary determinaton of the existing gradients. Some 29 cross sections of the Janoubi River were made to determine the existing channel capacity and increased capacity required to contain the flood flows of the river. This survey was conducted by SARG surveyors. However, only a portion of the data was made available by November 1978. Due to the delay in the receipt of the survey data, it could not be utilized in the preparation of feasibility designs. Rather, a more preliminary design and cost estimate was made

from limited data obtained earlier.

Existing Surface Drainage System

During the wet season (December-January), the existing drainage system was inventoried and categorized as to the following drain types:

a. Natural surface drain (continuous flow)

b. Natural surface drain (intermittent flow)

c. Constructed surface drains

d. Roadside borrow pits - utilized as drain

In order to obtain the required capacity of individual existing drains, the magnitude of flow was observed during periods of heavy storm runoff. An empirical determination of the magnitude of storm runoff was made for one of the large continuous flow surface drains on a sample basis only. This checked very favorably with the estimated flow observed in the field. The calculations are shown, subsequently, on the surface drainage requirement section of this appendix. Existing drains which were smaller than the required capacity were noted and recommended for improvement. During the field process of reviewing the status of the existing drainage system, appraisals were made for additional drains needed to control the design storm runoff.

DRAINAGE CHARACTERISTICS

Topography

The Akkar Plain Irrigation Project occupies an area of approximately 23,000 hectares which is bounded by the Mediterranean Sea on the west, the Janoubi River on the south, and mountainous areas on the east and northeast, Figure AII-1. The Plain occupies land that is traversed by two rivers, the Abrache and Arouse, and two smaller streams, the Kalife and Abo Falat, which are tributaries to the Arouse River. The Plain has a very irregular shape with an average width of approximately 12 km in a north-south direction

Railroad Station (Semaryan)
Mountar
Bahoozi
Semaryan
Safsafeh
Jamasah
Deir Hajar
New Tell Kazel
Gaging Station
Rihaniyah
Hamidyah
Tell Kazel
ABRACHE
RIVER
EXPRESSWAY (UNDER CONSTRUCTION)
Ayn Zebda
Arab Shati
MEDITERRANEAN SEA
Zakad
Shass
Dakaka
Soda
Tell Basisa
Basisat
Kharabah
Touehrisseh
Rantiyah
Sheik Jaber
Beni Na'im
Kharbet Akrad
Arida
20 KVA
10 KVA
N
S
E
W

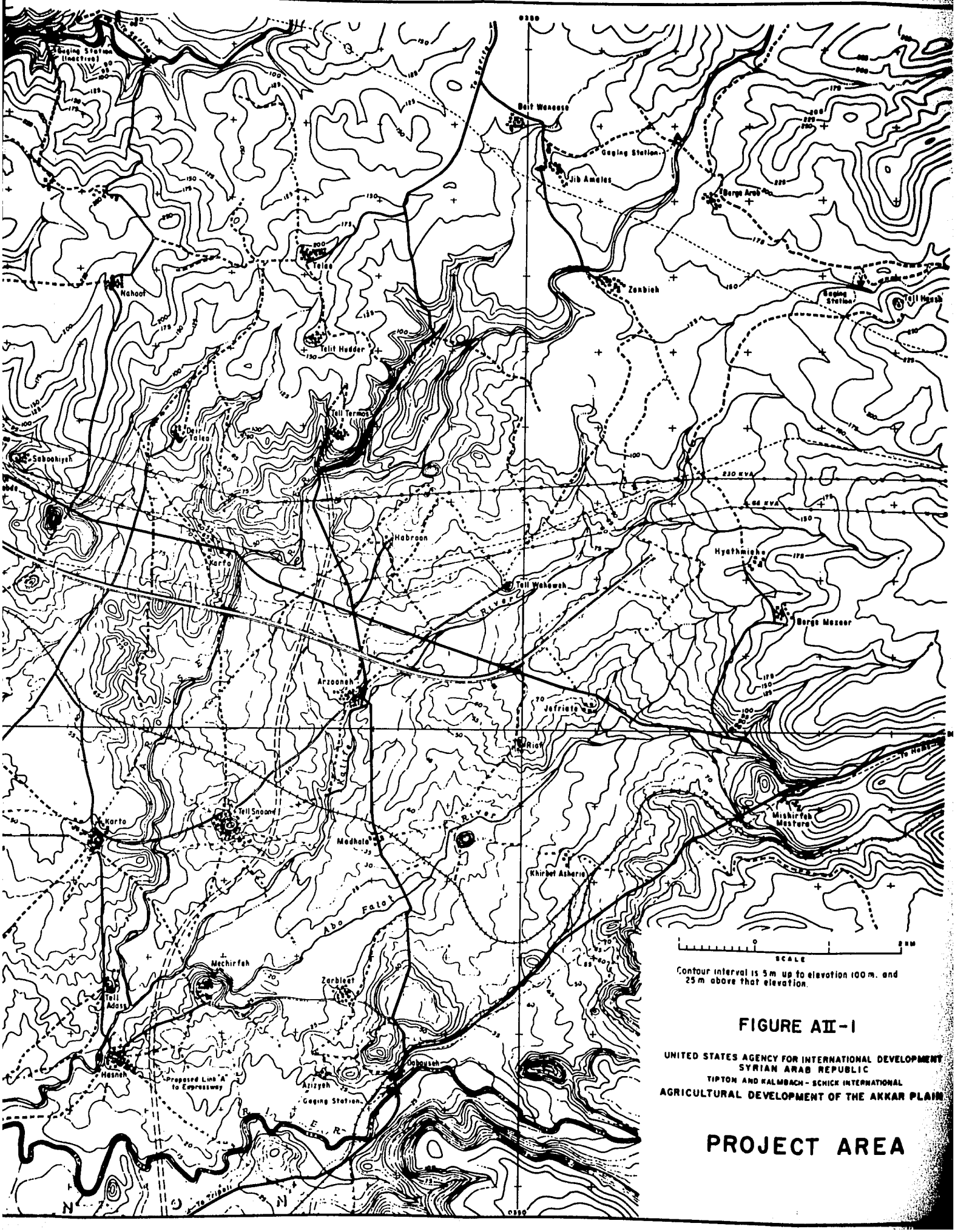


FIGURE AII-1

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
SYRIAN ARAB REPUBLIC
TIPTON AND KALMBACH - SCHICK INTERNATIONAL
AGRICULTURAL DEVELOPMENT OF THE AKKAR PLAIN

PROJECT AREA

and an average length of 20 km in an east-west direction.

The project lands can best be separated into three drainage areas for describing the topography and general configuration as follows: (1) low-lying lands, located on the western portion of the project, with drainage generally outleting directly to the Mediterranean Sea; (2) the Abrache River drainage occupying the central portion of the Plain; and (3) the Arouse River drainage, with tributaries, occupying the eastern portion of the Plain.

The general slope of the lower-lying lands located west and north of the Abrache River is in a west and southwesterly direction. The northern portion of these lands generally drains in a westerly direction to the Mediterranean Sea through independent drainage channels with an average ground surface gradient of approximately 4 meters per km. In the southern portion of this area, south of the latitude of Hamidyeh, the general slope of the land is to the southwest at an average gradient of approximately 3 meters per km. Due to a topographic rise along the sea coast this portion of the area slopes towards the Abrache River with the major drainage channel outleting approximately 1 km above its mouth. This low-lying area is occupied by one major depression and at least 4 minor depressions which presently drain out very slowly, by gravity, through small man-made channels. Because of the flatness of the land, coupled with erosion resistant soil and subsoils, there have been no deep channels formed on the lower lands.

There are two significant landforms with peculiar topographic features which influence the drainage status of the lower-lying lands. The first feature is a rather long and narrow topographic break about 8 km long by 1 km

wide, located approximately 3-1/2 km inland from, and parallel to, the Mediterranean Seacoast. Here the general transverse gradient of the ground surface is approximately 20 meters per km and flattens to approximately 4 meters per km at the base of the slope. The second landform is a narrow topographic rise bordering the seashore which is about 400 meters wide and rises approximately 3 meters higher than adjacent lands of the Plain.

The low-lying lands south of the Abrache River, in the general area of Ramit Laha, are the flattest lands in the project area. Here the Ramit Laha outlet gradient is in a north-westerly direction at about 1/2 meter per km while the gradient of the adjacent surrounding lands slopes toward Ramit Laha at approximately 1 meter per km. The drainage area contributing to Ramit Laha extends to the northeast into higher lands between the Abrache River and Arouse River drainages. These lands have some irregular topography with an average gradient of approximately 8 meters/km in the general direction of Ramit Laha. Ramit Laha is ponded during heavy storm runoff but drains off slowly by gravity. It remains marshy until the area dries out after the stormy season. The main channel, however, remains wet most of the year as a result of sea water encroachment caused by strong westerly winds.

There is a small basin located immediately east and adjacent to the village of Kharabeh which is approximately 1 meter below sea level. This area dries out late in the spring by evaporation. At present very little successful cropping is possible in this area.

The general topography of the Abrache River drainage area varies from rather smooth slopes in the lower portion to a characteristically ridgy topography in the central and upper portions. Several tells in this drainage

area are also prominent characteristics of the topography. The general gradient of these lands vary from approximately 6 meters per km on the lower slopes to about 15 meters per km on the higher area. The higher lands also have many rather steep transverse gradients into adjacent drainage channels. It was observed that most of the lower project lands in this drainage area were subject to varying degrees of surface drainage problems while on the higher lands with steep and ridgy topography there were very few of such problems.

Another very significant topographic feature creating surface drainage problems are three small, ponded, marshy areas situated immediately above the Homs Highway and west of the Abrache River. Under existing conditions only a portion of the water in these small basins drains out by gravity. In addition to the prevention of crop production, this condition creates adverse mosquito breeding habitat. These swamp areas are located within the basin being considered, as an alternative, for dam and reservoir development.

The Arouse River drainage area, in general, has topographic characteristics quite similar to those of the Abrache River except there are more tells with steeper topography adjacent to the Arouse River. The land surfaces in both areas are generally quite irregular. This is principally due to the variation and irregularities in geologic formations, and subsequent deposition. Within the general boundaries of the project area the Arouse River drainage with its tributaries covers much more area than the Abrache River drainage. The upper lands, however, are not quite as hilly but there are many tells scattered throughout the area. There are also more drainage channels dissecting these lands. The lower-lying land includes several areas

adjacent to major streams with restricted surface drainage resulting in varying degrees of surface drainage problems. The gradient of these lands varies from about 3 meters to 8 meters per km while gradients on upper-lands vary from 8 meters to about 20 meters per km.

Beginning approximately 1 km below the mouth of the Arouse River and extending westward for nearly 10 kms, there is a slight gradient away from the Janoubi River in a northwesterly direction extending through the Ramit Laha area to the Mediterranean Sea which is the path of the presently uncontrolled Janoubi River floodwaters.

It is of interest to note the different land classes throughout the project area as they relate to the variation in topography. A summary of the average slope for each of the subclasses follow:

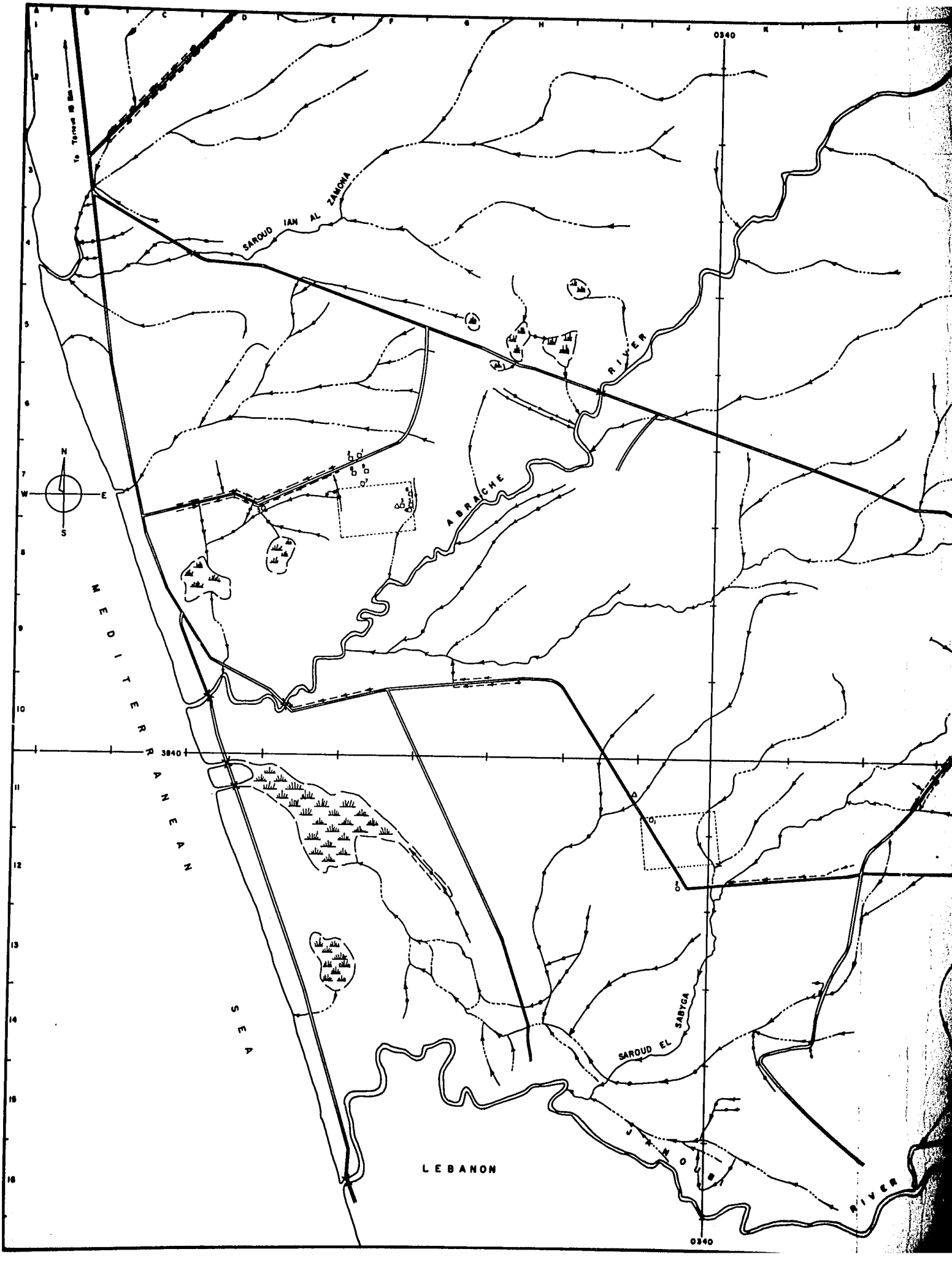
LAND CLASS	AVERAGE SLOPE (Meters/km)
1	1
2s	15
2st	20
2sd	7
3st	20
3sd	6
5sd (near Hamidyeh)	5
5sd (Ramit Laha)	0.5

The range in slope on the different subclasses is from about 1/2 to approximately 2 times the average slope.

Water Table Characteristics

The water table within the lower-lying lands of the project is represented by 52 dug wells scattered throughout that portion of the Plain. The lowest water table on these lands during the year is probably represented by the concentrated observations made just prior to the winter storm which began December 3, 1977. The average depth to the water table prior to the storms was 2.8 meters and varied from 1.2 meters along the base of a major slope paralleling the Mediterranean Sea, situated approximately 3 1/2 kms inland, to approximately 5.4 meters along the topographic rise adjacent to the Mediterranean Sea-front. The water table depths indicated that there is a general water table gradient towards the Sea on the lower lands ranging from 2 meters to 4 meters per km.

There is a pronounced seasonal fluctuation of the water tables as determined from dug wells selected for monitoring on a monthly basis, Figure AII-2. These wells were selected for concentrated study and are principally located on model farms. The depth to water table for each of these wells is presented in Table AII-1. A typical well hydrograph, on the (5d) lower lands, Figure AII-3, (well number 5, location D-7), shows that the water table raises from a low level of 1.8 meters below ground surface in early December to a high level of 0.3 meters during the latter part of the wet season in February and early March. Beginning about the middle of March, the water table recedes on a very steady downward trend to 1.7 meters below ground surface by July 10,1978. (This water table drawdown is due primarily to the pumping of dug wells in the area and secondarily from groundwater movement to the sea). Where these high water tables occur through the wet period, no winter season crops can


SAROUD IAN AL ZAMONA
RIVER
ABRACHE
MEDITERRANEAN
SEA
SAROUD EL SABYGA
LEBANON
RIVER
0340
3840
N
S
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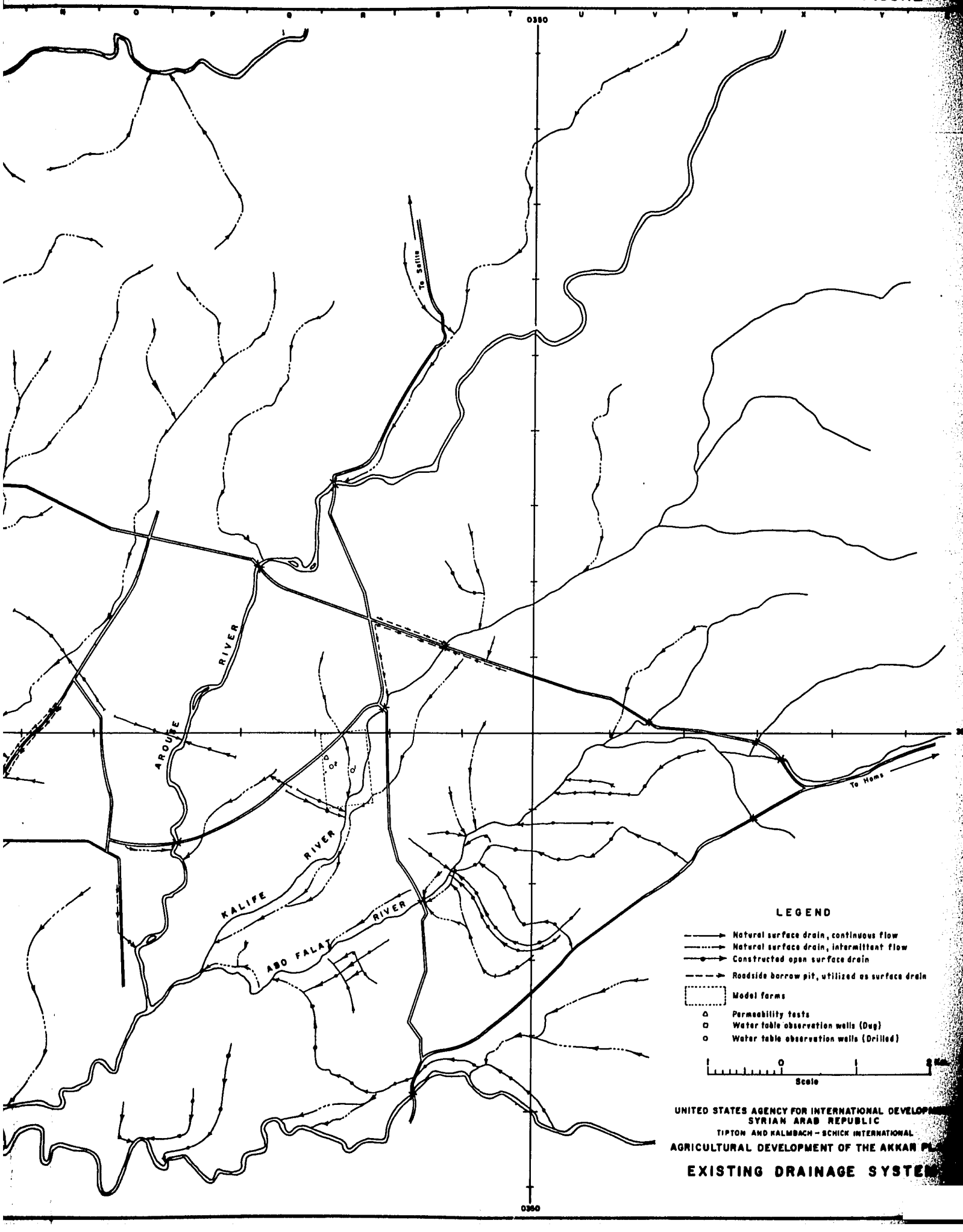
E

FIGURE


R O P Q R S T U V W X Y
0350
To Sellia
AROUBE RIVER
KALIFE RIVER
ABO FALAT RIVER
To Homs
LEGEND
Natural surface drain, continuous flow
Natural surface drain, intermittent flow
Constructed open surface drain
Roadside borrow pit, utilized as surface drain
Model farms
Permeability tests
Water table observation wells (Dug)
Water table observation wells (Drilled)
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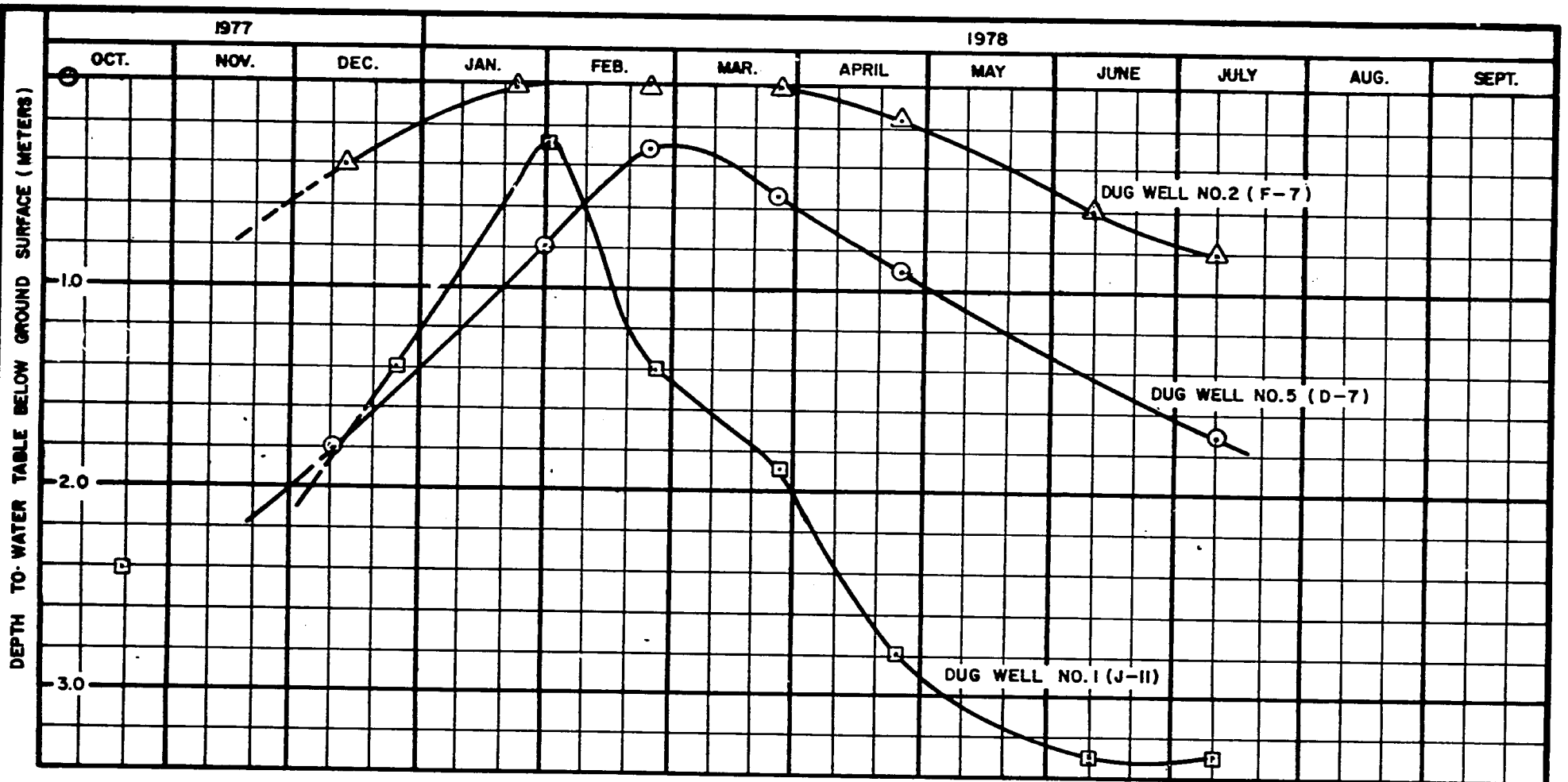
AGRICULTURAL DEVELOPMENT OF THE AKKAR PL
EXISTING DRAINAGE SYSTE

Table AII-1. Depth to Ground Water Observations - Akkar Plain - Model Farm Areas (Unit - Meters below Referenced Point) 1/

MODEL FARM	WELL NO.	1977 26 NOV	1977 19 DEC	1978 24 JAN	1978 25 FEB	1978 26 MAR	1978 25 APR	1978 MAY	1978 10 JUNE	1978 10 JULY	1978 AUG
DUG WELLS JAMASEH (F-7)	1		2.5	0.6	0.2	0.2	0.7		1.8	1.7	
	2		(Dec. 13) 0.4	0 2/	0 2/	0 2/	0.1		0.5	0.8	
	3		3.0	2.2	2.1	2.3	2.8		4.0	3.7	
	4		1.0	1.2	1.2	1.5	2.6		4.2	4.0	
	5		0.5	0.7	0.8	1.3	2.2		2.2	2.7	
	6		1.8	0.6	0	0.4	2.0		2.3	2.5	
	7		3.5	2.1	1.4	1.2	1.8		2.6	3.9	
	8		5.0	3.3	2.6	2.3	2.9		4.7	4.7	
	9		0.6	0.2	0	0.2	0.6		1.7	2.3	
Near Hamideh (D-7)	Dug Well 5		(Dec. 13) 1.8	(Jan. 31) 0.8	0.3	0.5	0.9		1.4	1.7	
LAKAKA	Dug Well 1 (J-11)		1.4	0.3	1.4	1.9	2.8		3.3	3.3	
	Tube Well 2 (J-12)	6.0		7.0	6.0	2.5	Pumping 10.5			8.0	
ARZOONEH	Tube Well 1 (R-11)	5.0		3.1	3.5	3.7	4.5		6.5	6.7	
	Tube Well 2 (R-11)	8.0		4.6	3.7	4.0	5.2			7.3	

1/ Referenced Point is approximately 0.1 above ground surface.
2/ Small artesian flow.



NOTES:

- DUG WELL NO.2 (F-7) HYDROGRAPH REPRESENTS WATER TABLE FLUCTUATION AT BASE OF MAJOR TOPOGRAPHIC BREAK.
- DUG WELL NO.5 (D-7) HYDROGRAPH REPRESENTS GENERAL WATER TABLE FLUCTUATION ON LOWER LYING LAND.
- DUG WELL NO.1 (J-11) HYDROGRAPH REPRESENTS THE WATER TABLE FLUCTUATION ON IRRIGABLE (CLASS 3) LAND NEAR CENTER OF PROJECT AT DAKAKA.

FIGURE AII-3

AKKAR PLAIN PROJECT

TYPICAL
WATER TABLE HYDROGRAPHS

develop satisfactorily and planting of spring crops is delayed until approximately the middle of April when planting conditions are favorable.

A smaller but very significant area troubled with a high water table is located along the base of a topographic break approximately 8 kms in length located 3-1/2 kms inland from and paralleling the Mediterranean Seacoast. The water table fluctuation here is represented by the groundwater hydrograph of dug well number 2 (F-7), Figure AII-3. As shown in the figure, the water table remains about 1.0 meter depth, below ground surface, through most of the year. In early December the water table was only 0.4 meters below ground surface. By the latter part of January the water level had raised to slightly above the ground surface level with a resulting small artesian flow from the well. This condition continued until after the heavy storms in March. Following these storms the water table then declined on a gradual basis to 0.8 meters below ground surface by mid-July. Because of the extremely high water table condition along this topographic break, the planting of crops is delayed until approximately the middle of May and the resulting yields are greatly reduced.

Water table conditions near the central part of the irrigable area (class 3 land) is represented by the water table hydrograph of dug well number 1 (J-11), Figure AII-3. This well is located on irrigated lands at the east side of the village of Dakaka. The first observation made on December 20, 1977, showed a depth to water table of 1.4 m below ground surface. Since this observation was made after the winter storms began, the water table was on the incline and by the last of January the water table peaked at 0.3 meters below ground surface. The water table then declined quite rapidly to 3.3 m below ground surface by the tenth of June at which time it levelled off. As

represented by this well, the water table in this general location is very peaky with a high water table above 1.0 m lasting only about one month. This indicates a good natural subsurface drainage capacity and therefore the water table experienced will not deter the growth of winter or summer crops.

The depth to water table on higher lands located in both the Abrache River and Arouse River drainages, is much less clearly defined than has been discussed for lower lands. This is because practically all of the wells located on higher lands are drilled wells rather than open dug wells. The water level in some drilled wells has been monitored on a monthly basis, but the static water level observed does not necessarily represent a non-confining water level. Therefore, a broad general estimate of the water table situation was made on the basis of a very few wells with supplemental information from deep cuts formed by road and railroad construction. The depth to water table below ground surface thus observed was generally greater than 1.0 meter even during the stormy season and does not pose any threat to good agricultural production for either wet season or dry season crops.

Subsurface Characteristics

Subsurface Materials, Structure, and Depth to Barrier:

The subsurface materials underlying the soils of the Akkar Plain are extremely permeable by comparison to the overlying soils and subsoils. The characteristics of soils, as previously discussed, is predominantly very fine-textured, ranging from a silty clay loam to an impermeable black massive clay, while the subsurface materials are entirely opposite in texture and structure. The subsurface materials consist of permeable formations of weathered sandy limestone or decomposed basaltic materials depending on the location. Generally

the sandy limestone materials are found in the western part of the project while the basalt material is located on the eastern side. Within the central portion of the project area both types of materials are encountered as a result of faults and other special geologic phenomena.

The limestone materials are soft, weathered and highly fractured. In the lower areas these materials are rather continuous to known depths of 8 m below ground surface as evidenced by dug wells in the area. The upper level of the limestone formation ranges from about 1 to 2 meters below the ground surface. Evidence of the depth to the limestone materials is shown on the deep auger hole logs presented in the Soils and Land Capability Classification Appendix A I. In some of the intermediate areas the sandy limestone appears in the form of laminations with rather irregular layers of sandy clays and sandy clay loams intermixed.

The basaltic materials encountered generally occur at quite shallow depths ranging from only 30 cm to about 80 cm below ground surface. These materials are highly weathered, decomposed and break into peds very readily thus accounting for their favorable permeability as subsequently explained under that topic. These materials appeared to have depths greater than 8 meters as evidenced along the deep railroad cuts in the area north of the village of Karto. The estimated greater depth of this material is also evidenced by the favorable subsurface drainage capacity of these materials.

It is significant to note that the alluvial fine-textured materials (class 1 land) bordering the Janoubi River is much deeper than the fine-textured materials for other land classes. Here the depth of these materials range from about 1.5 meters along the upper or northern edge of class 1 land

to approximately 7 meters along the Janoubi River border. These materials are principally underlain with sandy limestone.

With reference to subsurface drainage, "barrier materials" is a stratum or layer that restricts the movement of water. The depth to barrier materials is generally unknown on the Akkar Plain except in the lower lying areas where many wells have been dug through the sandy limestone materials and terminate on the barrier stratum. Through interviews with farmers and many well depth measurements, it has been determined that the depth-to-barrier on these lower lying lands average about 7 m and varies from about 5 m to 9 m below ground-surface. In the upper areas the depth-to-barrier materials are deeper as evidenced by the deep railroad cuts previously mentioned.

Permeability:

The permeability of the subsurface materials is an important parameter in determining the adequacy of subsurface drainage. It has little bearing, however, on the evaluation of surface drainage.

In general, the permeability of the coarse subsurface sandy limestone and decomposed basalt materials of the Akkar Plain is thirty-seven times greater than the permeability of the upper subsoils. This is a very favorable condition which promotes good natural subsurface drainage when other drainage parameters, such as gradients and depth to barrier materials, are adequate. If any parameter is inadequate a subsurface drainage deficiency exists. On this basis there is no subsurface drainage deficiency on higher lands where favorable topography exists. On the low-lying lands, however, there is a gradient limitation which is created by the elevation of the Mediterranean Sea and insufficient depth to the barrier materials. Thus a subsurface drainage

deficiency exists on these lands.

Because of the presence of many rocks in the soil and subsurface profile the type of permeability test conducted was generally limited to the "Test Pit Method". A typical test sheet with actual test data and permeability calculation is shown, Figure AII-4. An actual field data sheet (not shown) was utilized in obtaining the basic quantity of flow per unit of time which was required in making the permeability calculation. As previously indicated there was a total of four of these permeability tests conducted on three model farms. The results of these tests are summarized in Table AII-2. It is noteworthy that the calculated permeability for the coarser subsurface materials varies from 2.9 to 6.4 meters per day while the permeability of the finer-textured subsoils range from only 0.07 to 0.18 meters per day. Thus, the average permeability of the coarse subsurface materials is thirty-seven times more permeable than that of the fine-textured subsoils above. The upper subsoils therefore represent a semi-confining layer and this is a major reason that some small artesian flow is occurring from dug wells at the base of the major topographic break located about 3-1/3 kms east of the Mediterranean Seacoast.

As indicated under drainage investigations, there were also three conventional bail-out permeability tests conducted in areas of high water table. The results of these tests were not reliable because of the artesian effect recognized as the auger hole was drilled. In two of the auger holes, sandy limestone rock was encountered at depths of 1.0 meters and 1.5 meters, respectively. As the holes were being drilled no free water was observed, but as soon as the sandy limestone materials were encountered, water raised in the hole immediately to nearly the top of the hole or the true water table level.

Table AII-2. Results of Permeability Tests on Model Farms

Model Farm	Materials Tested: Subsoil	Materials Tested: Coarse Subsurface Material1/	Depth of Test	Permeability "K"
Jamaseh	Clay loam (some lime nodules)		70-100 cm	0.18 m/day
Arzooneh	Clay (with heavily weathered basalt rock)		20-50 cm	0.07 m/day
Arzooneh		Decomposed basalt rock (breaks into peds readily)	75-90 cm	2.9 m/day
Dakaka		Sandy limestone (soft-fragmented)	83 cm	6.0 m/day

1/ Subsurface materials, as represented, has a very coarse texture and underlies subsoils of a much finer texture.

These tests did, however, confirm the previously assumed artesian conditions.

Data received from farmers concerning the water recovery rate in their dug wells were also very informative in understanding the permeable nature of the sandy limestone materials. The following data are typical of the information received from the individual well owners.

Dug well #1 (C-7)

1- Dug well diameter = 3.5 m

2- Water table = 2.9 m (11/16/77)

3- Well depth = 8.0 m

4- Sandy limestone layer between 4 m and 8 m

5- Well is pumped dry in 1 hour

6- Water level in well recovers in 24 hours and is pumped dry each day

Figure AII-5 shows the method applied and the calculated permeability of the sandy limestone subsurface materials. The calculated permeability of the subsurface materials surrounding this well is 2.7 m per day. While there is no standard formula for determining the permeability under these specific recovery conditions of such large dug wells, the method applied is believed to yield a fair approximation of the actual permeability. The permeability thus calculated checks very favorably with the permeability of similar materials as determined from the use of the test pit method, Table AII-2.

In summary, it is recognized that because of the favorable permeability of the subsurface materials throughout the project area, there are generally no subsurface drainage problems on higher lands under existing conditions and no such problems are expected to develop under project conditions with a full

ESTIMATE OF PERMEABILITY "K" OF THE SANDY LIMESTONE SUBSURFACE MATERIALS

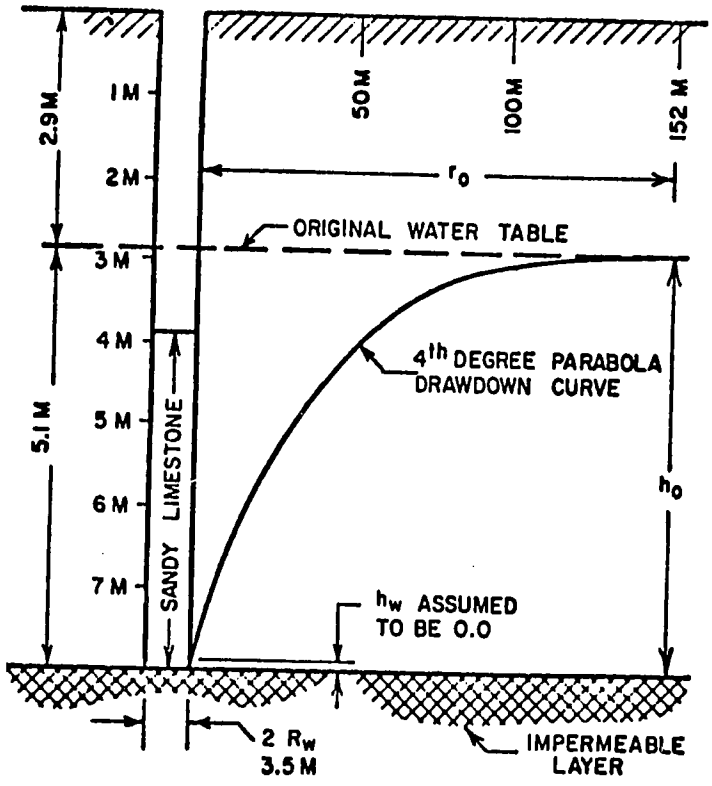
(Based on water level recovery time in the dug wells after well has been pumped dry).

Dug Well #1 (C-7)- Nr. Hamidyeh
(Info. rec'd from farmer)

(1) Well dia = 3.5 m
(2) Water table = 2.9 m (11/16/77)
(3) Well depth = 8.0 m
(4) Limy sandstone = 4 m to 8 m
(5) Well is pumped dry in 1 hr.
(6) Water level recovers in 24 hrs. and is pumped dry each day.

Assume:

(a) Drawdown curve and cone of depression as shown.
(b) Impermeable layer at the bottom of the well.
(c) Radius of influence = 152m This estimate is based on continuous pumping which is needed to determine "K".



Formula P. 84 – Ground Water Hydrology by "Todd"

$$Q \text{ (Water Vol.)} = 5.1 \times \pi (1.75)^2 = 5.1 \times 9.6 = 49.0 M^3$$

$$Q = \frac{\pi K \; h_o^2 - h_w^2}{\ln (r_o / r_w)} \quad \text{(For Unconfined Aquifer)}$$

$$K = \frac{Q \ln r_o/r_w}{\pi (h_o^2 - h_w^2)}$$

$$K = \frac{49.0 \ln 152/1.75}{\pi (16.7^2)} = \frac{49.0 \times 2.305 \times \text{Log } 87}{\pi (279)}$$

$$K = \frac{49.0 \times 2.305 \times 1.94}{81.7} = \frac{219}{817.} = 2.7 \text{ M/Day}$$

NOTE: For the purpose of determining "K" it was assumed that the actual volume pumped (in 1 hr) each day was spread out over 24 hours on a continuous pumping basis. This would give a conservative value of "K", as the average gradient moving water toward the well would be much greater under continuous flow and may yield as much as twice the total volume.

FIGURE AII-5

water supply as only 5 percent of the farm application is expected to enter the water table as deep percolation.

On lower-lying (5d) lands the subsurface permeabilities are favorable but the ground surface and water table gradients are unfavorable and thus a subsurface drainage problem as well as a surface drainage problem exists under present conditions. If this area were to receive a full water supply a more serious subsurface drainage problem would be created.

Surface Drainage Problems

Inadequate surface drainage is a major problem on the lands of the Akkar Plain. This problem occurs during the wet winter season and during short periods of high intensity storms. For ease of discussion this subject is here divided into two parts: (1) problems caused "From Direct Precipitation", and (2) problems caused "From River Flooding".

From Direct Precipitation:

The average annual precipitation on the Akkar Plain is 860 mm with approximately 60 percent occurring during the winter period, December thru February. As evidenced during field investigations, major storms occur during this period from 2 to 4 times per month with a storm duration of 3 to 4 days. The intensity of these storms ranges from about 60 mm to over 100 mm.

There are many surface drainage problems on the Akkar Plain as a result of the general flatness and undulating characteristics in the topography and an inadequate number and size of drainage channels. The soil it totally saturated each year after the first major winter storm and surface drainage problems begin immediately to appear. The estimated runoff is 44 percent of the total rainfall. Flow quantities were estimated from rainfall runoff

relationship curves assuming very wet soil conditions, slow infiltration rates and a storm rainfall intensity of 60 to 100 mm. An average runoff of about 35 mm occurs following each major storm. Such storm runoff would not be a major problem if the surface configuration of the area was conducive to good drainage.

The surface drainage problems occur in many forms. In the low topographic depressions where there is a limited gravity outlet the water ponds for an extended period beyond the winter season. In the case of the depression near Kharabeh there is no gravity outlet because the bottom of the depression is approximately one meter below sea level. This ponded area eventually dries up late in the spring by evaporation. As a result very limited cropping is practiced in this depressional area.

Another very significant reason for the development of surface drainage problems is the inadequate size of existing drainage channels traversing the area. There are also far too few drainage channels and road culverts. Those that do exist generally have a capacity of about 50 percent of that required to adequately control the storm runoff. Associated with these outlet channels there are several borrow pits paralleling the farm road which have limited surface drainage capacity because of poor initial construction, interference from farming operations and little or no maintenance.

A secondary source adding to the surface drainage problems are winter diversions from Janoubi River through an existing irrigation canal. This canal delivers uncontrolled water to the area near the village of Zarbleet throughout the winter season. This is a very unbeneficial practice which intensifies the surface drainage problem and should be controlled under project development.

There is also a major on-farm surface drainage problem which accounts for much of the restricted crop production on the Plain. This is created by poor cultural practices in preparing the land for planting and subsequent irrigation procedures. The current practice is to plow the land in a direction parallel the length of the field without regard to the contour. No form of land levelling is involved in preparing the soil for planting, rather, the seeds are broadcast or placed by hand and covered by a second light plowing operation.

Many surface irregularities result because levelling is not part of the land preparation. Many times back furrows are left creating water catchment areas that compound the surface drainage problem. Surface drainage is transferred to adjacent lands in the absence of a farm waste ditch collection system. As a result of inadequate drainage, the soils remain saturated for an extended period of time. Water logged or saturated soils limit root development of winter crops and delay planting of spring crops. An on-farm drainage plan to correct this problem is subsequently discussed under the topic of Ancillary Drainage Requirements.

From River Flooding:

Flooding from the Janoubi River is also recognized as a very serious problem. The flooding restricts crop production on an extended area bordering the Janoubi River from Khirbet Akrad to within approximately 2 kms of the river's mouth for a total of 10 kms. The path of the floodwater is to the northwest thru the Ramit Laha swamp area and into the Mediterranean Sea.

In evaluating the frequency of Janoubi River flooding, it was estimated

that damaging floods occur 2 out of 3 years for a 66 percent frequency. It was further estimated that 1 of 10 years a greater flood of much higher severity occurs. During the 1977-78 period of investigation there were three major storms which produced damaging flood flows from the Janoubi River. The observed flooding provided guidance for determining the area that would be covered by the respective 66% and 10% frequency floods. The extent of the area flooded, Figure AII-6, is subdivided by land class and flood frequency rate as follows:

LAND CLASS	IRRIGABLE AREA COVERED (Hectares)	
	10% Frequency	66% Frequency
1	390	259
2	289	192
3	69	46
5	537	354
TOTAL	1285	851

The Ramit Laha area will be protected by the Janoubi River dike but it will not produce crops until drainage is provided.

Drainability

Lands with a Surface Drainage Deficiency:

It has been determined as a result of the Drainage Feasibility Investigations and related studies that all of the net irrigable lands of the Akkar Plain, totaling 17,179 acres, have some degree of surface drainage deficiency. The deficiency can be divided into two broad catagories:

(1) Lower-lying lands, generally below the 50 m contour, are subject to topographic deficiencies, inadequate existing drainage channels, and are in

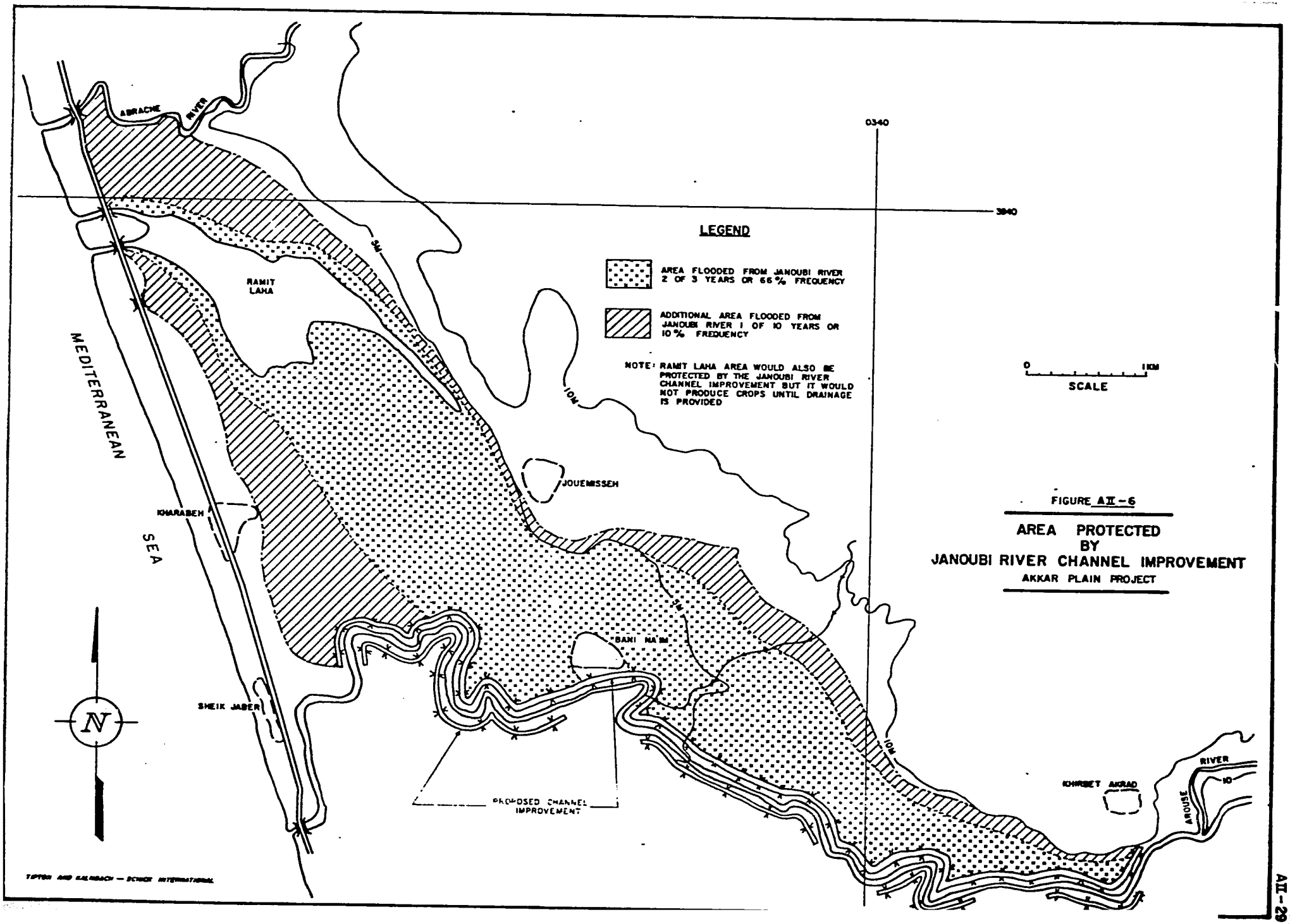


FIGURE AII-6

AREA PROTECTED BY JANOUBI RIVER CHANNEL IMPROVEMENT

AKKAR PLAIN PROJECT

a position to receive direct storm runoff transferred from higher lands. Also these lower-lying lands are subject to major on-farm drainage problems. Because of the deficiencies indicated much of this land is temporarily inundated following each major storm.

(2) Included in this second category are lands generally located above the 50 m contour on lands with favorable topography such as the steeper slopes, ridges, and foothills which are free from contributing areas of surface runoff. A small portion of these lands are also located below the 50 m and the 40 m contours. The lands in this category are subject to a lesser degree of drainage deficiency which consists of on-farm drainage problems resulting from poor cultural practices of preparing the land surface for planting and an absence of drainage waste collection ditches to permit pockets of on-farm ponded water to be channeled to a drainage outlet channel.

Improved surface drainage would reduce the time of inundation and the amount of infiltration and deep percolation on all irrigable lands. This would allow better root development of wet season crops and would permit earlier planting of spring crops.

Lands with a Subsurface Drainage Deficiency

In evaluating the subsurface characteristics of the lands on the Akkar Plain it was clearly determined that the lower-lying (5d) lands have a subsurface as well as a surface drainage deficiency. It was further determined that a subsurface drainage deficiency exists on a long narrow strip of land lying at the base of the major topographic break located approximately 3-1/2 kms east and parallel to the Mediterranean Seacoast.

The subsurface drainage deficiency on the 5d lands results from a

comparatively flat gradient of the water table associated with the flat topography and the impermeable nature of the soils and subsoils. The subsurface sandy limestone materials, however, have good permeability which provide favorable characteristics for the open well irrigation pumping being conducted rather extensively throughout the low-lying area.

The drainage deficient land at the base of the topographic break is drainage deficient because of extremely high water table conditions. These conditions are created partially by artesian pressure resulting from an abrupt change in topography. In this situation the drainage capacity of the permeable subsurface materials is exceeded and the confining nature of the overlying fine textured materials create a small artesian pressure during the wet season. Following the wet season, high water tables decline on a gradual basis but continue to constitute a drainage deficiency through the spring and the early summer season. The extent of the area experiencing a subsurface drainage problem is approximately 8.0 kms long and about 400 meters wide.

A deep subsurface interceptor drain at the base of the topographic break would adequately control the high water table to permit earlier spring cultivation, planting and unrestricted plant growth.

Existing Drainage System

The existing surface drainage outlet system is very extensive throughout the project area. This system is adequate on higher lands but is totally inadequate on all of the lower lands for removal of the storm runoff without temporarily inundating much of the area. As previously explained the existing drainage system was mapped in the field during the stormy season which made it

easier to locate the channels. The existing drainage channels have been divided into categories as follows:

(a) Natural surface drains (continuous flow)

(b) Natural surface drains (intermittent flow)

(c) Constructed surface drains

(d) Roadside borrow pits utilized as drains

The complete system of existing surface drains that serves the entire Akkar Plain was shown previously on Figure AII-2. The complete length of the existing drainage system is 223.2 km. A summary showing the length of drains in each designated category follows:

(a)	Natural surface drains (intermittent flow)	120.0 km
(b)	Natural surface drains (constant flow)	11.4 km
(c)	Constructed surface drains	72.1 km
(d)	Roadside borrow pits utilized as drains	19.7 km
	TOTAL	223.2 km

There are no existing subsurface drains of any type on the Akkar Plain.

FLOOD CONTROL REQUIREMENTS

A flood control plan on the Janoubi River is essential in order to realize the potential benefits of improved agriculture on approximately 1,300 hectares of the Akkar Plain. Accordingly, flood control measures are included in the first phase of the development plan as follows: (1) channel improvement on the Janoubi River for a distance of 10 km.; (Details are shown under subject of "Flood Control Design") (2) a flap gate structure with a capacity of 2.5 m^3/s at the mouth of Saroud El Sabyga to contain the Janoubi River water during flood stages; (3) three spoil bank crossings, one each at the existing

farm road river crossings. Each would require a special bank with side slopes of about 8:1, with armored facing to prevent wearing and erosion of the bank surfaces.

The following paragraphs contain a brief discussion of the Janoubi River Flood Review and peak flood flows utilized as flood control design criteria.

Janoubi River Flood Review:

Personal observations were made during December-January 1977-78 of heavy flooding conditions in the Ramit Laha area, which was principally a result of flooding from the Janoubi River. During that period, accumulated flood flows which overtopped the Janoubi River banks were estimated and utilized for design purposes. The floodwater temporarily inundates a large portion of the irrigable lands adjacent to the Janoubi River as well as other irrigable lands at lower elevations. Because the general slope of the agricultural lands is away from the Janoubi River, all of the floodwaters occurring on the Syrian side of the river flow in a northwesterly direction to the Mediterranean Sea through a broad topographic low area known as Ramit Laha. This flow enters the sea through two channels known as North and South Ramit Laha Outlets.

During the field investigation period, major storms which produced flooding of the Janoubi River were on December 17, January 17, and January 27. The maximum flood flows through the Ramit Laha outlets during these storms were estimated to be approximately 66 m^3/s. It was also estimated that 16 m^3/s of this flood flow was contributed as direct runoff from the Akkar Plain, with the remaining 50 m^3/s from the Janoubi River floodwaters occurring below Khirbet Akrad.

During the June 1978 field review and engineering surveys of the Janoubi River channel, it was estimated that about one-third of the total floodwaters overtopping the river banks was to the south or over the Lebanon bank of the river. Based on the foregoing estimate, the total flood flows escaping from the Janoubi River channel below Khirbet Akrad would be 75 m^3/s with about 25 m^3/s flooding on the Lebanon side. From inspection of available maps it appears that most of this flood flow on Lebanon lands returns to the Janoubi River approximately 0.5 km above its mouth.

Stream Flow Records:

The streams involved and the flow data available for use in evaluating the flood hydrology for the Janoubi River Channel Improvement include the following:

<u>Janoubi River at Dabouseh</u>

Average daily flow records	1974-75 thru 1977-78
Average monthly flow data	1961-62 thru 1977-78 except 1973-74

<u>Arouse River at gage near Berg Arab</u>

Average daily flow records	1965-66 thru 1977-78 except 1974-75 and 1976-77

<u>Kalife River at gage near Tel Hauche</u>

Average daily flow records	1965-66 thru 1975-76

<u>Abo Falat River</u>

No gage

There is also a long stream flow record on the Janoubi River at the Arida Gaging Station located about 25 km upstream from the Dabouseh Gage.

However, these flows do not correlate well with the flows at the Dabouseh Gage, and, therefore, they are not used in evaluating the flood hydrology for the Janoubi River Channel Improvement.

The 1978 draft of the Akkar Plain Drainage Appendix and Report included flood hydrology based on only three years of record (1974-75 thru 1976-77) on the Janoubi River at the Dabouseh Station which was essentially extended by correlation with the recorded flows of the Janoubi River at the Arida Gaging Station. This was a very poor correlation but was utilized in the report draft because better data was not available at that time.

In December 1978 additional stream flow records were obtained for the Janoubi River at the Dabouseh Station covering the period 1961-62 thru 1972-73. Average monthly flows for the period 1965 to 1978, Figure AII-7, were utilized in determining the magnitude and general frequency of the peak floods. Daily flow records were also obtained in December 1978 for the 1977-78 water year at these stations: Janoubi River at Dabouseh and Arouse River at Berg Arab.

Peak Flow Data: A review of the hydrograph for Janoubi River at Dabouseh indicates a high flood frequency of about once in ten years with secondary intensities occurring in most years. The greatest flood flow happened in February 1967 with the next highest flood in February 1976. Concurrent flow records on the Arouse and Kalife Rivers were also examined with the aid of the Janoubi River hydrograph at Dabouseh to determine the combined peak flow on the Janoubi River below the confluence with the Arouse River. Peak flows were also evaluated for the 1977-78 wet season when the investigations were being conducted.

A summary of peak flows for 1977-78 and 1966-67 water years, respectively, are presented as follows:

The peak flood flow of the Janoubi River during investigations resulted from the storm of January 26-27, 1978. The total flow of the Janoubi River below its confluence with the Arouse River is the summation of the following flows:

Janoubi River at Dabouseh	116 m^3/s	
Arouse River at mouth	37 m^3/s	1/
Kalife River at mouth	16 m^3/s	2/
Abo Falat River at mouth	7 m^3/s	3/
Combined flow of Janoubi River below confluence with Arouse River	176 m^3/s	

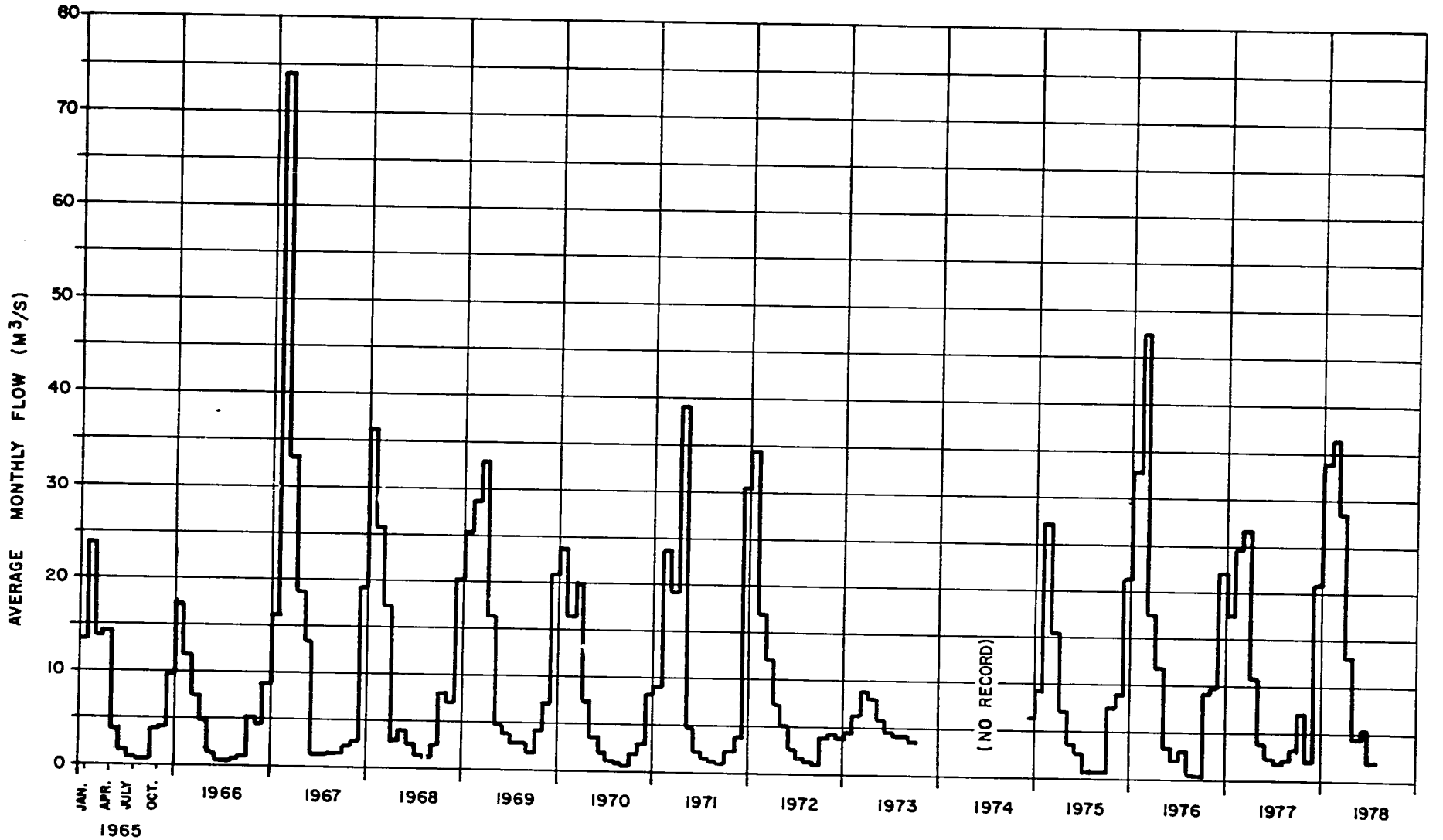
1/ Arouse River at mouth is estimated to be 150% of gaged flow at Berg Arab as determined from the ratio of contributing areas above respective stations.

2/ In the absence of peak flow records on the Kalife River at the gage near Tel Hauche, it is estimated to be 35% of the Arouse River flows as determined from the relationship of recorded peak flows for the two streams in 1967, a similar high water year. The flow at the mouth of the Kalife River is estimated to be 205% of the flow at the gage as determined from the ratio of contributing areas above the respective stations.

3/ (No gage available) Flow assumed to be 20% of Arouse River.

The only available flow records of the Janoubi River at Dabouseh prior to 1974-75 are average monthly flows beginning in 1961-62 and continuing to 1974-75, except for the year 1973-74. A review of this data shows that the maximum average monthly flows of 74.0 m^3/s occurred in February 1967 (See Figure AII-7).

The maximum daily or peak flow is not known but is estimated by



JANOUBI RIVER AT DABOUSEH
HYDROGRAPH
AVERAGE MONTHLY FLOWS M^3/S

FIGURE AII-7

TIPTON AND KALMBACH — SCHICK INTERNATIONAL

determining the ratio between average monthly flow and peak flows for the 1974-75 to 1977-78 period of record. The stormy season months of December, January, February, and March were used for each of the four years of available record. The resulting ratio of average monthly peak flows was determined to be 3.70.

Applying this ratio to the maximum monthly flow of 74.0 m^3/s produces an estimated peak flow of 273.8 m^3/s for the Janoubi River at Dabouseh. To determine the combined flow of the Janoubi River below the confluence of the Arouse River, the peak flows for the Arouse, Kalife, and Abo Falat Rivers are added as follows:

Janoubi River at Dabouseh, calculated as explained above	273.8 m^3/s
Arouse River above confluence with Kalife River equal gaged flow of 8.2 plus estimated inflow below gate at 50% of gaged flow	12.3 m^3/s
Kalife River at mouth - equals gaged flow of 3.2 plus estimated inflow below gage of 105% of gaged flow	6.6 m^3/s
Abo Falat River at mouth - equals 20% of Arouse River flow at mouth	2.5 m^3/s
Janoubi River below confluence with Arouse River	295.2 m^3/s
Rounded for design purposes	300.0 m^3/s

DRAINAGE REQUIREMENTS

An effective drainage plan is also a prerequisite to achieve the agricultural potential of the Akkar Plain and would be included in the first phase of development. The drainage features to be constructed are summarized in the following tabulation:

Item	Range in Capacity (m^3/s)	Total Length (kms)	No. of Stuctures
DRAINAGE			
Improvement of Existing Drains			
Natural surface drains (constant flow)	2.80-5.10	11.4	
Natural surface drains (intermittent flow)	.10-2.80	57.2	
Constructed drains	.15-10.20	38.5	
Roadside borrow pits	.15-1.40	13.4	
New Surface Drains	.10-16.10	63.3	
Subsurface Drains (1.8 m depth)		8.3	
Special Drainage Structures			
Drainage inlet pipes			
12" diameter			80
15" diameter			12
Bridge culverts (highway crossings) 1/			5
Flap gates 15" diameter			8
Drainage pump (140 liters/s)			1

A brief review of the requirement and design for each of the several categories of drains is treated separately in the following paragraphs.

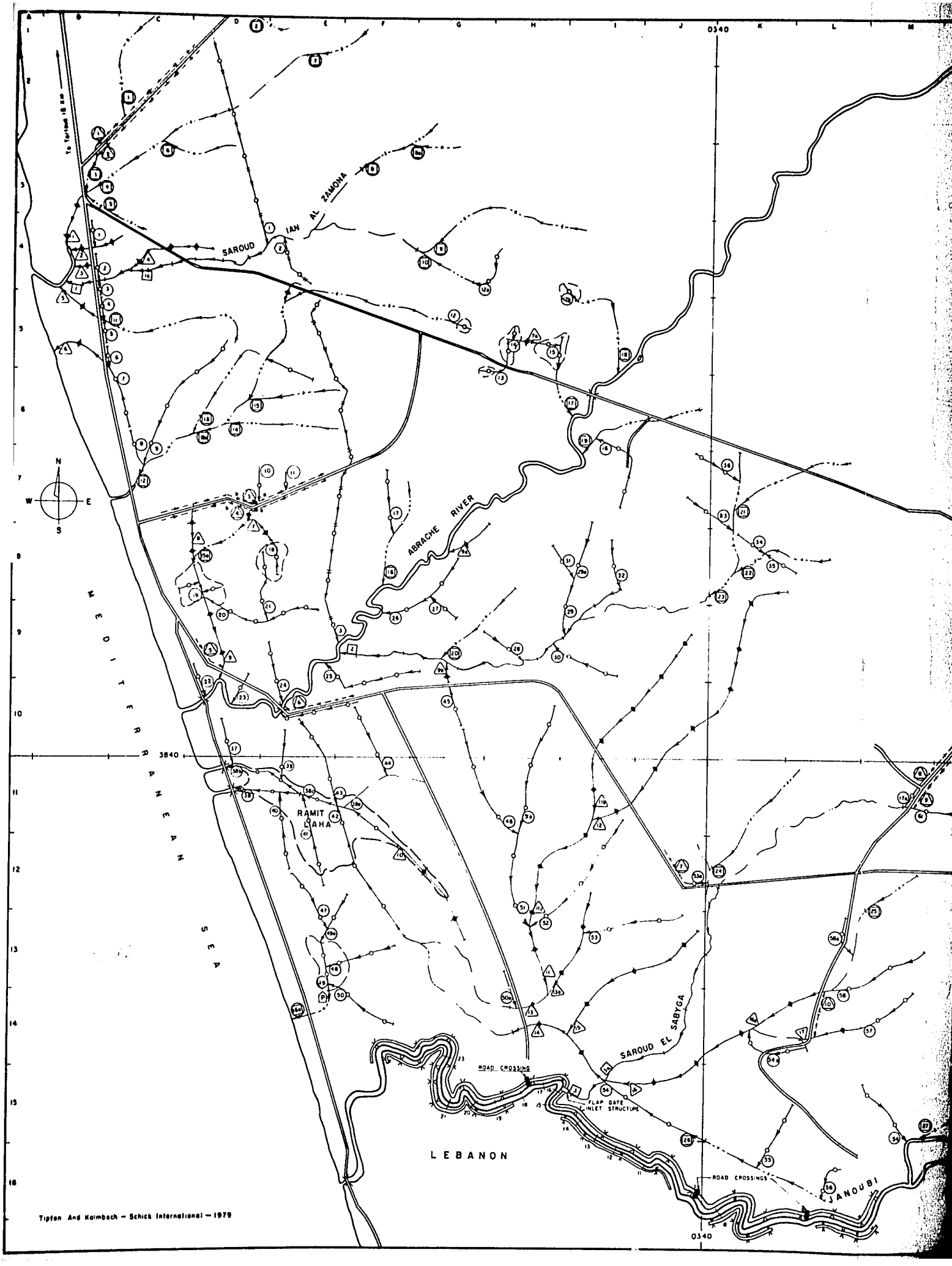
Surface Drainage Requirement

The surface drainage requirement for the Akkar Plain is based on the 1977-78 winter storm runoff which represents about a 5-year frequency storm. The required drains, Figure AII-8, are discussed under two categories: (1) existing surface drains requiring improvement, and (2) proposed new surface drains.

Existing Drains Requiring Improvement:

The existing drains requiring improvement total 120.5 kms in length and are concentrated on the western portion of the Akkar Plain. They consist of

1/ Includes only drainage culverts under major highways. All drainage culverts required for farm roads are included in the infrastructure development.



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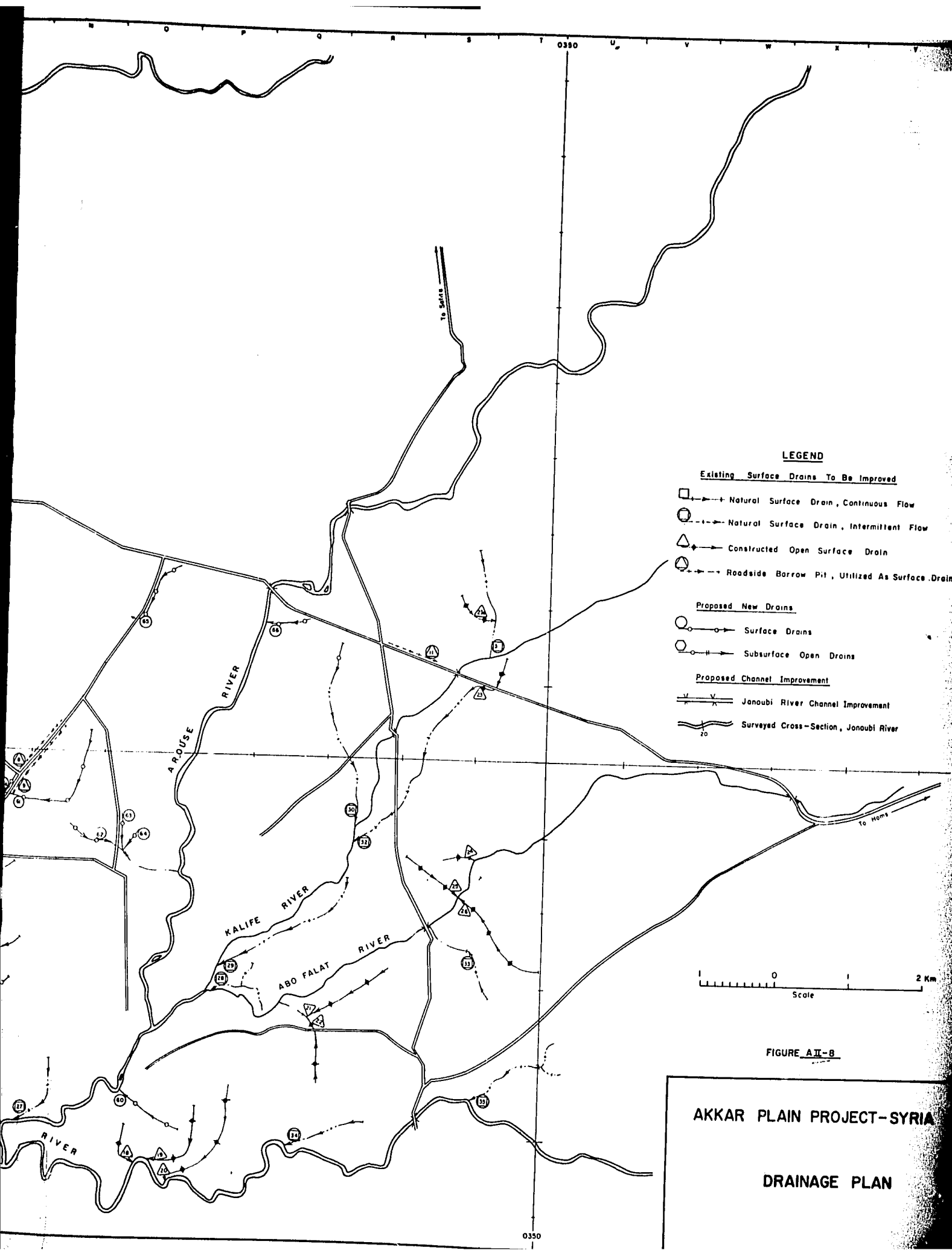


FIGURE AII-8

AKKAR PLAIN PROJECT-SYRIA

DRAINAGE PLAN

the following drain categories and accumulated lengths.:

Natural surface drains (intermittent flow)	57.2 km
Natural surface drains (constant flow)	11.4 km
Roadside borrow pits	13.4 km
Constructed surface drains	38.5 km

Natural surface drains with intermittent flow represent about one-half of the total existing drains requiring improvement. These drains flow only during the stormy season and have an estimated average of fifty percent of the capacity required. One of the significant problems relating to the inadequacy of these drains is the undersized road culverts which create excessive flooding of the related roads and adjacent land areas. Each of these drains and culverts will be enlarged to handle the estimated storm runoff.

The natural surface drains with constant flow have an accumulated length of 11.4 km and include 3 quite large channels. Each of these channels are spring fed with low flows in summer but have only about 55 percent of the required capacity to adequately control the heavy storm runoff. Each channel is presently quite brushy because of the constant available moisture.

An empirical determination of the magnitude of storm runoff, employing U.S.B.R. storm runoff standards, was made on a sample basis to check the observed runoff. The sample area selected was the Saroud Ian Al Zamona drainage basin, or Natural Surface Drain No. 1, Location (B-4) in the Drain Category of "Continuous Flow". (See Figure AII-8 and Table AII-6).

The calculations are shown on the following page. As indicated in the calculations, the results checked very favorably with the estimated flow observed in the field.

The roadside borrow pits utilized for drainage purposes have an accumulated length of 13.4 km. As previously discussed, these borrow pits are inadequate in size, have many man-made restrictions, and appear to have no maintenance. It is estimated that under existing conditions the average channel section is only about sixty percent of the total required capacity.

The constructed drains which need improvement have an accumulated length of 38.5 km. Most of these drains probably originated as natural drains but because of their insufficient capacity, local farmer groups have enlarged them to provide some of the needed control of the drainage water. However, it was very evident during field investigations that the size of these channels was very insufficient for controlling the storm runoff, and, accordingly, on the average, these channels were estimated to be only fifty percent of the required size.

New Surface Drains:

The requirement for proposed new surface drains on the Akkar Plain is very significant, with an accumulated length of 63.3 km. The largest of these drains would be located in the Ramit Laha area where most of the deepest flooding occurs. In general, these new drains would be positioned between widely spaced existing drains to provide adequate outlet for lands now damaged by sheet flooding. Wherever the situation is technically feasible, these drains would be located along existing farm roads in order to minimize the disturbance of farm tract boundaries.

EMPIRICAL METHOD - FLOOD RUNOFF CALCULATIONS - AKKAR PLAIN

Sample Area - Saroud Ian Al Zamana
Drainage basin = 4,238 acres or 1,716 hectares

Applying U.S. Bureau of Reclamation Standards - 1978 Drainage Manual, pages 35-39

McMath formula: Q = C i S-1/5 A-4/5 (English units)

	Veg		Soils		Topog.			
C =	.16	+	.22	+	0.8	=	0.46	(basin characteristics)

$$i = \frac{y}{x} \qquad y = b + \frac{x}{10}$$

b = 0.31 inches/hour (40 mm or 1.57 inches in 5 hours as recorded at Tartous 12/4/77)

x = 2.1 (required time of concentration)

$$y = 0.31 + \frac{2.1}{10} = 0.52$$ (5 year any hour rainfall)

$$i = \frac{0.52}{2.1} = 0.25$$ (rate of rainfall for time of concentration)

$$S = \frac{120}{9.500} = 12.6$$ (fall of main channel)

A = 4,238 acres (drainage basin)

$$Q = 0.46 \times 0.25 \times 12.6^{1/5} \times 4{,}238^{4/5}$$

$$Q = 152 \text{ ft}^3/\text{s} \text{ or } 4.3 \text{ m}^3/\text{s}$$

This flood flow checks extremely well with the estimated 4.2 m^3/s flood flow observed in the field during the heavy runoff.

The Ramit Laha area will require an especially wide but shallow drain in order to create the proper hydraulics for delivery of the drainage water into the Mediterranean Sea.

During extremely windy conditions seawater is backed into the Ramit Laha area. This water will be controlled under project development by providing high banks with flap gate inlet structures to control the seawater, yet allowing surface water runoff to enter the outlet drain as soon as the heavy winds subside. Generally the winds precede the heavy rainfall and, therefore, runoff from precipitation would flow through the drainage inlet structures after the seawater returns to the sea.

Subsurface Drainage Requirement

A subsurface drainage deficiency exists on a long, narrow strip of land lying at the base of a major topographic break located approximately 3.5 km east and parallel to the Mediterranean seacoast. This drainage deficiency is a result of extremely high water table conditions created partially by artesian pressure resulting from an abrupt change in topography and a decrease in the depth of permeable water-bearing subsurface material.

A deep subsurface interceptor drain located at the base of the topographic break should adequately control the high water table to permit early spring cultivation, planting, and unrestricted plant growth for improved agricultural production. The extent of the area adversely affected is approximately 8 km long and .4 km wide.

Ancillary Drainage Requirement

A drainage waste ditch collection system to serve each farm tract

with a surface water outlet is a very necessary requirement for all irrigable land (17,180 hectares) of the Akkar Plain. This system coupled with improved on-farm cultural practices is necessary to readily eliminate precipitation water and thus achieve better production of the irrigable lands.

As a basis for making a cost appraisal, a tentative design is proposed as follows:

It is estimated that the average spacing of the proposed project drains, new and existing, is one kilometer and that these drains will serve as an outlet for the proposed waste ditch collection system. It is also estimated that for each square kilometer or 100 hectares there are sixteen separate farm tracts or an average of approximately six hectares per tract. Drainage waste ditches would, therefore, be required on a 250 m spacing. Each waste ditch would serve four tracts and would be placed along the lower edge of each tract and would outlet into the nearest drainage outlet channel. This would result in 4 km of drainage collection ditch per 100 hectares.

The estimated average capacity of the collection waste ditches is .10 m^3/s. The channel would be only 20 cm deep with a bottom width of 30 cm and comparatively flat side slopes of 3:1. The resultant top width would be 150 cm. The collection ditch would be a grass-covered channel and could be utilized for grazing purposes as well as drainage. The grass would also serve as an erosion control measure.

It is estimated that the cost for constructing the ancillary drainage will be approximately $30.00 or 117 S.P. per hectare and would total $515,000 for the 17,180 hectares of project lands. This includes the cost of seedbed

preparation and grass seeding of the entire channel surface. The cost of excavation is based on local Syrian prices. It is proposed that the Agricultural Service Center be responsible for the construction of this system.

FLOOD CONTROL DESIGN

Design of Janoubi River Channel Improvement

The proposed Janoubi River Channel Improvement, Figure AII-8, is 10 km in length beginning directly south of the village of Khirbet Akrad and extending continuously to a point about 2 km above the river's mouth. Required improvement on the south or Lebanon side of the river would extend for a total distance of only 7 km but would not be continuous. The difference in requirement on the two sides is due to a topographic rise in the landscape at several locations along the south side. Small villages generally occupy these elevated areas because they are not subject to river flooding.

Based on visual evidence and many interviews with local farmers, some degree of flooding over the river bank occurs on at least 95 percent of the designated 10 km along the north side of the river. The flooding is most severe in the upper and central reaches and where the channel is smallest and is restricted by heavy brush growth. Under existing conditions, the least degree of flooding is being experienced on the lower river reaches. This is probably due to the fact that most of the surplus flow has spilled from the river channel in the upper reaches and there is comparatively little tributary inflow below those points. Under conditions

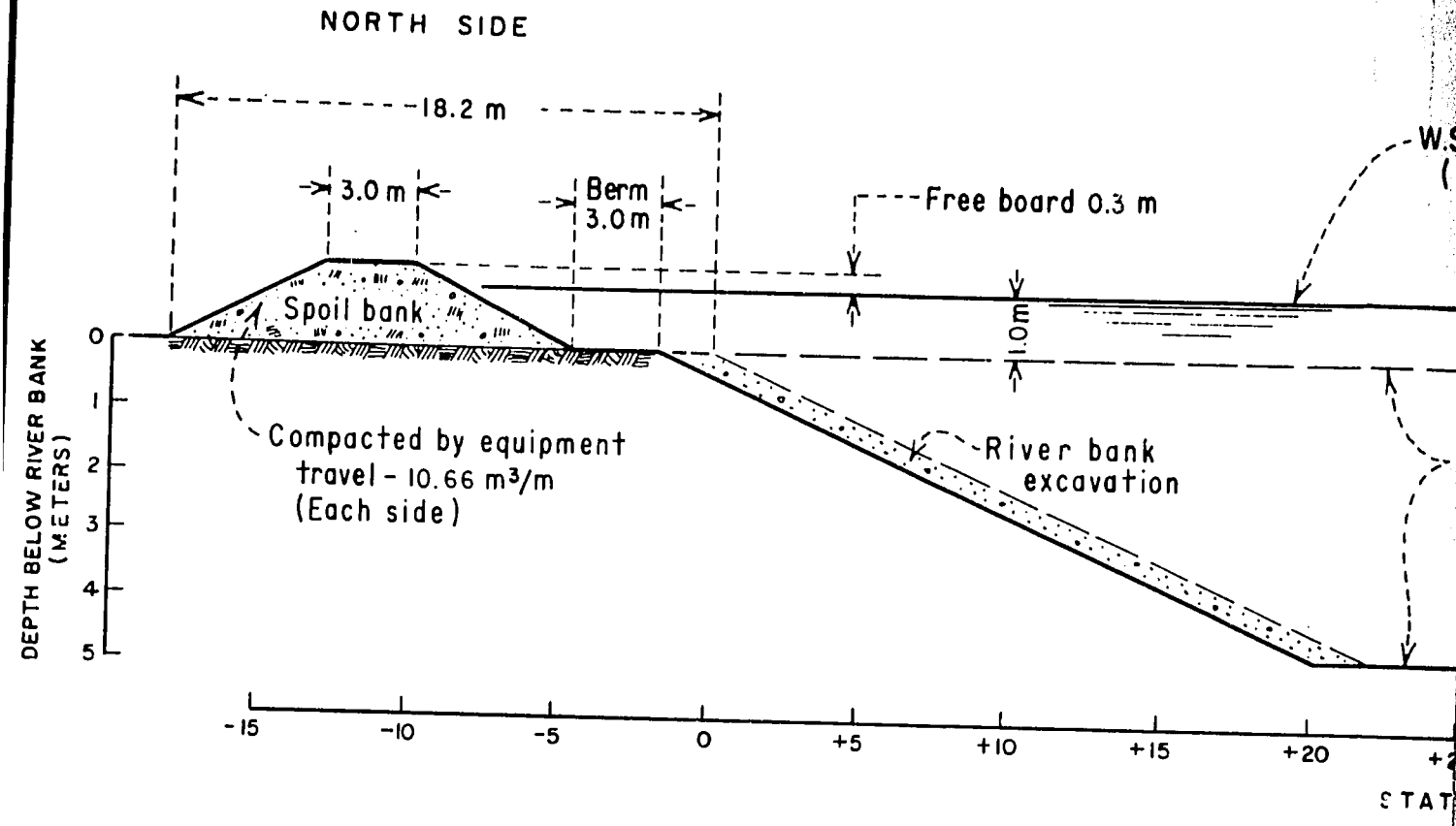
of full channel development, all of the flows should be contained within the river. Therefore, there is a greater need for improving the lower river reaches than is currently apparent to local farmers.

The main feature of the improvement would be the placement of spoil banks on either side of the river. The spoil banks would consist of compacted earthfill with a 3 m top width and side slopes of 4:1, Figure AII-9. The material for the fill would be excavated from the river bank. Approximately 20 percent additional excavation would be required to allow for shrinkage in the compacted material. A berm 3 m wide would be provided between the edge of the excavated river bank and the inside toe of the spoil bank.

The material to be excavated from the river bank will consist of fine-textured alluvial materials; sand, silt and clay should be ideal for easy compaction by equipment travel without the need for additional moisture. Clearing of numerous trees and brush from the river banks will be required before bank excavation can properly be accomplished.

The flat side slopes of 4:1, provided in the design of the dike, will accommodate the establishment of grass or other vegetative growth for grazing purposes. The side slopes of the river bank should also be left as smooth as possible for improving stream hydraulics. Reseeding of the river bank with appropriate grass varieties will also be necessary to control bank erosion.

In order to provide engineering information for the design of the necessary channel improvement for feasibility cost estimates, thirteen cross sections of the river were utilized. The cross sectional area of each of these sections is shown in Table AII-3.



HYDRAULIC PROPERTIES
IMPROVED CHANNEL

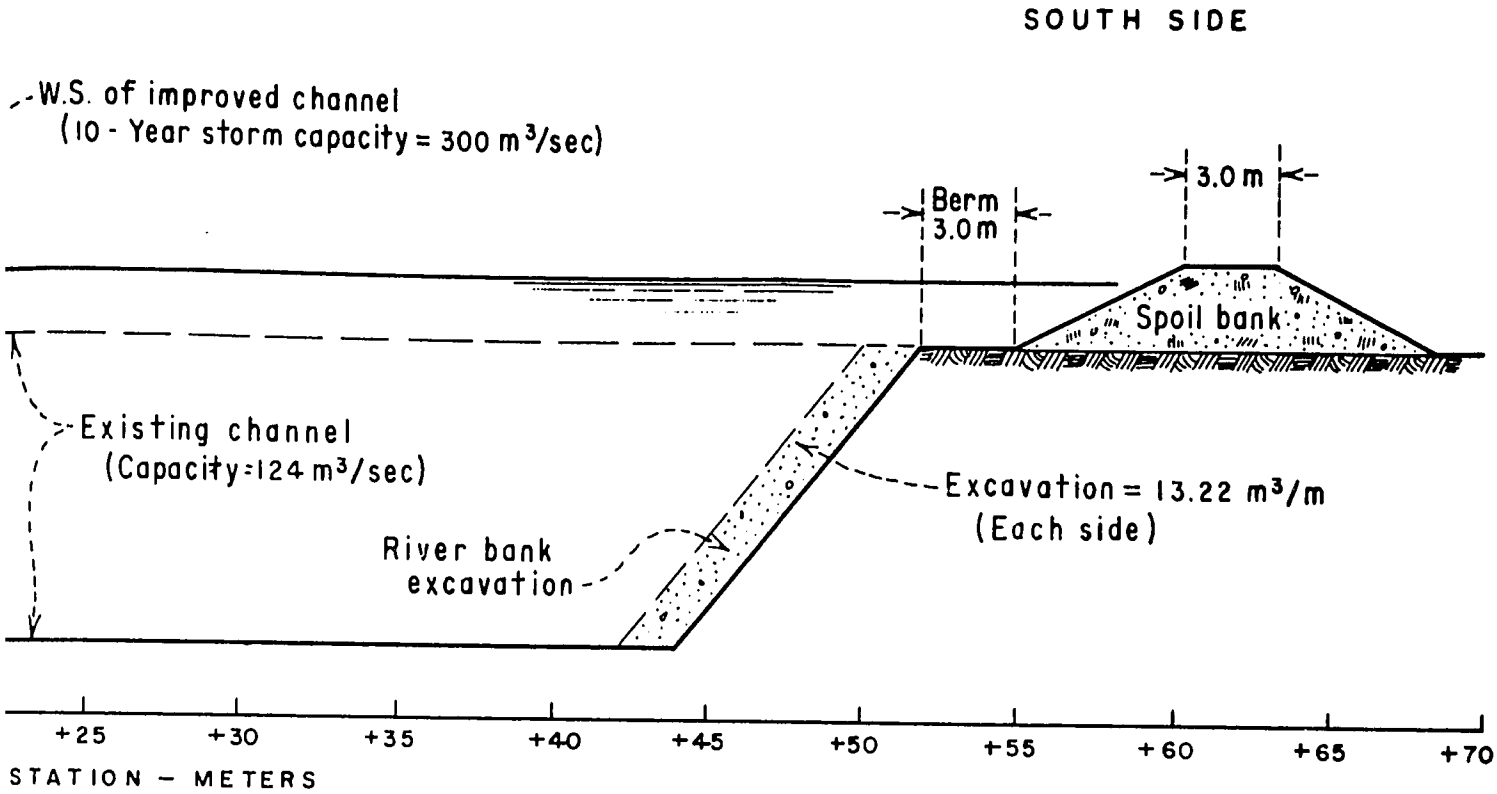
Cross-sectional area	= 256.6 m²
Wetted perimeter	= 71.0 m
Hydraulic radius	= 3.6 m
S (Slope)	= 0.0005
n (Roughness coef.)	= 0.045
V (Velocity)	= 1.17 m/sec
Q (10 Year storm)	= 300 m³/sec

MANNINGS FOR

$$V = \frac{r^{2/3}\ s^{1/2}}{n}$$

NOTE

Required river excavation equals compacted spoil bank plus 20% to allow for shrinkage



FORMULA

$\frac{3 \quad S^{1/2}}{n}$

HYDRAULIC PROPERTIES
EXISTING CHANNEL

Cross-sectional area	= 158.7 m²
Wetted perimeter	= 52.4 m
Hydraulic radius	= 3.0 m
S (Slope)	= 0.0005
n (Roughness coef.)	= 0.060
V (Velocity)	= 0.78 m/sec
Q (Present capacity)	= 124 m³/sec

JANOUBI RIVER CHANNEL IMPROVEMENT
AT
AVERAGE SECTION – NO. 17
Akkar Plain Project

Table AII-3. Available Janoubi River Cross Section Data

Section Number	Cross Sectional Area m^2	
8	235.6	
11	204.6	
12	217.0	
13	176.1	
14	173.6	
15	223.2	
16	153.8	
17	158.7	Average section selected.
18	124.0	
19	132.7	
20	97.0	Control section selected.
21	96.8	
23	101.7	
Average	161.1	

Note: Cross sectional area does not include area below the W.S. at time of survey during June-July 1978.

Probably the most important river section for analyses is the average cross section which will be used for cost estimating purposes. Surveyed Section No. 17 meets this criterion. The required height of spoil bank for the average conditions is 1.3 meters. The hydraulic properties for the channel improvement design if based on the application of Manning's formula for open channels. The formula is explained in Table AII-4 and a range of values for coefficient of roughness under various surface conditions is listed in Table AII-5.

Hydraulic Properties:

The hydraulic properties with related design have been analyzed for two conditions: (1) the average river cross section (previously indicated), and (2) the smallest or most critical cross section which was evaluated for determining the existing capacity of the river. The height of spoil bank at this critical section was determined to be 1.8 m and represents the maximum spoil bank requirement. Design data for this section is included in the supporting data.

The applied hydraulic properties which need specific discussion include the hydraulic gradient or slope "s" and the coefficient of roughness "n".

Since survey data was not made available for determining the effective slope of the stream channel, an estimated average slope for the total 10 km of .0005 was used for both sections analyzed. The estimated roughness coefficient "n" for the two channel sections under existing and future conditions follow.

Table AII-4. Flow Formula Explanation

The formula applied for determining the velocity of water in open drainage and flood channels on the Akkar Plain is that developed by Robert Manning which follows. This formula is used very extensively for calculating water flow in open channels.

English Application	Metric Application
$V = \frac{1.486\ r\ 2/3\ S\ 1/2}{n}$	$V = \frac{r\ 2/3\ S\ 1/2}{n}$
where:	
V = Mean velocity of water in ft/sec.	V = Mean velocity of water in m/sec.
1.486 is an empirical number for converting between the metric and english application.	R = Hydraulic radius in m where A is expressed in m^2 and wetted perimeter (wp) in m.
R = Hydraulic radius in ft. is equal to $\frac{A}{wp}$ where A is the water cross-sectional area in ft^2 and wp is the wetted perimeter in ft.	S = Slope of water surface or hydraulic gradient.
	N = Coefficient of roughness of the channel.
S = Slope of the water surface or, hydraulic gradient = ratio of vertical drop to horizontal distance.	S = Same
N = Roughness coefficient of the channel, (details on following page).	N = Same
The resulting discharge formulas are:	
Q = AV	Q = AV
where Q = flow in cfs or ft^3/sec.	Q = Flow in m^3/sec
A = Cross sectional area of the channel below the water surface expressed in ft^2.	A = Cross sectional area of channel below water surface in m^2.
V = Mean velocity ft/sec. as shown above.	V = Mean velocity m/sec as shown above.

Table AII-5. Coefficient of Roughness "n" to be Used with Manning's Formula. (Horton's Values)

Surface	Best	Good	Fair	Bad
Canals and ditches:				
Earth, straight and uniform	0.017	0.020	0.0225	0.025
Rock cuts, smooth and uniform	0.025	0.030	0.033	0.035
Jagged and irregular	0.035	0.040	0.045	
Winding sluggish canals	0.0225	0.025	0.0275	0.030
Dredged earth channels	0.025	0.0275	0.030	0.033
Canals with rough stony beds, weeds on earth banks	0.025	0.030	0.035	0.040
Earth bottom, rubble sides	0.028	0.030	0.033	0.035
Natural stream channels:				
1. Clean, straight bank, full stage, no rifts or deep pools	0.025	0.0275	0.030	0.033
2. Same as 1, but some weeds and stones	0.030	0.033	0.035	0.040
3. Winding, some pools and shoals, clean	0.033	0.035	0.040	0.045
4. Same as 3, lower stages, more ineffective slope and sections	0.040	0.045	0.050	0.055
5. Same as 3, some weeds and stones	0.035	0.040	0.045	0.050
6. Same as 4, stony sections	0.045	0.050	0.055	0.060
7. Sluggish river reaches, rather weedy or with very deep pools	0.050	0.060	0.070	0.080
8. Very weedy reaches	0.075	0.100	0.125	0.150

	Existing "n"	Future "n"
Average channel section (very brushy and crooked)	0.60	0.45
Smallest (critical) section (quite brushy and irregular)	0.50	0.40

The roughness coefficient "n" is extremely variable for the different reaches of the river. The variation in roughness is a result of the wide variation in the intensity of trees and brush located on the banks within the flow prism. The roughness coefficient "n" varies from an estimated 0.35 for straight reaches with clean banks to 0.60 for crooked reaches with very brushy banks. As a result of many variations in hydraulic properties, the present capacity of the different river reaches and the depth of flooding over the river bank is quite variable.

The spoil bank for the average section was designed to provide for the estimated 10-year peak flow frequency with a freeboard of 0.3 m. This design was used for cost estimating purposes.

The critical section was designed to contain the flood but with no freeboard. This condition is representative of only the most critical condition of the river and was analyzed to determine the maximum spoil bank requirement as well as the existing channel capacity of 94 m^3/s. All flows above this amount presently flood over the river banks.

Minor structures associated with the north side river bank improvement include: (1) a flap gate structure with a capacity of 2.5 m^3/s at the mouth of Saroud El Sabyga to contain the Janoubi River water during flood stages, and (2) three spoil bank crossings, one each at the existing farm road river crossings. Each would require a special design with side slopes of 8:1 and armored facing to prevent excessive wearing and erosion

of the bank surfaces.

DRAINAGE DESIGN

General Design of Surface Drains

The design of the individual surface drains is dependent upon the maximum flow for each. The respective length, slope, capacity, and excavation required is shown in Tables AII-6 thru AII-9. The required capacity of these drains vary from as little as .10 m^3/s for a few of the minor drains to 16.1 m^3/s for the major Ramit Laha drain; see Table AII-10.

Typical designs for selected drains with representative capacities are shown on Figures AII-10 and AII-11. The hydraulic properties for each of the drain designs is also based on the application of Manning's formula for open channels. The applicable coefficient of roughness "n" selected for the proposed drains is 0.030. It is anticipated that the channels will be smooth with short vegetative growth during the wet season when they will be required to handle maximum flow. This conforms to the short vegetative condition of the existing channels which are maintained by sheep and livestock grazing. One exception is the constant flow channels where brush will need to be controlled by spraying, as well as by grazing, in order to maintain good channel hydraulics.

These drains are each designed with 2:1 side slopes, with most of the spoil material being placed on the bank for access road purposes. It is estimated that the access road materials to be compacted will average only 75 percent of the total earth excavation for all drains. The excavated topsoil could be spread on adjacent farmland in accordance with the landowner's desires. The design provides for cmp surface water inlets on a spacing of approximately 300 meters for most drains with a capacity larger than .90 m^3/s.

Table AII-6. Drain Requirements and Excavation Required for Existing Surface Drains to be Improved

Drain No.	Drain Location	Length (kms)	Slope	Capacity m^3/s	Required Volume 1/ m^3/m	Required Volume 1/ $1000m^3$
Natural Surface Drains - Continuous Flow (11.4 kms)						
1	(B-4)	0.9	.002	4.20	6.70	6.030
1a	(C-4)	2.2	.006	2.80	3.75	8.250
2	(F-9)	4.3	.004	2.80	4.20	18.060
3	(I-15)	0.7	.001	4.80	8.30	5.810
3a	(I-15)	3.3	.003	5.10	6.70	22.110
Subtotal						60.260
Roadside Borrowpits Utilized as Surface Drain (13.4 kms)						
1	(B-3)	1.9	.005	1.40	2.60	4.940
2	(B-3)	1.9	.005	1.10	2.10	3.990
3	(D-7)	0.9	.003	.60	1.35	1.210
3a	(D-7)	1.4	.001	.30	1.10	1.540
4	(D-7)	0.9	.003	.60	1.35	1.215
4a	(D-7)	1.4	.001	.40	1.50	2.100
5	(D-9)	0.5	.001	.15	0.68	.340
6	(E-10)	1.0	.006	.15	0.51	.510
7	(J-12)	0.4	.001	.15	0.68	.272
8	(M-11)	0.8	.006	.15	0.51	.408
9	(M-11)	1.1	.006	.30	0.72	.792
10	(L-14)	0.6	.001	.30	1.10	.660
11	(S-9)	0.6	.001	.30	1.10	.660
Subtotal						18.637

1/ See table AII-11 for existing channel volume and new excavation required.

Table AII-7. Drain Requirements and Excavation Required for Existing Surface Drains to be Improved - Natural Surface Drains - Intermittent Flow (57.2 kms)

Drain No.	Drain Location	Length (kms)	Slope	Capacity m3/s	Required Volume 2/ m^3/m	Required Volume 2/ $1000m^3$
1	(C-2)	1.4	.004	.30	0.80	1.120
2	(D-1)	0.7	.01	.15	0.48	.336
3	(B-3)	0.5	.002	2.80	5.10	2.550
4	(B-3)	2.2	.005	.60	1.20	2.640
5	(B-3)	0.9	.002	.30	0.93	.837
6	(C-3)	1.0	.005	.15	0.53	.530
7	(E-1)	0.9	.005	.15	0.53	.477
8	(F-3)	1.2	.004	.30	0.80	.960
8a	(G-2)	0.6	.004	.15	0.54	.324
9	(G-4)	2.4	.007	.60	1.14	2.736
10	(G-4)	0.8	.01	.30	0.68	.544
11	(B-5)	2.1	.006	.15	0.51	1.071
12	(C-7)	1.0	.004	2.80	3.20	3.200
12a	(D-6)	4.5	.004	.90	1.80	8.100
13	(D-6)	2.3	.006	.10	0.34	.782
14	(D-6)	1.5	.004	.20	0.66	.990
15	(D-6)	1.2	.005	.40	1.03	1.236
15a	(D-8)	1.0	.003	1.40	3.10	3.100
16	(F-8)	1.5	.01	.40	1.50	2.250
16a	(E-14)	0.7	.001	.15	2.60 1/	1.820
17	(I-6)	0.6	.02	.60	0.93	.558
18	(I-5)	1.4	.01	.15	0.48	.672
19	(I-6)	1.7	.008	1.40	2.15	3.655
20	(G-9)	1.3	.01	.30	0.68	.884
21	(K-7)	1.7	.01	.30	0.68	1.156
22	(K-8)	1.5	.005	.60	1.20	1.800
23	(K-8)	2.0	.01	1.10	2.00	4.000
24	(K-12)	1.7	.006	.30	0.74	1.258
25	(M-12)	0.8	.01	.30	0.68	.544
26	(J-15)	2.0	.001	1.10	4.00	8.000
27	(M-15)	1.1	.004	.60	1.30	1.430
28	(P-14)	1.2	.004	.30	0.81	.972
29	(P-13)	2.2	.003	.90	1.90	4.180
30	(R-11)	2.4	.008	1.10	1.80	4.320
31	(T-9)	1.4	.02	.30	0.60	.840
32	(R-11)	2.5	.007	1.10	2.00	5.000
33	(T-13)	0.7	.006	.60	1.20	.840
34	(Q-16)	1.1	.005	.30	0.78	.853
35	(T-15)	1.5	.01	.90	1.40	2.100
Subtotal						78.670

1/ Pump discharge channel (includes additional excavation for sump inlet).
2/ See table AII-11 for existing channel volume and new excavation required.

Table AII-8. Drain Requirements and Excavation Required for Existing Surface Drains to be Improved - Constructed Surface Drains (38.5 kms)

Drain No.	Drain Location	Length (kms)	Slope	Capacity m^3/s	Required Volume 1/ m^3/m	Required Volume 1/ $1000m^3$
1	(B-4)	0.7	.002	3.40	6.10	4.270
2	(B-4)	0.8	.002	.40	1.25	1.000
3	(B-4)	0.2	.002	1.10	2.25	.450
4	(C-4)	1.3	.006	1.40	2.25	2.925
5	(B-4)	0.6	.002	.60	1.50	.900
6	(B-5)	0.7	.002	2.00	3.34	2.338
7	(D-7)	0.4	.001	.15	0.68	.272
7a	(H-5)	0.2	.002	.30	0.93	.186
8	(D-8)	0.7	.001	.60	1.80	1.260
9	(D-9)	1.1	.001	3.40	7.00	7.700
9a	(G-8)	0.7	.005	0.15	0.53	.371
9b	(G-9)	0.3	.005	0.30	0.78	.234
10	(G-12)	1.5	.001	.90	2.60	3.900
11	(H-14)	0.9	.004	4.40	5.90	5.310
11a	(H-12)	1.9	.006	3.40	5.00	9.500
11b	(I-11)	2.5	.005	1.40	2.60	6.500
12	(I-11)	4.2	.006	1.70	2.70	11.340
13	(H-14)	0.4	.001	4.70	8.00	3.200
13a	(H-13)	1.6	.005	0.30	.77	1.232
14	(H-14)	1.3	.001	10.20	16.10	20.930
15	(I-14)	2.2	.004	0.60	1.30	2.860
16	(I-15)	2.1	.003	3.40	5.70	11.970
16a	(K-14)	1.2	.008	1.70	2.40	2.880
17	(L-14)	0.8	.008	1.40	2.15	1.720
17a	(M-11)	0.3	.01	.15	.48	.144
18	(O-16)	0.6	.01	.15	.48	.288
19	(P-16)	1.2	.006	.15	.51	.612
20	(Q-16)	1.7	.008	.15	.50	.850
21	(Q-14)	1.3	.005	.30	.77	1.001
22	(Q-14)	0.9	.005	.30	.77	.693
23	(T-10)	0.7	.005	.15	.53	.371
23a	(T-9)	0.6	.02	.30	.60	.360
24	(S-12)	0.5	.01	.15	.48	.240
25	(S-12)	0.9	.01	.15	.48	.432
26	(T-12)	1.5	.006	.40	1.00	1.500
Subtotal						109.739

1/ See table AII-11 for existing channel volume and new excavation required.

Table AII-9. Drain Requirements and Excavation Required for Proposed New Surface Drains (63.3 kms)

Drain No.	Drain Location	Length (kms)	Slope	Capacity m^3/s	Excavation Required m^3/m	Excavation Required Total $1000m^3$
1	(B-4)	0.3	.001	.30	1.09	0.327
2	(B-4)	0.4	.001	.30	1.09	0.436
3	(B-4)	0.1	.001	.30	1.09	0.109
4	(B-5)	0.3	.001	.30	1.09	0.327
5	(B-5)	0.3	.001	.30	1.09	0.327
6	(B-5)	0.2	.001	.30	1.09	0.218
7	(C-6)	0.9	.0008	.60	1.90	1.710
8	(C-7)	0.5	.001	.30	1.09	0.545
9	(C-7)	2.3	.004	.25	.70	1.610
10	(D-7)	0.4	.001	.15	0.68	0.272
11	(E-7)	0.2	.001	.15	0.68	0.136
12	(G-5)	0.2	.01	.15	0.48	0.096
12a	(G-4)	0.6	.004	.15	0.55	0.330
12b	(I-4)	0.3	.004	.15	0.55	0.165
13	(H-5)	0.3	.006	.15	0.52	0.156
14	(H-5)	0.7	.001	.30	1.09	0.763
15	(H-5)	0.7	.001	.60	1.79	1.253
16	(I-6)	1.2	.01	.30	0.68	0.816
17	(F-7)	0.8	.02	.30	0.60	0.480
18	(E-8)	0.4	.004	.15	0.55	0.220
19	(D-8)	0.9	.001	2.80	6.20	5.580
19a	(D-8)	0.2	.001	.60	1.79	0.358
19b	(D-8)	0.2	.001	.60	1.79	0.358
20	(D-9)	1.6	.004	.60	1.29	2.064
21	(E-9)	1.0	.001	.15	0.68	0.680
22	(D-10)	0.5	.001	.15	0.68	0.340
23	(D-10)	0.5	.001	.10	0.48	0.240
23a	(D-10)	1.1	.006	.15	0.52	0.572
24	(D-10)	0.8	.002	.15	0.61	0.488
25	(E-9)	1.5	.005	.30	0.78	1.170
26	(F-9)	1.3	.006	.30	0.75	.975
27	(G-9)	0.4	.02	.10	0.30	.120
28	(H-9)	0.6	.001	.15	0.68	.408
29	(I-9)	0.8	.02	.40	0.80	.640
29a	(I-8)	0.7	.006	.30	0.75	.525
30	(H-9)	1.0	.007	.15	0.50	.500
31	(I-8)	0.5	.001	.10	0.48	.240
32	(I-8)	0.7	.01	.15	0.48	.336
33	(K-8)	0.7	.008	.10	0.33	.231

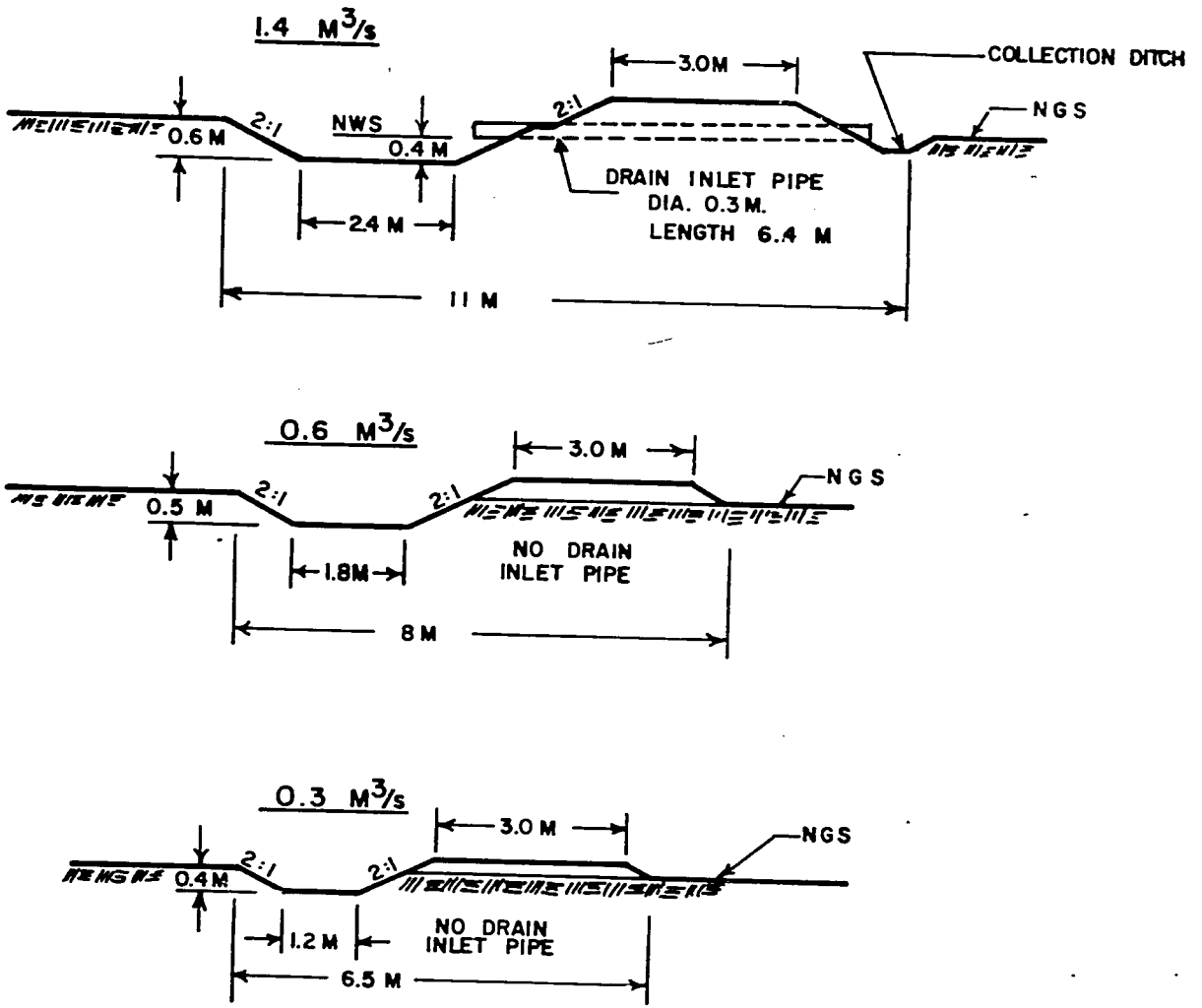
Table AII-9. continued. Drain Requirements and Excavation Required for Proposed New Surface Drains (63.3 kms)

Drain No.	Drain Location	Length (kms)	Slope	Capacity m^3/s	Excavation Required m^3/s	Excavation Required Total $1000m^3$
34	(K-8)	0.5	.008	.10	0.33	.165
35	(K-8)	0.5	.008	.10	0.33	.165
36	(K-7)	0.7	.01	.10	0.33	.231
37	(D-10)	0.6	.001	.15	0.68	.408
38	(E-11)	0.7	.0005	13.00	9.54	6.680
38a	(F-11)	1.0	.001	.90	2.56	2.560
38b	(E-11)	0.8	.0005	3.50		0 1/
38c	(E-11)	0.7	.0005	16.10	28.67	20.069
39	(E-11)	0.8	.001	.15	0.68	0.544
40	(E-11)	1.0	.001	.15	0.68	0.680
41	(E-11)	1.2	.0006	.15	0.76	0.912
42	(F-11)	2.0	.0006	14.90	26.53	53.060
43	(E-11)	1.3	.001	.15	0.68	0.884
44	(F-11)	1.0	.003	.15	0.57	0.570
45	(G-10)	0.5	.004	.10	.37	0.185
46	(H-11)	1.5	.004	.30	0.81	1.215
47	(E-13)	0.9	.001	.15	0.68	.612
48	(F-13)	1.0	.001	.15	0.68	.680
49	(E-13)	0.9	.001	.30	1.79	.161
49a	(E-13)	0.5	.001	.15	0.68	.340
50	(F-14)	1.0	.001	.15	0.68	.680
50a	(H-13)	0.5	.004	.15	0.55	.275
51	(H-12)	1.3	.007	.90	1.55	2.015
51a	(H-11)	1.6	.006	.60	1.17	1.872
52	(H-13)	1.9	.01	.15	0.48	0.912
53	(I-13)	1.4	.01	.15	0.48	0.672
53a	(J-12)	0.4	.02	.15	0.44	0.176
54	(J-15)	1.3	.001	1.10	2.54	3.302
54a	(K-14)	0.6	.008	.30	0.71	0.426
55	(K-16)	0.9	.01	.15	0.48	0.432
56	(L-16)	0.5	.01	.10	0.33	0.165
57	(M-14)	0.8	.004	.60	1.29	1.032
58	(M-19)	1.3	.008	.60	1.10	1.430
58a	(L-13)	0.5	.01	.10	0.33	0.165
59	(M-15)	0.9	.02	.40	0.80	0.720
60	(Q-15)	1.0	.006	.30	0.75	0.750
61	(N-11)	1.9	.005	.60	1.20	2.280
62	(O-12)	0.8	.001	.15	0.68	0.544
63	(O-12)	0.5	.001	.30	1.09	0.545
64	(O-12)	0.3	.001	.10	0.48	0.144
65	(O-8)	1.0	.006	.60	1.17	1.170
66	(Q-9)	0.6	.01	.15	0.48	0.288
				TOTAL		136.237

1/ Existing north Ramit Laha channel has adequate capacity.

Table AII-10. Summary of Project Surface Drains by Drain Capacity - Unit = kms.

Drain Capacity m^3/sec	Existing Drains to be Improved: Nat. Surface Drains Intermittent Flow	Nat. Surface Drains Constant Flow	Roadside Borrows	Constructed Surface Drains	Proposed New Drains	Total (kms)	Percent	
.10	2.3				5.6	7.9	4.3	
.15	6.7		2.7	7.0	23.9	40.3	21.9	
.20	1.5					1.5	0.8	
.25					1.2	1.2	0.7	(.10-.40m^3)
.30	13.5		3.7	4.9	11.9	34.0	18.5	50%
.40	2.7		1.4	2.3	1.7	8.1	4.4	
.60	8.5		1.8	3.5	11.1	24.9	13.5	
.90	8.9			1.5	2.3	12.7	6.9	
1.10	8.9		1.9	0.2	1.3	12.3	6.7	
1.40	2.7		1.9	4.6		9.2	5.0	(.60-2.00m^3/s)
1.70	1.0			5.4		6.4	3.5	36%
2.00				0.7		0.7	0.4	
2.80	0.5	6.5			0.9	7.9	4.3	
3.40				5.8		5.8	3.1	
4.20		0.9				0.9	0.5	
4.40				0.9		0.9	0.5	(2.80-4.80m^3/s)
4.70				0.4		0.4	0.2	9%
4.80		0.7				0.7	0.4	
5.10		3.3				3.3	1.8	
10.20				1.3		1.3	0.7	
13.00					0.7	0.7	0.4	(5.10-16.10m^3/s)
14.90					2.0	2.0	1.1	5%
16.10					0.7	0.7	0.4	
TOTAL	57.2	11.4	13.4	38.5	63.3	183.8	100.0	



MAXIMUM Q = 1.4 M^3/s
MAX. W. DEPTH = 0.4 M
DRAIN DEPTH = 0.6 M
BOTTOM WIDTH = 2.4 M
SIDE SLOPES = 2:1
N (COEF.) = 0.030
S (SLOPE) = .006
V (VELOCITY) = 1.1 MPS
HEIGHT OF SPOIL BANK = 0.5 M

MAXIMUM Q = 0.6 M^3/s
MAX. W. DEPTH = 0.4 M
DRAIN DEPTH = 0.5 M
BOTTOM WIDTH = 1.8 M
SIDE SLOPES = 2:1
N (COEF.) = 0.030
S (SLOPE) = 0.002
V (VELOCITY) = 0.63 MPS
HEIGHT OF SPOIL BANK = 0.35 M

MAXIMUM Q = 0.3 M^3/s
MAX. W. DEPTH = 0.24 M
DRAIN DEPTH = 0.4 M
BOTTOM WIDTH = 1.2 M
SIDE SLOPES = 2:1
N (COEF.) = 0.030
S (SLOPE) = 0.004
V (VELOCITY) = 0.67 MPS
HEIGHT OF SPOIL BANK = 0.25 M

FIGURE AII-10

TYPICAL DRAIN SECTIONS
AKKAR PLAIN PROJECT

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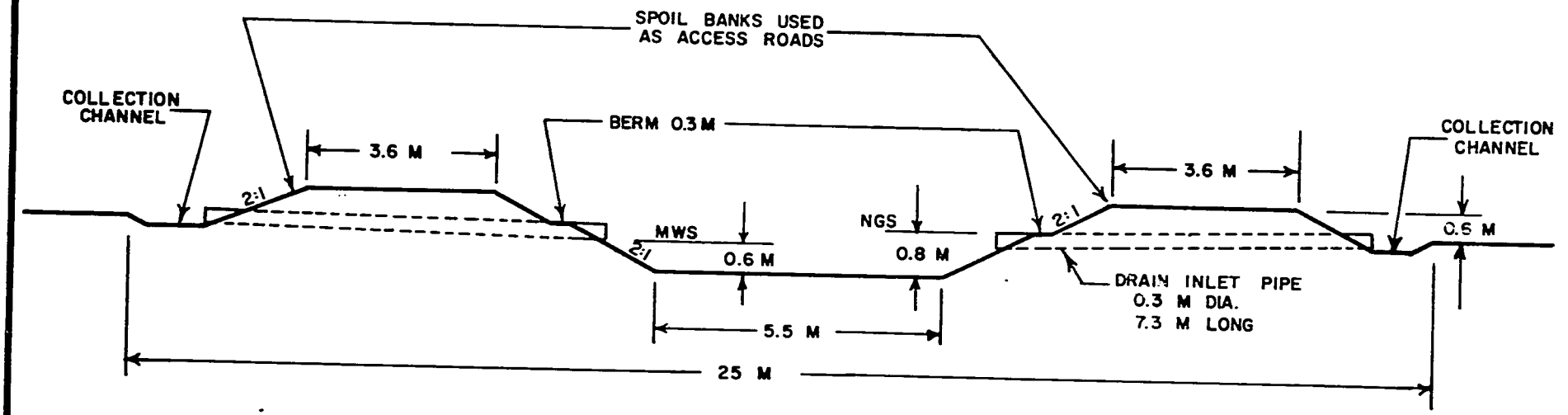


MAXIMUM Q = 2.8 M^3/s
MAX. W. DEPTH = 0.6 M
DRAIN DEPTH = 0.8 M
BOTTOM WIDTH = 5.5 M
SIDE SLOPES = 2:1
N (COEF.) = 0.030
S (SLOPE) = 0.001
V (VELOCITY) = 0.67 MPS

FIGURE AII-11

DRAIN SECTION
(2.8 M /sec Capacity)
AKKAR PLAIN PROJECT

TIPTON AND KALMBACH — SCHICK INTERNATIONAL

This will control bank erosion, silting of the channel and provide proper drainage of adjacent land. On smaller drains no surface water inlet pipes are considered necessary.

The average slope and length of each channel was determined from the use of the available 5 m contour topographic map. Because of the large contour intervals, slope estimates were necessarily made on all of the flatter lands. This procedure was assumed to be adequate for feasibility designs only.

Because of the method of solving the Manning's formula is a tedious process of trial and error, a standard set of U.S. Bureau of Reclamation Hydraulic and Excavation Tables based on Manning's formula were utilized in determining the hydraulic properties of the large number of drainage channels to be improved or newly constructed. The standard data determined for each of the channels and individual channel reaches include the following parameters:

BW - bottom width of channel

D - depth of water in channel

A - cross-sectional area of water prism

WP - wetted perimeter

r - hydraulic radius = $\frac{A}{wp}$

N - coefficient of roughness selected from Horton's values

S - hydraulic gradient, obtained from 5 m contour topographic map

V - mean velocity of water in channel

FB - freeboard

Excavated volume

The detailed calculations are not for final design purposes but to provide a feasibility cost estimate. Accordingly, detailed topography or equivalent surveys will be required for final designs.

A summary of required excavation as determined for existing drains and new drains is tabulated in Table AII-11.

Ramit Laha Drain Design

The Ramit Laha drain with a maximum capacity of 16.1 m^3/s is the largest and most complex drain proposed for the Akkar Plain. This drain has two outlets to the sea consisting of the north and south channels. With the future control of the Janoubi River floodwater the respective coast road bridges each provide adequate capacity for the anticipated drainage water.

The lower 700 m of the north Ramit Laha channel has adequate capacity to handle a design flow of 3.5 m^3/s, but the lower 700 m of the south channel is very inadequate and will need extensive improvement to provide for the required capacity of 13.0 m^3/s. At the 700 m station the two channels merge. There is no defined Ramit Laha channel above this station. The required capacity of the proposed Ramit Laha channel from 700 m to 1,400 m is 16.1 m^3/s and reduces to 14.9 m^3/s for the upper reach from 1,400 m to 3,400 m.

The very flat gradient of the Ramit Laha area extending to the Mediterranean Sea impose design limitations on the proposed Ramit Laha drain as follows:

(1) A maximum channel depth of 0.7 m with an appropriate width to contain the drainage waters below the ground surface level. (The required width for the 16.1 m^3/s channel is 39 m).

(2) High spoil banks, to contain wind-driven sea water within the

Table AII-11. Required Excavation for all Drains

Drain Catagory	Channel Volume Required 1000m3	Existing Channel Volume 1000m3	New Excavation Required	
			Volume 1000m3	Percent of Total
Existing Surface Drains to be Improved				
Nat. Surface Drains (Constant Flow) 11.4 kms	60.3	33.1	27.2	45
Nat. Surface Drains (Intermittent Flow) 57.2 kms	78.7	39.3	39.4	50
Constructed Surface Drains 38.5 kms	109.7	54.8	54.9	50
Borrow Pits 13.4 kms	18.6	11.1	7.5	40
SUBTOTAL			129.0	
Proposed New Drains				
Surface Drains 63.3 kms	136.2	-	136.2	100
SURFACE DRAINS SUBTOTAL			265.2	
Subsurface Drains 8.3 kms	60.2	-	60.2	100
GRAND TOTAL (New excavation)			325.4	

channel banks. (The required bank height is 1.2 m for the maximum capacity channel). The spoil banks would be compacted and utilized as O & M roads.

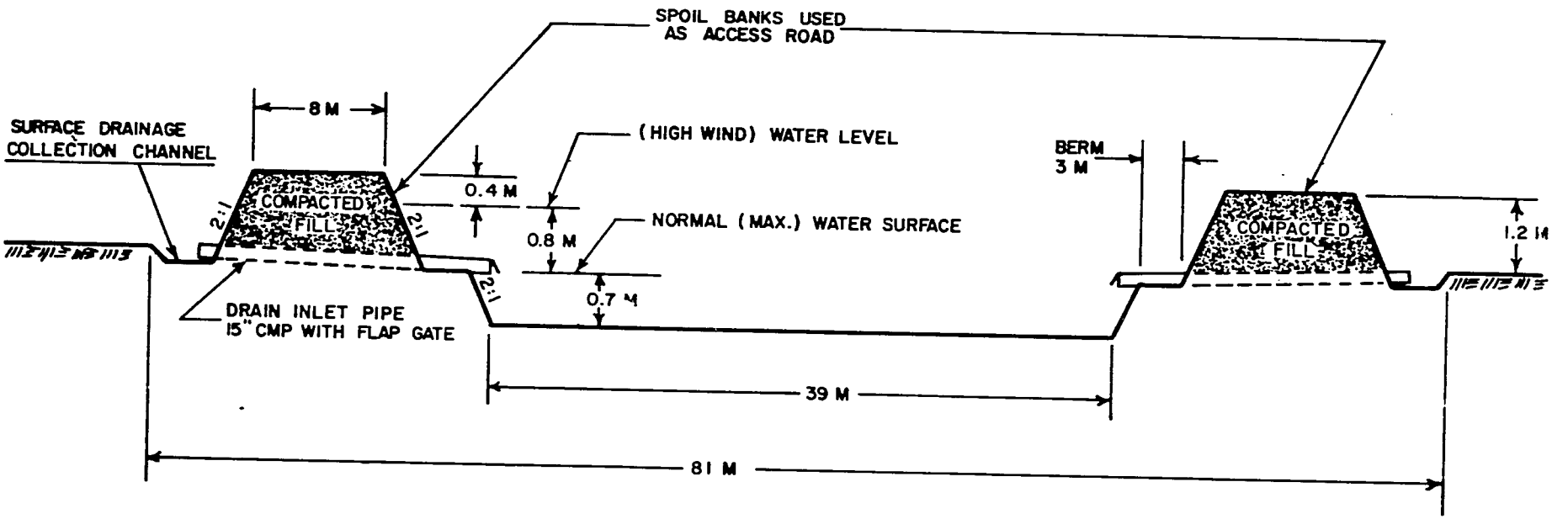
(3) Surface water inlet pipes, through the spoil banks, with a flap gate closure to prevent the wind-driven sea water from entering on cultivated land.

A typical section of the Ramit Laha drain with appropriate hydraulic properties is shown on Figure AII-12.

Subsurface Drain Design

There are three separate subsurface drains involved which total 8.3 kms. They lie end for end along a topographic break generally between the 15 and 20 meter contours. They were separated into three drains because of the outlet opportunities for each. The longest of these drains is designated subsurface drain number 3 with a length of 4.7 kms. Since each of the drains would have the same basic design, only drain number 3 will be shown in this Appendix, Figure AII-13.

This drain would be 1.8 meters deep and would penetrate approximately 0.8 meters into the sandy limestone. A subsurface drain under these conditions should respond very favorably due to the permeable nature of the rock materials. As indicated in the figure, the drain would be designed with side slopes of 1.5 to 1, bottom width of 1.2 m and two operation and maintenance roads, one on either side of the drain. These roads would be constructed from the excavated spoil material and would also be used as access roads to adjacent farmlands. The roads would be compacted, by special equipment travel. They would have side slopes of 1.5 to 1 and a top width



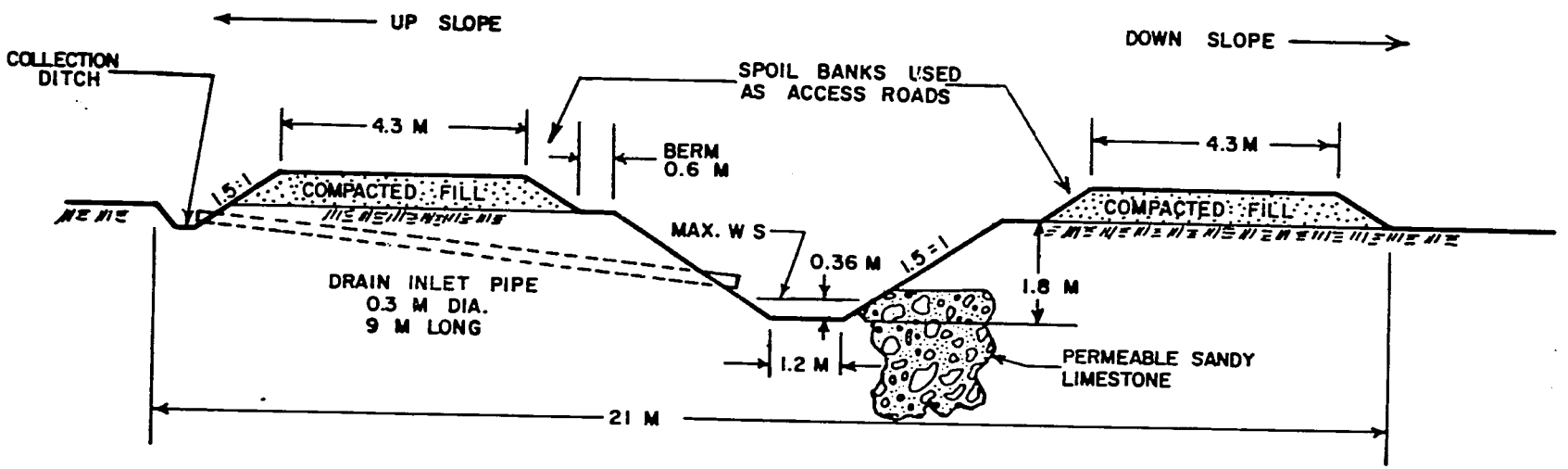
HYDRAULIC PROPERTIES

BOTTOM WIDTH	= 39 M
WATER DEPTH	= 0.7 M
SIDE SLOPES	= 2:1
CROSS-SECTIONAL AREA	= 28.7 M^2
S (SLOPE)	= .0005
N (COEF.)	= 0.030
HYDRAULIC RADIUS	= 0.67 M
V (VELOCITY)	= 0.57 MPS
MAXIMUM Q	= 16.1 M^3/s

FIGURE AII-12

TYPICAL SECTION
RAMIT LAHA DRAIN
AKKAR PLAIN PROJECT

TIPTON AND KALMBACH—SCHICK INTERNATIONAL



AVERAGE HYDRAULICS, DRAIN NO. 3 (E-9) (LENGTH OF DRAIN = 4,680 M)

SIDE SLOPE = 1.5:1
N (COEF.) = 0.030
S (SLOPE) = 0.003
BOTTOM WIDTH = 1.2 M
HYDRAULIC RADIUS = 0.26 M
DRAIN DEPTH = 1.8 M
CROSS-SECTIONAL AREA = 165 M^2
V (VELOCITY) = 0.73 MPS
Q (MAX. WINTER FLOW) = 0.46 M^3/s
Q (SUMMER FLOW) = 0.07 M^3/s

FIGURE AII-13

TYPICAL
SUBSURFACE DRAIN DESIGN
AKKAR PLAIN PROJECT

TIPTON AND KALMBACH — SCHICK INTERNATIONAL

of 4.3 m.

The design provides for a ditch above the drain to collect surface drainage water and convey it to the subsurface drain via the cmp surface water inlet pipe. These inlets are necessary to prevent erosion of the banks and silting in of the deep subsurface drain and also act as a culvert under the O & M and access road. The drainage inlets would be spaced approximately 300 meters apart. However, surface drainage inlets would not be provided for 3 major natural cross-drainage channels carrying from .30 to .40 m^3/s. This water would be channelled across the subsurface drain in a supported 18" welded steel pipe and would continue in its natural course as an integral part of the surface drainage outlet system.

The design flow in subsurface drain number 3 is calculated as follows:

Surface Runoff from Precipitation:

Estimated contributing area above drain = 200 hectares

Assumed average major storm 1/ = 80 mm occurring over a 48 hr period

Estimated runoff 44% = 35 mm

Total runoff = $\frac{.035}{2}$ m = .0175 m/day = .0175 x 200 m x 10,000 m = 3.5×10^4 m^3

$$= \frac{3.5 \times 10^4}{3600 \times 24} = .43 \ m^3/s$$

Surface Runoff from Irrigation:

It is estimated that 15% of the water applied to the farm results in surface runoff which is contributed to the subsurface drain; estimates follow:

Average summertime consumptive use per day = 4.3 mm

(Assuming 60 efficiency)

1/ Refer to discussion under subject of Surface Drainage Problems.

Diversion requirement = $\frac{4.3}{.60}$ = 7.2 mm

Farm delivery = 90% of the diversion requirement = 6.5 mm

Surface waste = 15% x 6.5 = .98 mm

Total volume = .00098 m x 200 x 10,000 m^2 = 1960 m^3/day = $\frac{1960}{3600 \times 24}$ = 0.023 m^3/s

Subsurface Flow:

In the determination of water to be intercepted by the subsurface drain the Darcy formula Q = KIA was applied as representing a close approximation of the intercepted inflow to a single drain at the base of a steep slope. This formula is applicable under the existing laminar flow conditions. An explanation of the formula and calculations of subsurface flow follows:

Q = KIA

Q = m^3 per day

K = permeability in m per day of the sandy limestone

(The permeability of this material is 6.0 m/day and was determined in the test made at the Dakaka model farm area).

I = water table gradient which is approximately 30 meters/1000 on the topographic break in question.

A = cross section area in m^2 through which the water flows in entering the drain. (The depth of this area is assumed to be the full depth of the permeable surface materials which is 5.2 m.

Q = 6.0 m x 0.03 x 5.2 m x 4700 m = 4400 m^3/day

$$\frac{4400}{(3600 \times 24)} = .051 \ m^3/s$$

Thus:

Winter Flows in Subsurface Drain

Surface runoff from precipitation= .43 m^3/s

Subsurface inflow = .05 m^3/s

Total winter flow during storm =0.48 m^3/sec

Summer Flows in Subsurface Drain (during no storms)

Surface runoff from irrigation = .02 m^3/s

Subsurface inflow to drain = .05 m^3/s

Total summer flows =0.07 m^3/s

Based on the above calculations the entire length (8.3 kms) of subsurface drains would produce 0.84 m^3/s during winter storms and 0.13 m^3/s during normal summer operation.

DRAINAGE SYSTEM AND JANOUBI RIVER CHANNEL IMPROVEMENT COSTS

The unit costs applied for all items were based on Syrian prices if they were available. Other unit costs were based on local U.S. prices with an appropriate allowance for shipping. Unit prices applied for individual items with explanation follow:

Item	Unit	Source of Unit Prices: Syria SP	Source of Unit Prices: US $
Drains and Related Features			
Earth excavation	m^3	8 1/	
Earth compaction (by equipment travel)	m^3	8 1/	
Rock excavation	m^3	16 2/	
Backfill & compaction about structures	m^3	16	
cmp drainage inlet pipe (in place)	kg	6	
Flap gates 15" dia, (38 cm)	ea		260
Sump pump 5 ft^3/s. (142 liters/s)	ea		15,000

1/ Syrian prices adjusted in accordance with the estimated ease of performing the specific function.

2/ The rock to be excavated is porous, partially decomposed and comparatively easy to excavate.

Item	Unit	Source and Unit Prices	
		Syria S.P.	U.S. $
Janoubi River Channel Improvement			
Earth excavation	m^3	8	
Earthfill placement and compaction (by equipment travel)	m^3	8 1/	
River bank clearing (brush and trees)	ha	3,460	
Flap gate structure	LS		12,000
Spoil bank river crossings (3 required)	each	10,000	

Cost summaries for the Drainage System and Janoubi River Channel Improvement are tabulated in Tables AII-12 and AII-13, respectively. In each case the net costs have been increased by 20 percent for contingencies and 15 percent for engineering.

The total cost for the Channel Improvement shown in Table AII-12 of $752,000 represents the improvement cost of the Syrian side of the river only. The equivalent cost of the channel improvement for the Lebanon side would be $486,000. This cost was not used in determining the economy of the project since it only benefits the Lebanon area and is totally related to that economy.

The cost estimate for the south side channel improvement is based on the same general design and unit costs as determined for the Syrian side, except that no special structures are deemed necessary on the south side. This is because there is essentially no surface water inflow on the south side and no requirement for spoil banks in the locality of farm road crossings.

Support for quantities and other details is filed with the supporting data in the office of Schick International, Inc.

1/ Placement of materials for the spoil bank will be very simple as part of the excavation process. Moisture conditions should be ideal and, therefore, no watering of the fill will be required.

Table AII-12. Summary of Drainage Costs.

Construction Item	Quantity	Unit	Unit Costs S.P.	Unit Costs U.S. $	Total Costs S.P.	Total Costs U.S. $
Surface Drains						
Total excavation	265,186	m^3				
20% Rock	53,036	m^3	16	4.10	848,050	217,450
80% Earth	212,150	m^3	8	2.05	1,696,150	434,910
Compaction (75% of earth exc)	159,112	m^3	6	1.54	955,620	245,030
Subsurface Drain						
Total excavation	60,175	m^3				
40% Rock	24,070	m^3	16	4.10	384,890	98,690
60% Earth	36,105	m^3	8	2.05	288,680	74,020
Compaction	36,105	m^3	6	1.54	216,840	55,600
Drainage Structures						
Backfill & compaction around structures	535	m^3	16	4.10	8,540	2,190
Subsurface drain crossings	3	ea	1,794	460.00	5,380	1,380
Drainage inlet pipes (cmp)						
80 @ 12" diameter	600	m	70	18.03	42,200	10,820
12 @ 15" diameter	258	m	88	22.53	22,660	5,810
Automatic flap gates for Ramit Laha drain inlets, 15" or 38 cm diameter	8	ea	1,014	260.00	8,100	2,080
Bridge culverts - Tartous-Homs and Hamidyeh highways (5) Reinforced concrete	160	m^3	800	205.00	127,920	32,800
Drainage Pump Installation for Kharabeh Ramit 5 ft^3/s or 142 liters/sec. capacity	1	ea	58,500	15,000.00	58,500	15,000
Net drainage system cost					4,663,530	1,195,780
Contingencies @ 20%					932,720	239,160
Contract Costs					5,596,270	1,434,940
Engineering @ 15%					839,440	215,240
Project drainage system cost					6,435,700	1,650,180
Ancillary drainage development cost					2,008,000	515,000
Total drainage development cost					8,444,000	2,165,000
Local Costs					6,299,000	1,615,000
Foreign Costs 1/					2,145,000	550,000

1/ Foreign costs include: 2 backhoes, 6 tractors with land plane and ditcher attachments.

Table AII-13. Cost Summary - Janoubi River Channel Improvement (Syrian side only)

Item	Quantity	Unit	Unit Costs S.P.	Unit Costs U.S. $	Total Costs S.P.	Total Costs U.S. $
Earth Excavation (River bank excavation allows for 20% shrinkage in spoil bank)	132,200	m^3	8	2.05	1,057,000	271,000
Placement and Compaction (Compaction by equipment travel)	106,600	m^3	8	2.05	852,200	218,500
Spoil Bank (River crossing)	3	ea	39,000	10,000.00	117,000	30,000
Flap Gate Structure (Capacity 2.55 m^3/s mouth of Saroud Sabyga)	1	ea	46,800	12,000.00	46,800	12,000
River Bank Clearing (Trees and brush)	15	ha	3,460	890.00	52,100	13,400
			Net Costs		2,125,100	544,900
			Contingencies @ 20%		425,000	108,900
			Contract Costs		2,550,000	653,800
			Engineering @ 15%		382,500	98,200
			TOTAL COSTS		2,932,600	752,000
			Local Costs		2,152,600	552,000
			Foreign Costs 1/		780,000	200,000

1/ Foreign costs include imported dragline with accessories.

OPERATION AND MAINTENANCE COST

Janoubi River Channel Improvement

The annual operation and maintenance required for the Janoubi River Channel Improvement would consist, principally, of exterminating brush from the river bank. The estimated annual cost for this purpose would be 3,900 S.P. ($1,000). Other minor features to be maintained would include the flap gate structure and road crossings, but the cost would be minimal.

Drainage System

The estimated annual operation and maintenance required for the drainage features of the Akkar Plain Project are based on experience of the U.S. Bureau of Reclamation for similar features. The cost breakdown for the separate drain categories follow:

	S.P.	U.S. $
Natural surface drains (constant flow)	2,000	500
Natural surface drains (intermittent flow)	5,800	1,500
Constructed drains	4,300	1,100
Roadside borrow pits utilized as drains	1,600	400
Subsurface drains	3,000	800
Sump pump	4,300	1,100
TOTAL DRAINAGE SYSTEM ANNUAL O & M	21,000	5,400

The actual operation and maintenance work would be accomplished in conjunction with other project features by the Akkar Plain Authority.

AKKAR PLAIN AGRICULTURAL DEVELOPMENT PROJECT

APPENDIX AIII

AGRICULTURE

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APPENDIX AIII

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APPENDIX AIII

AGRICULTURE

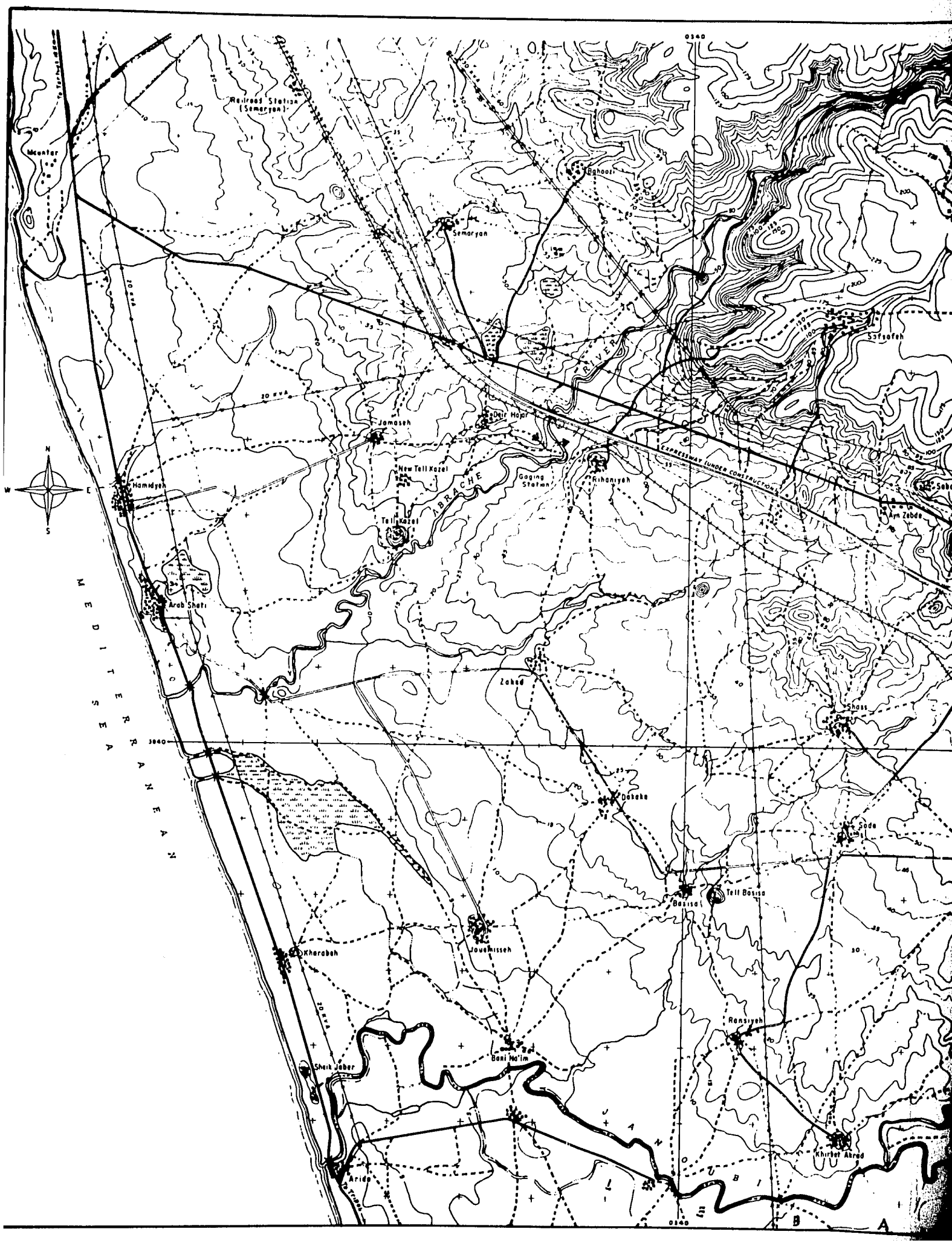
IRRIGATION

IRRIGATION - GENERAL

The Akkar Plain Project is located on the Mediterranean Coast approximately 25 km south of Tartous. The project comprises approximately 23,000 hectares. Four rivers traverse the Plain; the Abrache, Arouse, Kalife, and Abo Falat. The Janoubi River, which forms the south boundary of of the project, is the boundary between Syria and Lebanon, Figure AIII-1. Diversions for irrigation total 955 hectares. There are approximately 800 wells on the project (dug and tube) and a number of small pumps on the Janoubi River which are used to irrigate approximately 1,550 hectares making the total irrigated area from all sources approximately 2,500 hectares.

Cropping Pattern

A cropping pattern was developed to utilize double-cropping of high intensity crops. A pattern was developed for each of the four land capability classes based on what crops would produce best on each class. The soil condition was taken into consideration along with the climate of the area, the water requirements, the adaptability of the crop, and the potential market or marketability of each crop. No crops were included which are not presently grown in the area. Table AIII-1 shows the approximate percent of each crop to be grown on each land class. It was determined that the net irrigable area constitutes approximately 86 percent of the gross land areas.


Railroad Station (Semaryan)
Mounter
Semaryan
Bahoos
Sarsafeh
Jamaseh
Deir Hajar
New Tell Kazel
Gaging Station
Rihaniyeh
EXPRESSWAY (UNDER CONSTRUCTION)
Tell Kazel
ABRACHE
RIVER
Hamidyeh
Arab Sheri
Zaheb
Shass
Dakaka
Sada
Tell Bassa
Bassisa
Jouehisseh
Kherabah
Ransiyeh
Bani Ma'lim
Sheik Jaber
Arida
Khirbet Ahrad
MEDITERRANEAN
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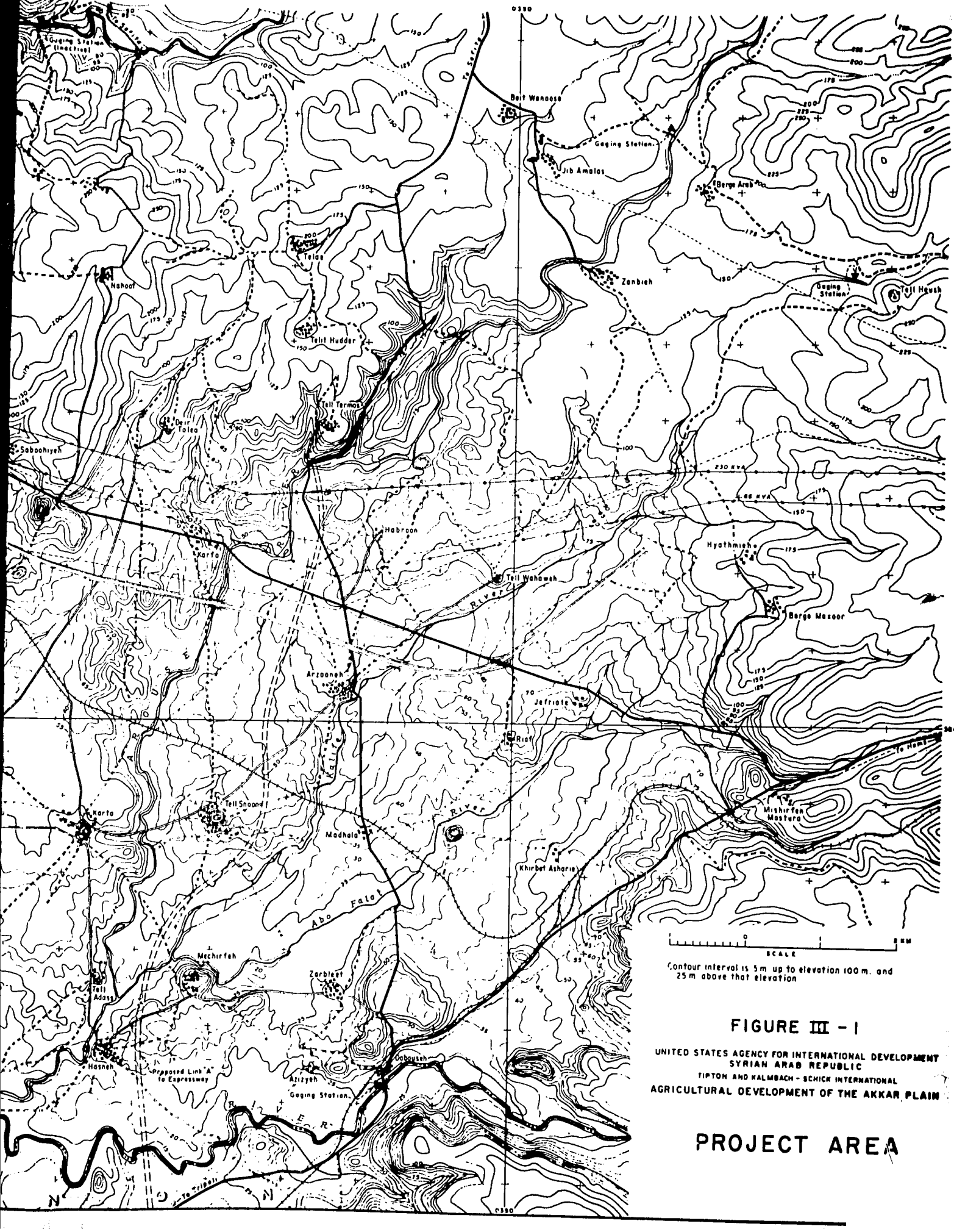


FIGURE III - 1

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
SYRIAN ARAB REPUBLIC
TIPTON AND KALMBACH - SCHICK INTERNATIONAL
AGRICULTURAL DEVELOPMENT OF THE AKKAR PLAIN

PROJECT AREA

Table AIII-1. Future Cropping Pattern by Land Capability Class

Crop	Spring Season %	Summer Season %
CLASS I		
Small Vegetables	27	41
Tomatoes	27	27
Table Maize	5	0
Grain Maize	10	0
Melons	10	0
Cole Crops	0	15
Beans	0	10
Wheat	14	0
Citrus	1	1
Wasteland	6	6
	100	100
CLASS II		
Small Vegetables	26	20
Tomatoes	20	26
Wheat	22	0
Cole Crops	0	22
Melons	20	0
Beans	0	20
Vetch	0	5
Grain Maize	5	0
Citrus	1	1
Wasteland	6	6
	100	100
CLASS III		
Wheat	54	0
Beans & Lentils	0	49
Spanish Beans	20	0
Sorghum	0	20
Vetch	20	0
Grain Maize	0	20
Table Maize	0	5
Wasteland	6	6
	100	100
CLASS IV		
Sorghum	25	0
Sorghum-Sudan	25	0
Pasture	44	44
Wasteland	6	6
Fallow	0	50
	100	100

Diversion Requirement

The diversion requirement is the quantity of water necessary to divert from the source to provide sufficient water for the crop and to cover all losses in the conveyance system between the point of origin and the plant. The total requirement includes the plant consumptive use, canal losses, leaching requirements, and management losses. Water for leaching was not considered in determining the diversion requirement since approximately 600 mm of precipitation occurs on the Akkar Plain during the period of November through February when the crop requirement is low and the natural precipitation can leach through the soil.

Consumptive Use Methodology

Consumptive use, often called evapo-transpiration, is the amount of water used by vegetative growth in transpiration and building of plant tissue, evaporation from adjacent soil and precipitation intercepted and retained by plant foliage. In other words, this is the amount of water needed so that plant production is not limited by lack of water. This requirement is determined largely by the genetic characteristics of the plant, length of the growing season and the evaporative potential. The evaporative potential is determined by a number of variable factors, the most important of which are temperature, humidity and daylight hours (influenced mainly by latitude). It has been determined that the stage of a plant's growth is also an important factor in the rate of water use. This is especially true for annual crops which have three rather distinct stages of growth: (1) emergence and development of full vegetative growth; (2) the period of maximum vegetative cover; and (3)

maturation, which is a period of reduced consumptive use for most crops, where the plant is the limiting factor in the transpiration rate. These factors all influence the amount of water which is consumed in a given area. However, there are other factors which result in substantial differences in the rate of consumptive use. An example is where irrigation is required to fully mature some crops and to produce more than one crop, which is the case on the Akkar Plain. Here both the quantity and seasonal distribution of the project water supply will affect the consumptive use rate. Where the water supply is plentiful and cheap, farmers will tend to overirrigate which increases the evaporation potential by maintaining a moist soil surface. Perennial crops on the Akkar Plain will transpire water almost the entire year because of the lack of frost. Annual crops will consume water only during their short growing season. The consumptive use of all crops must be met to obtain maximum production. Information regarding seasonal and peak use rates is necessary to determine storage requirements and design of the irrigation distribution system and also in order to determine project costs and energy requirements for pumping.

Several methods have been developed for estimating the peak, monthly, and seasonal water requirements for crops. These methods are somewhat comparable in accuracy but differ in convenience of use, and some require more climatic and soils data than is available or can be obtained for many projects. Since climatic data for the Akkar Plain are mainly limited to temperature, precipitation, and humidity, a method that utilizes these parameters to determine consumptive use is desired.

Blaney and Criddle found that the consumptive use of water by crops was

closely correlated with the mean temperature and daylight hours. They developed coefficients that can be used to transpose consumptive use data developed in one area to other areas where only climatological data are available. Temperature, which has a direct bearing on radiation, is the most important factor affecting the water use requirements of crops. The Blaney-Criddle equation for estimating consumptive use has been used with satisfactory results throughout the world with only minor correction for conditions peculiar to a particular area. They have demonstrated that the monthly consumptive use of water by crops varies directly with the product of the mean monthly temperature and percentage of daylight hours, Table AIII-2, which can be expressed by the equation:

$$U = \sum u = \sum kf = k \sum p \quad \frac{(45.7t + 813)}{100}$$

where:

U = seasonal consumptive use

U = monthly consumptive use in millimeters

k = monthly consumptive use coefficient characteristic of each crop

$f = p \frac{(45.t= 813)}{100}$, the consumptive use factor in millimeters,

where p = the monthly percentage of daylight hours in the year, and t = mean monthly temperature in degree centrigrade (corresponds to $f = \frac{pt}{100}$, expressed in inches when t = degree Fahrenheit).

As pointed out above, the stage of the crops' growth has a major influence on the consumptive use; therefore, the monthly consumptive use

Table AIII-2. Monthly Percentage of Daytime Hours (p) of the Year for Latitude 35°North of the Equator

January	7.04
February	6.88
March	8.35
April	8.82
May	9.76
June	9.76
July	9.93
August	9.37
September	8.36
October	7.88
November	6.98
December	6.87

coefficients (k values) were modified by use of "Crop-Growth Stage Coefficient Curves" developed for various crops by Blaney and Criddle. These curves relate the stage of crop maturity to the elapsed time after planting instead of to the calendar or growing period. Crop-growth coefficients based on these curves for all project crops are shown in Table AIII-3. Another modification of the formula requires the use of climatic coefficients that are directly related to mean air temperature, Table AIII-4.

The growing season on the Akkar Plain is not limited by frost. The coldest temperature in 20 years of record at Tartous was -1°C which occurred during January, the coldest month of the year; the mean temperature is 12°C. The growing season for project crops was determined by a double-cropping pattern for some crops and the optimum growth period for single crops.

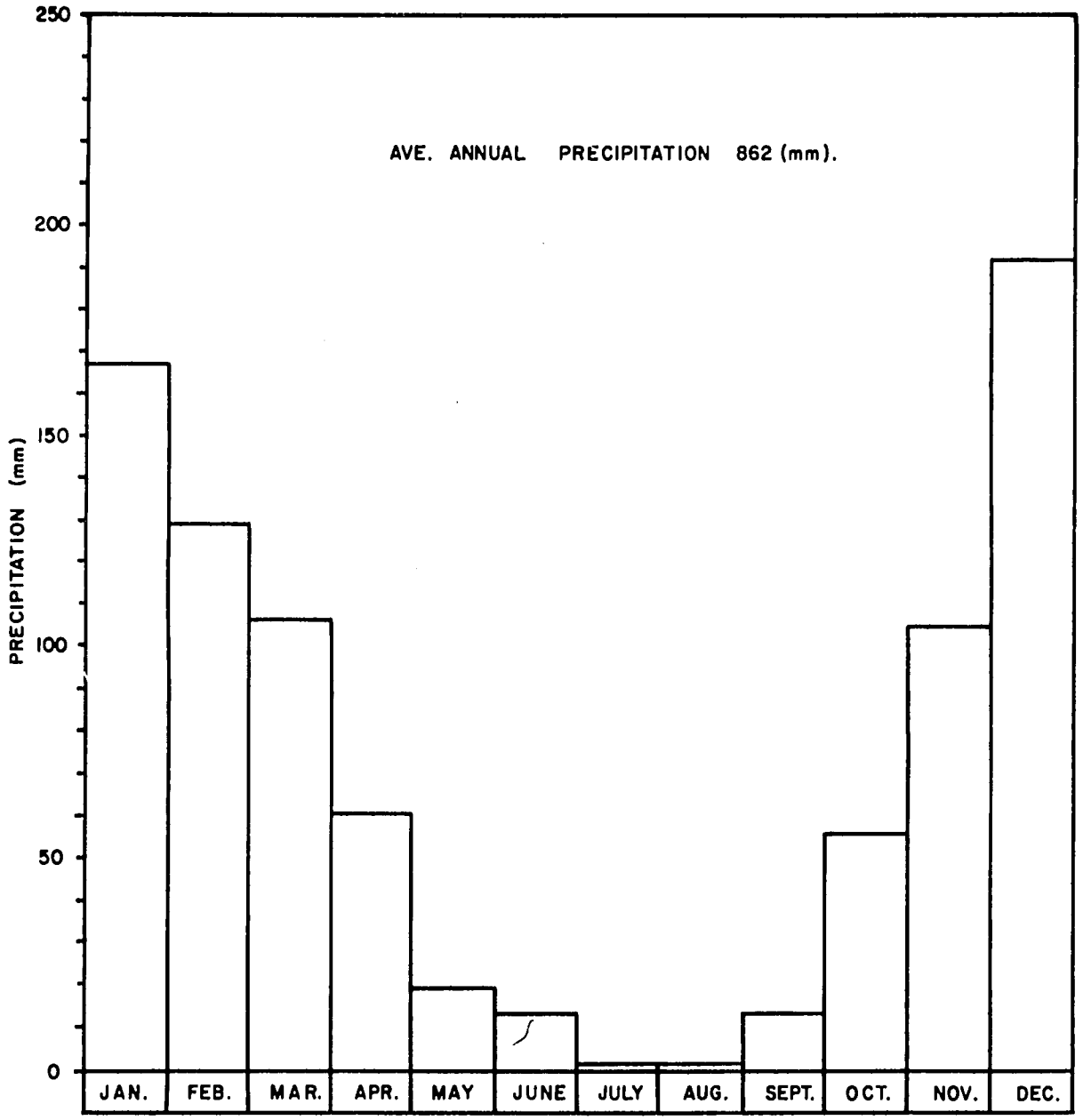
Twenty-three years of climatological data (1955-1977) are available for Tartous, 25 km to the northwest, and at Safita, 10 km west of the project at elevation 300 m. A short intermittent record of precipitation and temperature is available at Hamidyeh on the west boundary of the project. Climatological data at Tartous were used in the consumptive use study. Figures AIII-1A, AIII-2, and AIII-3 show the mean monthly precipitation, temperature, and humidity at Tartous. These data are considered generally representative of climatic conditions on the Akkar Plain, except it was noted during collection of field data that there was considerably stronger and more frequent wind on the Plain than at Tartous. Also, storm patterns were influenced by mountains around the project, especially the 3,000 m Lebanese mountains, 30 km south of the project. Storms from the west are deflected by these mountains to the

Table AIII-3. Crop Growth Stage Coefficients

Crop	Percent of Growing Season									
	10	20	30	40	50	60	70	80	90	100
Maize	0.49	0.58	0.71	0.92	1.05	1.08	1.06	1.00	0.93	0.85
Table Maize	0.50	0.47	0.71	0.92	1.05	1.07	1.07	1.06	1.03	1.00
Dry Beans	0.59	0.72	0.89	1.03	1.11	1.12	1.02	0.89	0.74	0.60
Melons	0.48	0.56	0.65	0.76	0.82	0.81	0.78	0.74	0.71	0.68
Small Vegetables	0.39	0.56	0.69	0.77	0.82	0.83	0.80	0.72	0.58	0.38
Tomatoes	0.46	0.48	0.56	0.76	0.95	1.03	0.99	0.90	0.80	0.69
Pasture Grass	0.53	0.65	0.85	0.92	0.97	0.92	0.90	0.77	0.60	0.47
Grain Sorghum	0.38	0.60	0.83	1.02	1.08	1.00	0.88	0.76	0.63	0.56
Winter Wheat	0.34	0.45	0.58	0.72	0.85	0.92	0.90	0.52	0.23	0.00
Citrus	0.65	0.67	0.70	0.71	0.72	0.72	0.71	0.68	0.66	0.63
Cole Crops	0.39	0.56	0.69	0.77	0.82	0.83	0.80	0.72	0.58	0.38
Beans-Lentils	0.59	0.72	0.89	1.03	1.11	1.12	1.02	0.89	0.74	0.60
Vetch	0.53	0.65	0.85	0.92	0.97	0.92	0.90	0.77	0.60	0.47

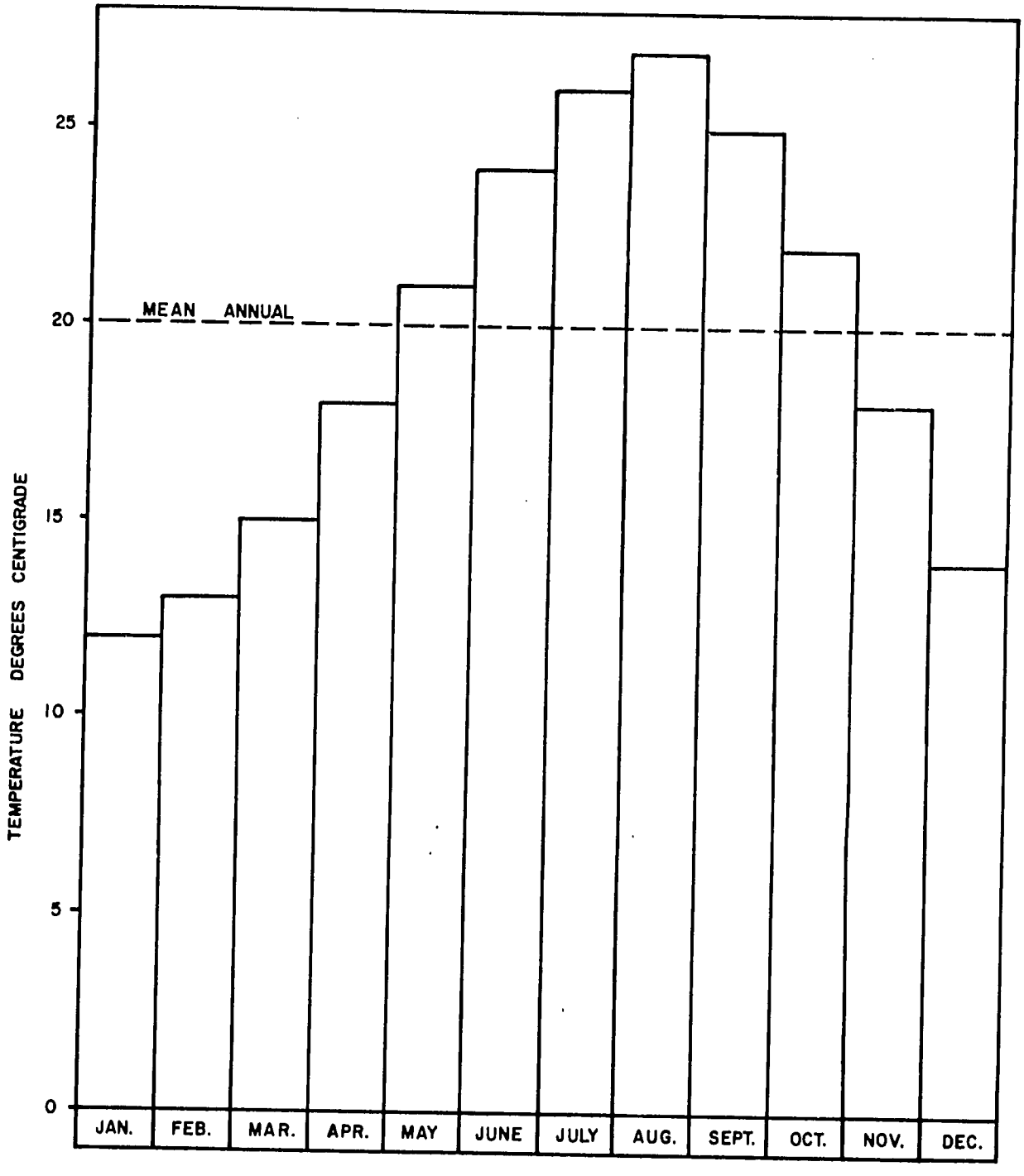
Table AIII-4. Values of the Climatic Coefficient, k_t for Various Mean Air Temperature, t

Temp °C	k_t	Temp °C	k_t	Temp °C	k_t
2.2	0.31	16.1	0.74	30.0	1.17
2.8	0.33	16.7	0.76	30.6	1.19
3.3	0.34	17.2	0.78	31.1	1.21
3.9	0.36	17.8	0.79	31.7	1.23
4.4	0.38	18.3	0.81	32.2	1.24
5.0	0.40	18.9	0.83	32.8	1.26
5.6	0.41	19.4	0.85	33.3	1.28
6.1	0.43	20.0	0.86	33.9	1.30
6.7	0.45	20.6	0.88	34.4	1.31
7.2	0.46	21.1	0.90	35.0	1.33
7.8	0.48	21.7	0.91	35.6	1.35
8.3	0.50	22.2	0.93	36.1	1.36
8.9	0.52	22.8	0.95	36.7	1.38
9.4	0.53	23.3	0.97	37.2	1.40
10.0	0.55	23.9	0.98	37.8	1.42
10.6	0.57	24.4	1.00	38.3	1.43
11.1	0.59	25.0	1.02	38.9	1.45
11.7	0.60	25.6	1.04	39.4	1.47
12.2	0.62	26.1	1.05	40.0	1.49
12.8	0.64	26.7	1.07	41.1	1.52
13.3	0.66	27.2	1.09	41.7	1.54
13.9	0.67	27.8	1.11	42.2	1.56
14.4	0.69	28.3	1.12	42.8	1.60
15.0	0.71	28.9	1.14		
15.6	0.72	29.4	1.16		



MEAN MONTHLY PRECIPITATION — TARTOUS
(1955–1977)

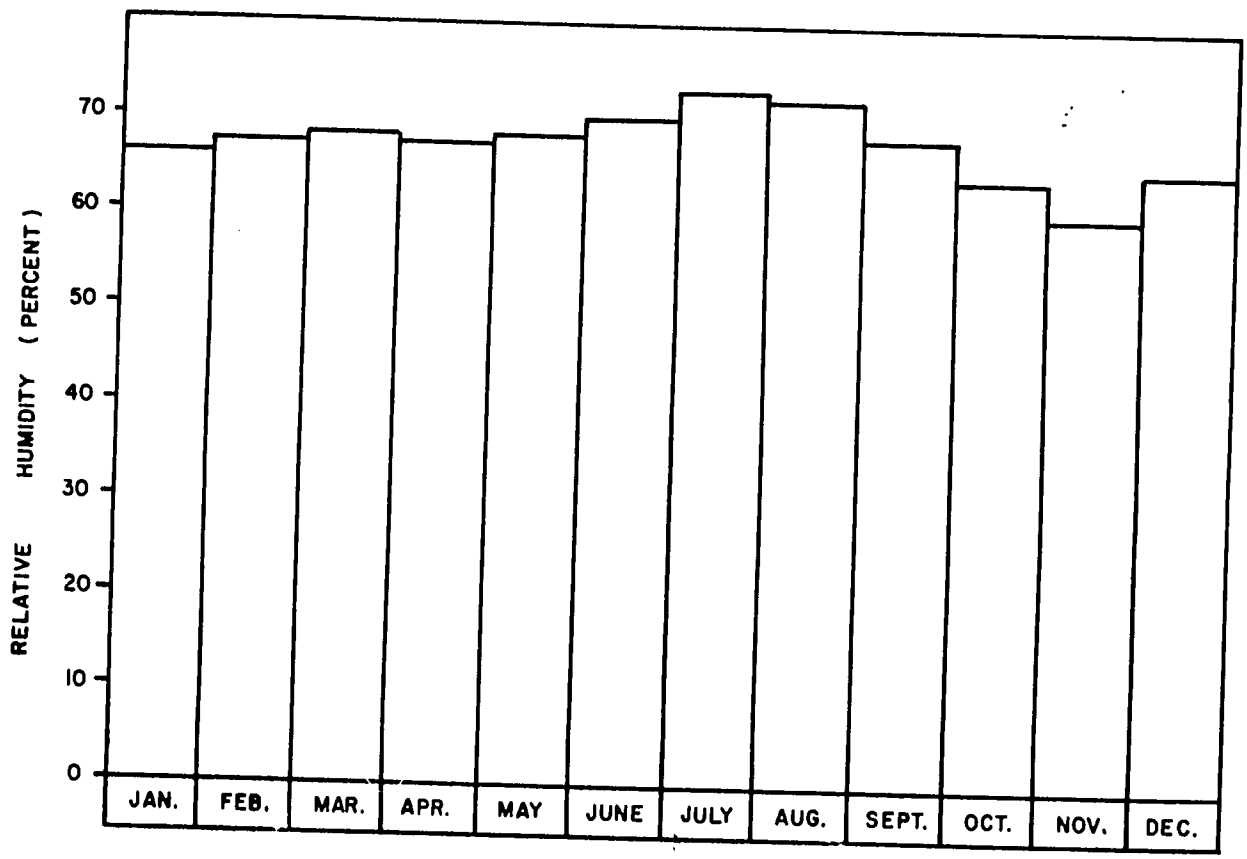
FIGURE A III - 1A



MEAN MONTHLY TEMPERATURE — TARTOUS
(1955–1974)

TIPTON AND KALMBACH — SCHICK INTERNATIONAL

FIGURE AIII - 2



MEAN MONTHLY RELATIVE HUMIDITY—TARTOUS
(1969-1971)

TIPTON AND KALMBACH — SCHICK INTERNATIONAL

FIGURE AIII - 3

lower mountains to the east and north of the project. This results in storms being somewhat contained over the project with a circling pattern, which probably increases the precipitation compared with Tartous.

Consumptive Use

Estimates of the average daily, monthly and seasonal consumptive use were made for each of the project crops, Table AIII-5 through AIII-30. Figure AIII-4, shows the cropping pattern and length of growing season. Consumptive use requirements by months for individual crops at the field were summarized, Table AIII-31. It is noted from the table that the rate of consumptive use for the various crops ranges from 268 mm for cole crops grown in the summer to 1,253 mm for pasture grass and vetch, which are perennial crops. The average for all crops is 487 mm.

Peak Period Consumptive Use

The maximum consumptive use rate is required for design of the irrigation systems. It is used to determine the minimum capacity for the distribution system including canals, laterals, pipelines, and control structures. Knowing the period peak demand is important from the standpoint of project administration which requires timely regulation of streams and storage reservoirs.

The peak period of consumptive use occurs when the weighted average daily rate of consumptive use for crops under the project cropping pattern is at a maximum. It is noted that under the double-cropping pattern, crops are being planted and harvested throughout the summer. Thus the daily rate of consumptive use varies widely depending on the stage of crop growth. While other factors, such as humidity, wind movement and elevation, influence peak

Table AIII-5. Estimate of Average Daily, Monthly and Seasonal Consumptive Use For Melons.

Season 15 March - 15 July (Days 122)
Kc = curve No. 15

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
15 Mar											
	Mar 23	8	7	59	2.25	1.33	0.71	0.46	0.33	11.2	1.5
Apr											
	Apr 15	31	25	64	8.82	5.64	0.79	0.60	0.47	67.3	2.3
May											
	May 15	62	51	70	9.75	6.83	0.90	0.82	0.74	128.3	4.1
June											
	June 15	92	75	75	9.75	7.31	0.98	0.76	0.74	137.4	4.6
July 15											
	July 8	100	82	79	2.68	2.12	1.05	0.74	0.78	41.4	5.1
							TOTAL			386 (mm)	

Table AIII-6. Estimate of Average Daily, Monthly and Seasonal Consumptive Use For Dry Beans and Lentils.

Season July 1 - November 1 (123 Days)
Kc = curve No. 8

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
July											
	July 15	15	12	79	4.96	3.92	1.05	0.61	0.64	63.8	4.3
August											
	Aug 15	46	37	81	9.37	7.59	1.09	1.00	1.09	210.1	6.9
Sept											
	Sept 15	76	62	77	8.36	6.44	1.02	1.10	1.12	183.0	6.1
Oct											
	Oct 15	107	87	72	7.88	5.67	0.93	0.79	0.73	105.2	3.6
Nov											
							TOTAL			562 mm	

Table AIII-7. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Dry Beans.

Season: 10 November - 5 April (146 Days)

Kc = curve No. 8

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
10 Nov											
	Nov 20	10	7	64	2.32	1.48	0.79	0.55	0.43	16.3	1.5
Dec											
	Dec 15	35	24	57	6.87	3.92	0.67	0.78	0.52	51.8	1.8
Jan											
	Jan 15	66	45	54	7.05	3.81	0.62	1.08	0.67	64.8	2.0
Feb											
	Feb 14	96	66	55	6.88	3.78	0.64	1.06	0.68	65.3	2.3
Mar											
	Mar 15	125	86	59	8.35	4.93	0.71	0.80	0.57	71.4	2.3
Apr											
	Apr 3	143	98	64	0.88	0.6	0.79	0.62	0.49	7.6	2.5
Apr 5											
							TOTAL			277 mm	

Table AIII-8. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Spanish Beans (Dry Beans).

Season 1 November - 1 April (151 Days)
Kc= curve No. 8

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Nov											
	Nov 15	15	10	64	3.49	2.23	0.79	0.59	0.47	26.7	1.8
Dec											
	Dec 15	45	30	57	6.87	3.92	0.67	0.90	0.60	59.7	2.0
Jan											
	Jan 15	76	50	54	7.05	3.81	0.62	1.11	0.69	66.8	2.3
Feb											
	Feb 14	107	71	55	6.88	3.78	0.64	1.02	0.65	62.5	2.3
Mar											
	Mar 15	135	89	59	8.35	4.93	0.71	0.76	0.54	67.6	2.3
Apr											
							TOTAL			283 mm	

Table AIII-9. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Cole Crops.

Season: 15 August - 15 November
Kc = curve No. 22
Lattitude 34° 53' North

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Aug 15											
	Aug 23	8	9	81	2.44	1.98	1.09	0.38	0.41	20.6	2.5
Sept											
	Sept 15	31	34	77	8.36	6.44	1.02	0.73	0.74	121.2	3.8
Oct											
	Oct 15	61	66	72	7.88	5.67	0.93	0.83	0.77	111.0	3.6
Nov											
	Nov 8	84	91	64	1.81	1.16	0.79	0.67	0.53	15.5	2.0
Nov 15											
							TOTAL			268 mm	

Growing Season: 92 Days

Table AIII-10. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Cole Crops.

Season: 1 August - 1 November
Kc = curve No. 22 (small vegetables)
Lattitude 34°53' north

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t °F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Aug											
	Aug 15	15	16	81	4.68	3.79	1.09	0.50	0.55	52.8	3.6
Sept											
	Sept 15	46	50	77	8.36	6.44	1.02	0.81	0.83	135.9	4.6
Oct											
	Oct 15	77	84	72	7.88	5.67	0.93	0.67	0.62	89.4	2.8
Nov											
							TOTAL			278 mm	

Growing Season (92 Days)

Table AIII-11. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Tomatoes.

Season: March 1 - June 30 (122 Days)
Kc = curve No. 21

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Mar											
	Mar 15	15	12	59	4.17	2.46	0.71	0.46	0.33	20.6	1.3
Apr											
	Apr 15	46	38	64	8.82	5.64	0.79	0.70	0.55	78.7	2.5
May											
	May 15	77	63	70	9.75	6.82	0.90	1.03	0.93	161.0	5.1
June											
	June 15	107	88	75	9.75	7.31	0.98	0.82	0.80	148.6	5.1
July											
							TOTAL			409 mm	

Table AIII-12. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Tomatoes.

Season: 15 March - 1 July (107 Days)
Kc = curve No. 21

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Mar 15											
	Mar 23	8	7	59	2.17	1.28	0.71	0.45	0.32	10.4	1.3
Apr											
	Apr 15	32	30	64	8.82	5.64	0.79	0.57	0.45	64.5	2
May											
	May 15	63	59	70	9.75	6.83	0.90	1.03	0.93	161.3	5.1
June											
	June 15	93	87	75	9.75	7.31	0.98	0.96	0.94	174.5	5.8
July											
							TOTAL			411 mm	

Table AIII-13. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Field Maize.

Season: 1 May to 1 September. (122 Days)
Kc = curve No. 1

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
May	May 15	15	12	70	4.88	3.42	0.90	0.50	0.45	39.1	2.5
June	June 15	46	38	75	9.75	7.31	0.98	0.89	0.87	161.5	5.3
July	July 15	76	62	79	9.92	7.84	1.05	1.08	1.13	225.0	7.4
Aug	Aug 15	107	88	81	9.37	7.59	1.09	0.94	1.02	196.6	6.3
Sept											
							TOTAL			622 mm	

Table AIII-14. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Field Maize.

Growing Season: 1 March - 15 July
Kc = curve No. 1
Lattitude 34°53' north

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t °F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Mar 1											
	Mar 15	15	11	59	4.18	2.47	0.71	0.50	0.36	22.6	1.5
Apr											
	Apr 15	46	33	64	8.82	5.64	0.79	0.78	0.62	88.9	3.0
May											
	May 15	77	56	70	9.75	6.83	0.90	1.08	0.97	168.4	5.3
June											
	June 15	107	78	75	9.75	7.31	0.98	1.02	1.00	185.7	6.1
July											
	July 8	115	83	79	2.58	2.04	1.05	0.98	1.03	53.3	6.6
July 15											
							TOTAL			519 mm	

Growing Season: (138 Days)

Table AIII-15. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Table Maize.

Season: March 1 - May 31 (92 Days)
Kc = curve No. 5 (122)

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Mar	Mar 15	15	16	59	4.17	2.46	0.71	0.55	0.39	24.4	1.5
Apr	Apr 15	46	50	64	8.82	5.64	0.79	1.05	0.83	118.9	4.1
May	May 15	77	84	70	9.75	6.82	0.90	1.07	0.96	166.4	5.3
June	Jun 15	107	88	75	9.75	7.31	0.98	103	1.01	(7.38) 1/	
July											
							TOTAL			310 mm	

1/ Not included in total below- used in peak period study.

Table AIII-16. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Pasture Grasses (Alta Fesque).

Season: Annual (365 days)
Kc = curve No. 17

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Jan											
	Jan 15	15	04	54	3.53	1.90	0.62	0.47	0.29	14.0	1.0
Feb											
	Feb 15	46	13	55	6.88	3.78	0.64	0.57	0.36	34.5	1.3
Mar											
	Mar 15	74	20	59	8.35	4.93	0.71	0.75	0.53	66.3	2.0
Apr											
	Apr 15	105	29	64	8.82	5.64	0.79	0.85	0.67	96.0	3.3
May											
	May 15	135	37	70	9.75	6.83	0.90	0.90	0.81	140.5	4.6
June											
	June 15	166	45	75	9.75	7.31	0.98	0.92	0.90	167.1	5.6
July											
	July 15	196	54	79	9.92	7.84	1.05	0.93	0.98	195.1	6.4
Aug											
	Aug 15	227	62	81	9.37	6.59	1.09	0.91	0.99	190.8	6.1
Sept											
	Sept 15	258	71	77	8.36	6.44	1.02	0.87	0.89	145.5	4.8
Oct											
	Oct 15	288	79	72	7.88	5.67	0.93	0.80	0.74	106.7	3.6
Nov											
	Nov 15	319	87	64	6.98	4.46	0.79	0.67	0.53	59.9	2.6
Dec											
	Dec 15	350	96	57	6.87	3.92	0.67	0.55	0.37	49.3	1.3
								TOTAL		1252 (mm)	

Table AIII-17. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Vetch.

Season: 1 October - 1 April (182 Days)

Kc = curve No. 17
(pasture grass)

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Oct	Oct 15	15	8	72	3.94	2.84	0.93	0.75	0.70	50.6	3.3
Nov	Nov 15	46	25	64	6.98	4.47	0.79	0.63	0.50	56.9	1.8
Dec	Dec 15	76	42	57	6.87	3.92	0.67	0.55	0.37	36.8	1.3
Jan	Jan 15	107	59	54	7.05	3.81	0.62	0.55	0.34	33.0	1.0
Feb	Feb 14	136	75	55	6.88	3.78	0.64	0.58	0.37	35.6	1.3
Mar	Mar 15	166	91	59	8.35	4.93	0.72	0.75	0.54	67.6	2.3
Apr											
								TOTAL		280 mm	

Table AIII-18. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Citrus.

Growing Season: 365 days

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Jan											
	Jan 15	15	04	54	3.54	1.91	0.62	0.62	0.38	18.5	1.27
Feb											
	Feb 15	46	13	55	6.88	3.78	0.64	0.66	0.42	40.4	1.52
Mar											
	Mar 15	74	20	59	8.35	4.93	0.71	0.68	0.48	60.2	2.03
Apr											
	Apr 15	105	29	64	8.82	5.64	0.79	0.70	0.55	78.7	2.54
May											
	May 15	135	37	70	9.75	6.82	0.90	0.71	0.64	110.7	3.56
June											
	June 15	166	45	75	9.75	7.31	0.98	0.72	0.71	131.8	4.32
July											
	July 15	196	54	79	9.92	7.84	1.05	0.72	0.76	151.4	4.83
Aug											
	Aug 15	227	62	81	9.37	7.59	1.09	0.71	0.77	148.3	4.83
Sept											
	Sept 15	258	71	77	8.36	6.44	1.02	0.70	0.71	116.1	3.81
Oct											
	Oct 15	288	79	72	7.88	5.67	0.93	0.68	0.63	90.7	3.05
Nov											
	Nov 15	318	87	64	6.98	4.47	0.79	0.67	0.53	60.2	2.03
Dec											
	Dec 15	348	95	57	6.87	3.92	0.67	0.64	0.43	42.9	1.27
								TOTAL		1050 (mm)	

Table AIII-19. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Small Vegetables.

Season: July 1 - October 15 (107 Days)
Kc= curve No. 22

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
July	July 15	15	14	79	4.96	3.92	1.05	0.46	0.48	47.8	3.3
Aug	Aug 15	46	43	81	9.37	7.59	1.09	0.79	0.86	165.9	5.3
Sept	Sept 15	77	72	77	8.36	6.44	1.02	0.78	0.80	130.8	4.3
Oct	Oct 8	100	93	72	1.97	1.42	0.93	0.52	0.48	17.3	2.0
Oct 15											
							TOTAL			362 mm	

Table AIII-20. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Sorghum.

Season: 15 March to 15 August (153 Days)
Kc = curve No. 19

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Mar 15											
	Mar 23	8	5	59	2.09	1.23	0.71	0.33	0.23	7.1	1.0
Apr											
	Apr 15	31	20	64	8.82	5.64	0.79	0.60	0.47	67.3	2.3
May											
	May 15	62	40	70	9.75	6.83	0.90	1.02	0.92	159.5	5.1
June											
	June 15	92	60	75	9.75	7.31	0.98	1.00	0.98	181.9	6.1
July											
	July 15	123	80	79	9.92	7.84	1.05	0.76	0.80	159.3	5.1
Aug											
	Aug 8	147	96	81	2.34	1.89	1.09	0.59	0.64	30.7	3.8
Aug 15											
							TOTAL			606 mm	

Table AIII-21. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Small Vegetables.

Season: 15 March - 1 July (107 Days)
Kc = curve No. 22
Lattitude 34°53' north

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Mar 15											
	Mar 23	8	7	59	2.26	1.33	0.71	0.36	0.26	8.9	1.0
Apr											
	Apr 15	39	36	64	8.32	5.32	0.79	0.75	0.59	79.8	2.5
May											
	May 15	70	65	70	9.75	6.82	0.90	0.82	0.74	128.3	4.1
June											
	June 15	100	93	75	9.75	7.31	0.98	0.52	0.51	94.7	3.0
July 1											
							TOTAL			312 mm	

Table AIII-22. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Small Vegetables.

Season: August 1 - November 15
Kc = curve No. 22 (107 Days)

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Aug											
	Aug 15	15	14	81	4.68	3.79	1.09	0.46	0.50	48.3	3.3
Sept											
	Sept 15	46	43	77	8.36	6.44	1.02	0.79	0.81	132.6	4.3
Oct											
	Oct 15	77	72	72	7.88	5.67	0.93	0.78	0.73	105.2	3.3
Nov											
	Nov 8	100	93	64	3.49	2.23	0.79	0.52	0.41	23.1	1.5
Nov 15											
								TOTAL		309 (mm)	

Table AIII-23. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Small Vegetables.

Season: March 15 - June 20 (97 days)
Kc = curve No. 22

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Mar 15											
	Mar 23	8	8	59	2.17	1.30	0.71	0.37	0.26	8.6	1.0
Apr											
	Apr 15	32	34	64	8.82	5.64	0.79	0.73	0.58	83.1	2.8
May											
	May 15	63	65	70	9.75	6.82	0.90	0.82	0.74	128.3	4.1
June											
	June 15	88	91	75	9.75	7.31	0.98	0.56	0.55	102.1	3.3
June 20											
								TOTAL		322 (mm)	

Table AIII-24. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Wheat.

Season: November 1 - June 1 (212 days)
Kc = curve No. 24

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Nov											
	Nov 15	15	7	64	3.49	2.23	0.79	0.32	0.25	14.2	0.10
Dec											
	Dec 15	46	22	57	6.87	3.92	0.67	0.45	0.30	29.3	1.00
Jan											
	Jan 15	77	36	54	7.05	3.81	0.62	0.66	0.41	39.6	1.30
Feb											
	Feb 15	105	50	55	6.88	3.78	0.64	0.85	0.54	51.8	1.80
Mar											
	Mar 15	136	64	59	8.35	4.92	0.71	1.02	0.72	89.9	2.30
Apr											
	Apr 15	166	78	64	8.82	5.64	0.79	1.15	0.91	130.3	4.30
May											
	May 15	197	93	70	9.75	6.83	0.90	1.30	1.17	203.0	6.60
June											
								TOTAL		558 (mm)	

Table AIII-25. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Sorghum-Sudan.

Season: March 1 - August 15 (168 days)
Kc = curve No. 19

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0C F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Mar	Mar 15	15	9	59	4.17	2.46	0.71	0.36	0.26	16.3	1.0
Apr	Apr 15	46	27	64	8.82	5.64	0.79	0.76	0.60	85.9	2.8
May	May 15	76	45	70	9.75	6.83	0.90	1.08	0.97	168.2	5.5
June	June 15	107	64	75	9.75	7.31	0.98	0.95	0.93	172.7	5.8
July	July 15	137	82	79	9.92	7.84	1.05	0.74	0.78	155.4	5.1
Aug	Aug 15	161	96	81	2.34	1.90	1.09	0.78	0.85	41.2	5.1
Aug 15								TOTAL		640 (mm)	

Table AIII-26. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Sorghum.

Season: May 1 - October 1 (153 days)
Kc = curve No. 19

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
May											
	May 15	15	10	70	4.88	3.42	0.90	0.38	0.34	29.5	2.0
June											
	June 15	46	30	75	9.75	7.31	0.98	0.83	0.81	150.4	5.1
July											
	July 15	76	50	79	9.92	7.84	1.05	1.08	1.13	225.0	7.4
Aug											
	Aug 15	107	70	81	9.37	7.59	1.09	0.88	0.96	185.2	6.1
Sept											
	Sept 15	138	90	77	8.36	6.44	1.02	0.65	0.66	108.0	3.6
Oct											
								TOTAL		698 (mm)	

Table AIII-27. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Table Maize.

Season: June 15 - October 1 (105 days)
Kc = curve No. 5

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
June 15											
	June 23	8	8	75	2.63	1.97	0.98	0.49	0.48	24.1	3
July											
	July 15	30	29	79	9.92	7.84	1.05	0.70	0.73	145.3	5
Aug											
	Aug 15	61	58	81	9.37	7.59	1.09	1.08	1.18	227.6	7
Sept											
	Sept 15	91	87	77	8.36	6.44	1.02	1.05	1.06	173.5	6
Oct 1											
								TOTAL		570 (mm)	

Table AIII-28. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Field Maize.

Season: April 15 - September 15 (150 days)
Kc = curve No. 1

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Apr 15											
	Apr 23	8	5	64	2.63	1.68	0.79	0.46	0.36	15.2	2
May											
	May 15	31	21	70	9.75	6.82	0.90	0.60	0.54	93.5	4
June											
	June 15	61	41	75	9.75	7.31	0.98	0.94	0.92	170.9	6
July											
	July 15	92	61	79	9.92	7.84	1.05	1.08	1.13	225.0	7
Aug											
	Aug 15	123	82	81	9.37	7.59	1.09	1.00	1.09	210.1	7
Sept											
	Sept 15.	131	87	77	2.26	1.74	1.02	0.96	0.98	43.2	3
Sept 15											
								TOTAL		758 (mm)	

Table AIII-29. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Dry Beans.

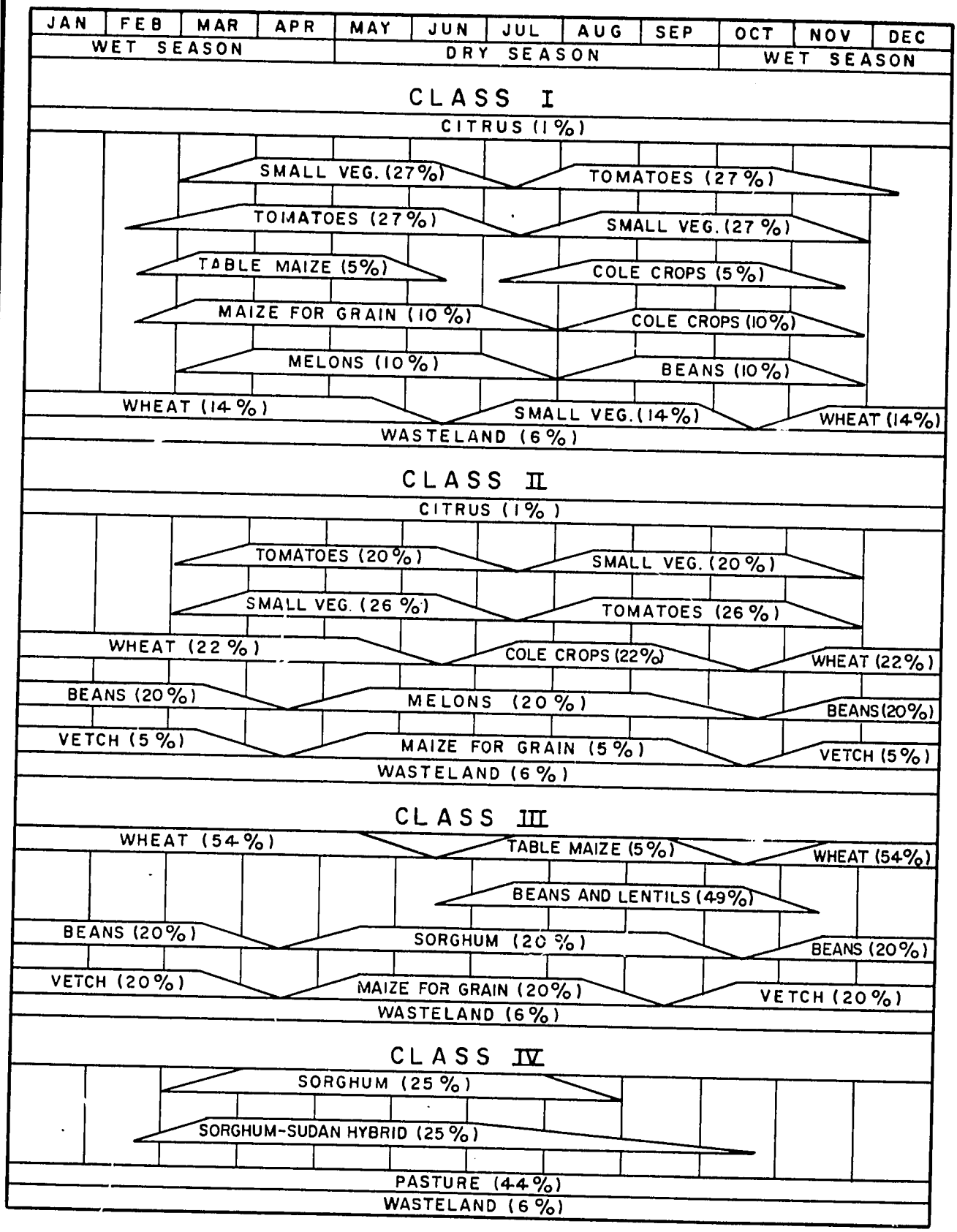
Season: August 15 - November 15 (92 days)
Kc = curve No. 8

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
Aug 15											
	Aug 23	8	9	81	2.53	2.05	1.09	0.58	0.63	32.8	4.1
Sept											
	Sept 15	31	34	77	8.36	6.44	1.02	0.95	0.97	159.0	5.3
Oct											
	Oct 15	62	67	72	7.88	5.67	0.93	1.06	0.99	142.5	4.6
Nov											
	Nov 8	86	93	64	1.41	0.90	0.79	0.70	0.55	12.7	1.5
Nov 15											
								TOTAL		347 (mm)	

Table AIII-30. Estimate of Average Daily, Monthly and Seasonal Consumptive Use for Melons.

Season: May 1 - September 5 (138 days)
Kc = curve No. 15

Month or period	Midpoint of period	Accum. days to midpoint	Percent of growing season	Mean air temp t 0° F.	Daylight hours p. percent	Cons. use factor f.	Climatic coef. k_t	Growth stage coef. k_c	Cons. use coef. k	Monthly cons. use u. mm	Daily cons. use u. m/day
May											
	May 15	15	11	70	4.86	3.4	0.90	0.48	0.43	37.1	2.5
June											
	June 15	46	33	75	9.75	7.31	0.98	0.68	0.67	124.6	4.1
Aug											
	Aug 15	107	76	81	9.37	7.59	1.09	0.76	0.83	160.0	5.1
Sept											
	Sept 8	130	94	77	2.26	1.74	1.02	0.70	0.71	31.5	4.1
Sept 15											
								TOTAL		524 (mm)	



FUTURE CROPPING PATTERN AND LAND USE WITH IRRIGATION BY LAND CAPABILITY CLASS

Akkar Plain Project

TIPTON AND KALMBACH - SCHICK INTERNATIONAL

Table AIII-31
Consumptive Use Requirements
(Values in mm at the Crop)

Crops	% Crop	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Land Capability Class I														
Spring Crops														
Small Vegetables	27			9	83	128	102							322
Tomatoes	27			21	79	161	148							409
Table Maize	5			24	119	167								310
Maize	10			23	89	168	186	53						519
Melons	10			11	67	128	138	42						386
Summer Crops														
Tomatoes	27								49	145	127	13		334
Small Vegetables	27								48	133	105	23		309
Cole Crops	5								53	136	89			278
Cole Crops	10								21	121	111	15		268
Dry Beans	10								33	159	142	13		347
Small Vegetables	14							48	166	131	17			362
Fall Crops														
Wheat	14	40	52	90	130	202						14	30	558
Perennial Crops														
Citrus	1	19	40	60	79	111	132	151	148	116	91	60	43	1050
Land Capability Class II														
Spring Crops														
Tomatoes	20			10	65	161	175							[illegible]
Small Vegetables	26			9	80	128	95							312
Melons	20					37	124	171	160	32				524
Maize	5					39	161	225	197					622
Summer Crops														
Small Vegetables	20								48	133	105	23		309
Tomatoes	26								49	145	127	13		334
Cole Crops	22							52	172	123				347
Fall Crops														
Wheat	22	40	52	90	130	202						14	30	558
Beans	20	67	62	67								27	60	283
Vetch	5	33	36	67							50	57	37	280
Perennial Crops														
Citrus	1	19	40	60	79	111	132	151	148	116	91	60	43	1050
Land Capability Class III														
Spring Crops														
Sorghum	20					30	150	225	185	108				698
Maize	20					39	161	225	197					622
Summer Crops														
Table Maize	5							45	178	135				358
Dry Beans & Lentils	49							64	210	183	105			562
Fall Crops														
Wheat	54	40	52	90	130	202						14	30	558
Beans	20	67	62	67								27	60	283
Vetch	20	33	36	67							50	57	37	280
Land Capability Class IV														
Spring Crops														
Sorghum	25			7	67	160	182	159	31					606
Sorghum-Sudan Hybrid	25			16	86	168	173	156	41					640
Perennial Crops														
Pasture	44	14	34	66	96	140	167	195	191	146	107	60	37	1253

consumptive use, mean air temperature, and net depth of irrigation are important. Since the formula for determining consumptive use is based on air temperature, it would follow that the shorter the peak period in days, the higher the mean temperature and consumptive use rate. However, this assumption does not hold completely for the Akkar Plain where mean temperature, humidity, evaporation, and precipitation are almost constant for the months of June through August.

Month	Temperature	Humidity	Evaporation	Precipitation
June	24°C	70%	130 mm	1 mm 1/
July	26	73	125	1
August	27	72	135	1

Based on the consumptive use study, the weighted monthly consumptive use rates for May, August, and September are almost equal with August, the month of highest consumptive use.

The length of the peak period is determined by the normal length of the irrigation application at the peak rate of use. The U.S. Department of Agriculture developed a table for determining the peak period average daily consumptive use rates based on estimated monthly use and net irrigation application, Table AIII-32.

1/ Mean is 1 mm except for one heavy storm (1976).

Since actual data are not available regarding water holding capacity and infiltration rate for the soil classes to be irrigated, it was necessary to make assumptions based on data developed on similar soils, Table AIII-33. It was assumed that the soil would have a field moisture capacity of approximately 165 mm per meter and that the farmer would start to irrigate at about 50 percent of field moisture level and bring the moisture up to field capacity. Thus the irrigation application was assumed to be 45 percent of field moisture capacity. Net irrigation application was determined for each crop based on each soil type for August, the peak month, Table AIII-34.

Utilizing average monthly consumptive use rates developed for each crops for August, estimated peak consumptive use was determined, Table AIII-35. The study indicates a weighted peak crop consumptive use rate of 6.16 mm per day. Using an overall irrigation efficiency of 60 percent results in a gross diversion requirement of 10.33 mm per day during August.

Effective Precipitation

Effective precipitation is that portion of the rainfall which supplies all or part of the consumptive use requirements of the crop. It is recognized that rains of moderate intensity over a prolonged period are more effectively utilized by crops than high intensity rainfall. Large magnitude and high intensity storms occur on the project during the winter months which often produce water in excess of that which can

Table AIII-32. Peak Period Average Daily Consumptive Use Rates (u_p) as Related to Estimated Actual Monthly Use (u_m)

Net Irrig. Applic. I (mm.) 2/	Computed Peak Monthly Consumptive Use Rate (u_m) in mm 1/																
	102	114	127	140	152	165	178	190	203	216	224	241	254	267	279	292	305 2/
	Peak Period Daily Use Rate (u_p) in mm per Day																
25	3.8	4.6	5.1	5.6	6.1	6.6	7.1	7.9	8.4	8.9	9.4	10.2	10.7	11.2	11.7	12.4	12.9
38	3.8	4.3	4.8	5.3	5.8	6.3	6.9	7.4	8.1	8.6	9.1	9.6	10.4	10.9	11.4	11.9	12.7
51	3.8	4.1	4.6	5.1	5.8	6.3	6.9	7.4	7.9	8.4	8.9	9.4	9.9	10.4	11.2	11.7	12.2
63	3.6	4.1	4.6	5.1	5.6	6.1	6.6	7.1	7.6	8.1	8.6	9.1	9.9	10.4	10.9	11.4	11.9
76	3.6	4.1	4.6	5.1	5.6	6.1	6.6	7.1	7.6	8.1	8.6	9.1	9.6	10.2	10.7	11.2	11.7
89	3.6	4.1	4.6	4.8	5.3	5.8	6.3	6.9	7.4	7.9	8.4	8.9	9.4	9.9	10.4	11.2	11.7
102	3.6	3.8	4.3	4.8	5.3	5.8	6.3	6.9	7.4	7.9	8.4	8.9	9.4	9.9	10.4	10.9	11.4
114	3.6	3.8	4.3	4.8	5.3	5.8	6.3	6.9	7.4	7.9	8.4	8.9	9.4	9.9	10.4	10.9	11.4
127	3.3	3.8	4.3	4.8	5.3	5.8	6.3	6.6	7.1	7.6	8.1	8.6	9.1	9.7	10.2	10.7	11.2
140	3.3	3.8	4.3	4.8	5.3	5.6	6.1	6.6	7.1	7.6	8.1	8.6	9.1	9.7	10.2	10.7	11.2
152	3.3	3.8	4.3	4.8	5.1	5.6	6.1	6.6	7.1	7.6	8.1	8.6	9.1	9.7	10.2	10.4	10.9

1/ Based on the formula $u_p = 0.034 \times u_m^{1.09} \times \frac{1}{I^{1.09}}$ where

u_p = Average daily peak period consumptive use in mm.
u_m = Average consumptive use for the peak month in mm.
I = Net irrigation application in mm.

2/ Values Rounded.

Table AIII-33. Water Retention of Soils

	Millimeters of water per meter of soil
Very coarse texture -- very coarse sands	33 - 62
Coarse texture -- coarse sands, fine sands, and loamy sands	62 - 104
Moderately coarse texture -- sandy loams and fine sandy loams	104 - 146
Medium texture -- very fine sandy loams, loams, and silt loams	125 - 192
Moderately fine texture -- clay loams, silty clay loams, and sandy clay loams	146 - 208
Fine texture -- sandy clays, silty clays, and clays	133 - 208
Peats and mucks	167 - 250

Table AIII-34. Akkar Plain Estimated Peak Consumptive Use - August

Crop	Percent of Cropped Areas	Cropped Area Hectares	Root Zone Depth Meters	0.45 of Root Zone Meters	Available Moisture Capacity cm/m	Net Irrigation Application cm	Monthly Consumptive Use Rate mm	Daily Consumptive Use Rate mm	Infiltration Rate mm/hr.	Time of Application Hours
Class I		326								
Citrus	1	3.3	1.83	0.82	1.67	13.7	148	5.3	8	17.1
Tomatoes	30	97.8	1.22	0.55	1.67	9.2	49	3.3	8	11.5
Small Vegetables	30	97.8	0.61	0.27	1.67	4.5	49	3.3	8	5.6
Cole Crops	5	16.3	0.92	0.41	1.67	6.8	53	3.6	8	8.5
Cole Crops	10	32.6	0.92	0.41	1.67	6.8	21	2.5	8	8.5
Beans	10	32.6	1.07	0.48	1.67	8.0	33	3.8	8	10.0
Small Vegetables	14	45.6	0.61	0.27	1.67	4.5	166	6.4	8	5.6
Class II		2962								
Citrus	1	29.6	1.83	0.82	16.7	13.7	148	5.3	8	17.1
Small Vegetables	20	592.4	0.61	0.27	16.7	4.5	48	3.3	8	5.6
Tomatoes	29	859.0	1.22	0.55	16.7	9.2	48	3.3	8	11.5
Cole Crops	25	740.5	0.92	0.41	16.7	6.8	172	6.4	8	8.5
Melons	20	592.4	1.07	0.48	16.7	8.0	160	5.8	8	10.0
Grain Maize	5	148.1	1.22	0.55	16.7	9.2	220	7.9	8	11.5
Class III		2935								
Table Maize	5	147	1.07	0.48	16.7	9.0	178	6.4	8	11.3
Dry Beans & Lentils	55	1614	1.07	0.48	16.7	9.0	210	7.4	8	11.3
Sorghum	20	587	1.07	0.48	16.7	9.0	185	6.4	8	11.3
Grain Maize	20	587	1.07	0.48	16.7	9.0	197	7.1	8	11.3
										Average= 10.4 hrs

Table AIII-35. Peak Consumptive Use Rate - Weighted Average

Crop	Cropped Area Hectares	Daily Cons. Use Rate mm	Cons. Use Rate Mult. by Area	
Class I				
Citrus	3.3	5.3	17.49	TOTAL NET IRRIG. AREA 5,897 HECTARES
Tomatoes	97.8	3.3	326.04	
Small Vegetables	97.8	3.3	322.74	
Cole Crops	16.3	3.6	58.68	
Cole Crops	32.6	2.5	81.50	
Beans	32.6	3.8	123.88	
Small Vegetables	45.6	6.4	291.84	
Class II				
Citrus	29.6	5.3	156.88	
Small Vegetables	592.4	3.3	1954.92	
Tomatoes	859.0	3.3	2834.70	
Cole Crops	740.5	6.4	4739.20	
Melons	592.4	5.8	3433.92	
Grain Maize	148.1	7.9	1169.99	
Class III				
Table Maize	147	6.4	940.80	
Dry Beans & Lentils	1614	7.4	11943.60	
Sorghum	587	6.4	3756.80	
Grain Maize	587	7.1	4167.70	
		TOTAL	36321	

Weighted Average 6.16 mm/day 1/

Irrigation Efficiency 60% 10.3 mm/day

1/ Based on Phase II Stage 1 net irrigated area of 5,897 ha. Revised net irrigated area = 6,469 ha.

be stored in the soil; it is lost by deep percolation and surface runoff. During the late fall, winter and early spring, November through March, effective precipitation is adequate to supply full crop requirements. During the period June through August, effective precipitation is practically nil. Since there are no records of effective rainfall which can be used for the remaining months, it is necessary to utilize total rainfall records and estimate the portion of the rainfall which is effective. The U.S. Department of Agriculture has developed curves for estimating the average monthly effective rainfall based on the mean monthly rainfall and the average monthly consumptive use which have been modified for use in this study, Table AIII-36.

Groundwater Contribution

Under certain conditions, high natural groundwater may reduce the irrigation requirement materially, unless the groundwater is the result of excess irrigation. The western side of the project area, comprised of approximately 2,400 hectares of heavy clay soils, has a high water table which is caused by the lack of adequate drainage. For these reasons, soils in the area were classified as 5d and have not been included in the area to receive irrigation.

Project Water Requirement

The total water required for the project is the summation of the gross requirements for the crops, losses incurred in the irrigation distribution system, evaporation and seepage when water is stored, losses due to use by phreatophytes, and administrative losses. The usual

Table AIII-3b. Average Monthly Effective Rainfall[1/] as Related to Mean Monthly Rainfall and Average Monthly Consumptive Use

Monthly Mean Rainfall mm	Average Monthly Consumptive Use, in mm										
	0.00	25	51	76	102	127	152	178	203	229	254
	Average Monthly Effective Rainfall, in mm										
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	7	8	8	9	9	10	10	11	11	12	13
25	15	16	17	18	19	20	21	22	24	25	25
38	22	24	25	26	28	29	31	33	35	37	38
51	29	31	32	34	36	38	40	43	45	48	51
63	35	37	40	42	44	47	49	52	55	58	62
76		44	46	49	52	55	58	61	65	69	73
89		50	53	56	60	63	68	70	74	79	83
102		57	60	63	67	71	75	79	83	88	93
114			66	71	74	78	83	88	93	98	104
127			73	77	81	86	91	96	102	107	114
140			78	83	86	93	98	104	110	117	123
152				90	95	100	106	112	119	125	133
165				96	102	107	114	120	127	134	142
178				102	108	114	121	128	136	143	151
190					115	121	128	136	144	152	161
203					121	128	136	144	152	160	170

1/ Based on 75 mm net depth of application. For other net depths of application, multiply by the factors shown below.

Net Depth of Application	(D)	19	25	38	51	63	76	102	127	152	178
Factor	(f)	.72	.77	.86	.93	.97	1.00	1.02	1.04	1.06	1.08

requirement for leaching and the contribution from groundwater have not been considered, as explained above.

The total project irrigation water requirement was estimated from the total annual consumptive use of 39,000,000 m^3 plus losses identified above. Evaluation of these losses indicated an overall irrigation efficiency of 60 percent. On this basis, the total project irrigation water requirement would be 65,000,000 m^3 annually not including reservoir losses. This requirement is based on irrigation of 6,380 hectares. It is anticipated that additional hectarage will be irrigated from groundwater. The total irrigation requirement cannot be estimated until test wells have been completed and tested, which will probably be during 1979.

AGRICULTURE

General

The Akkar Plain has been cultivated for several thousand years. The climate of the area would be excellent for growing crops except for the distribution of precipitation. The average annual precipitation is 862 mm which mainly occurs between November and March. This is adequate for growing winter crops but is very difficult for summer crops since precipitation during June through August averages only 1 mm per month. Thus, irrigation is required to mature late spring and summer crops.

Soils

Project lands were classified according to soils, slope and drainage conditions, Table AIII-37. Heavy clay soils are predominant on the majority of the land to be irrigated. The heavy soils, in conjunction with fairly

steep slopes on the Class II and II land (up to 5%), limit the type of irrigation that can be successfully employed. Farmers are presently using furrow and a modified level-basin-type of irrigation which are adapted to the heavy soils and slopes.

Land Preparation

Land levelling is influenced by the soil, slope, climate, crops, method of irrigation, drainage, and the expertise and desires of the farmer. Land Classes II and III, which comprise 95 percent of the irrigated area, have undulating topography with slopes up to 5 percent. This type of topography, associated with shallow soil profiles which average less than a meter in depth, virtually rules out a land levelling program which would normally be considered essential for intensively cultivated crops such as vegetables. Some areas are being cultivated which have soil profiles of only 20 to 30 cm. Under these conditions, only minor land levelling and smoothing is possible. This treatment would alleviate irrigation problems resulting from improper plowing which has left deep, dead furrows and the repair of above-average erosion caused by heavy winter precipitation. Some of these conditions would be corrected in time by proper plowing and tilling practices. Land smoothing should be accomplished concurrently with development of the drainage system under supervision of the Agricultural Service Center. To accomplish this land smoothing and construction of the ancillary drains within the scheduled time will require six 120 h.p. tractors with land planes and ditchers. Cost of the equipment would be $515,000 or 2,008,500 S.P., including operation and maintenance costs of $56,000 or 218,400 S.P.

On-Farm Irrigation

Soils on the project are considered to have an average infiltration rate

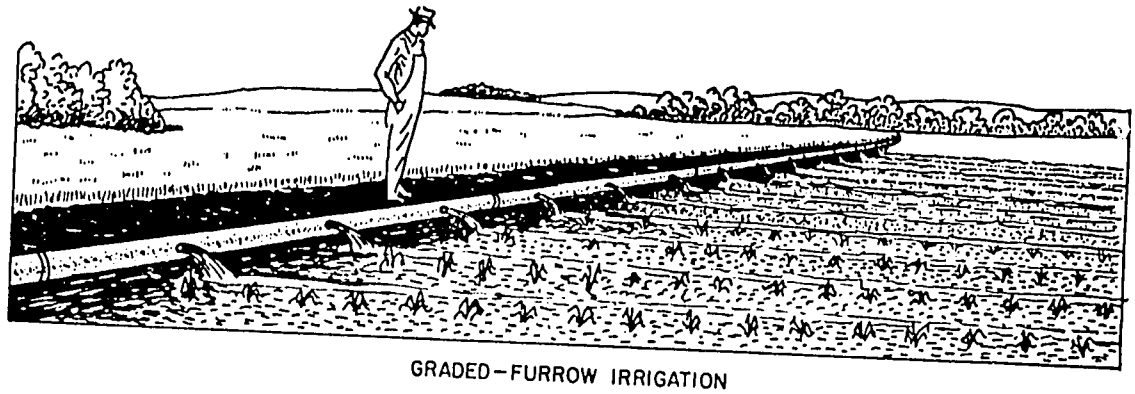
Table AIII-37 Land Classification Criteria for Irrigable Soils

Characteristics	Class 1 Irrigable	Class 2 Irrigable	Class 3 Irrigable	Class 5
Texture	Fine sandy loam to friable clay loam	Sandy loam to a clay loam	Loamy sand to a friable clay	Clay loam to massive clay
Depth				
To gravel or fractured rock	>75 cm.	>45 cm.	>30 cm.	>30 cm.
To fractured bedrock	> 2.0 m.	> 1.5 m.	>1.0 m.	>1.0 m.
Exchangeable sodium percentage	<10 percent	< 20 percent	< 30 percent	< 30 percent
Reaction	pH <8.0 0-1 m.	pH <8.0 0-70 cm.	pH <8.0 0-35 cm.	pH <8.0 0-35 cm.
Salinity or electrical conductivity	Conductivity of saturation extract 4 mhos/cm.	Conductivity of saturation extract 8 mhos/cm.	Conductivity of saturation extract 12 mhos/cm.	Conduc. of sat. extract 12 mhos/cm.
Slope	0-3 percent	0-5 percent	0-10 percent	0-10 percent
Relief	Gently undulating	Moderately undulating	Rolling	Gently undulating to rolling
Surface and Subsurface Drainage	Little or no surface drainage requirements anticipated. No subsurface drainage required.	Some surface drainage anticipated. No subsurface drainage anticipated.	Major surface drainage is anticipated. Limited subsurface drainage anticipated.	Major surface drainage will be required. Subsurface drainage not feasible.

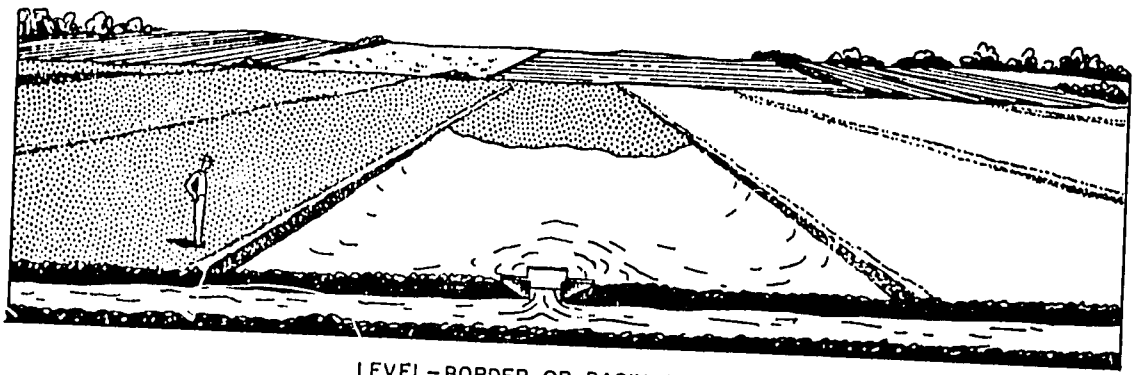
Class 6- Lands not meeting standards of irrigable classes.

of 8 mm per hour with an average water-holding capacity of 165 mm per meter. The "Level Border or Basin Method" of irrigation is considered practical for use on the smooth, gentle, uniform land slopes of the project, Figure AIII-5. This method is suited to soils which have a slow intake rate and good water-holding capacity. It employs a rapid application of irrigation water at a uniform depth until the desired amount of water has been taken into the soil. The major advantage of this method is that it can be used to irrigate a wide variety of crops, regardless of the planting pattern. Crops which are adversely affected by flooding can be planted in beds and irrigated with furrows. Row crops which are less affected by flooding can be bedded or flat-planted. Drilled or sown crops can be irrigated by border ditches to guide the water. Irrigation variations can be accomplished with only minor changes in layout or rate of application and still maintain good efficiency. Irrigation and rainwater can be used efficiently by unexperienced workmen. A disadvantage is that border dikes interfere somewhat with operation of farm machinery and may require well-managed tillage operations, using correct tools to maintain the level surface for efficient operation.

On areas with steeper slopes, Class II and III soils, which constitute the majority of the irrigated area, the "Graded Furrow Method" is considered the most practical method of irrigation, Figure AIII-5. This method employs small channels or furrows with nearly uniform slopes in the direction of irrigation. One or more furrows are located along each pair of rows. Shape and size of the furrows is dependent upon the crops grown, method of cultivation and spacing of rows. On the Akkar Plain, the grade of the furrows should be



GRADED-FURROW IRRIGATION



LEVEL-BORDER OR BASIN IRRIGATION

FIGURE AIII-5

AKKAR PLAIN PROJECT

approximately 0.001 to retain water in the furrow for a sufficient length of time to permit the desired intake with minimum waste at the end of the furrows.

It is recommended that gated pipe be used to convey the water from the laterals and regulate the flow to the furrows, Figure AIII-5. Aluminum pipe, which is commonly used, is lightweight and can be handled by one man. However, this type of pipe is becoming expensive and is now being replaced, to a considerable extent, by a lightweight non-rigid plastic pipe. The plastic pipe is cheap, can be set up and moved with minimum labor, and can be utilized for several tracts. Outlet devices can be installed in the pipe to regulate the rate of flow to each furrow regardless of furrow spacing. The pipe eliminates the need for head ditches and can be rolled for convenient, off-season storage.

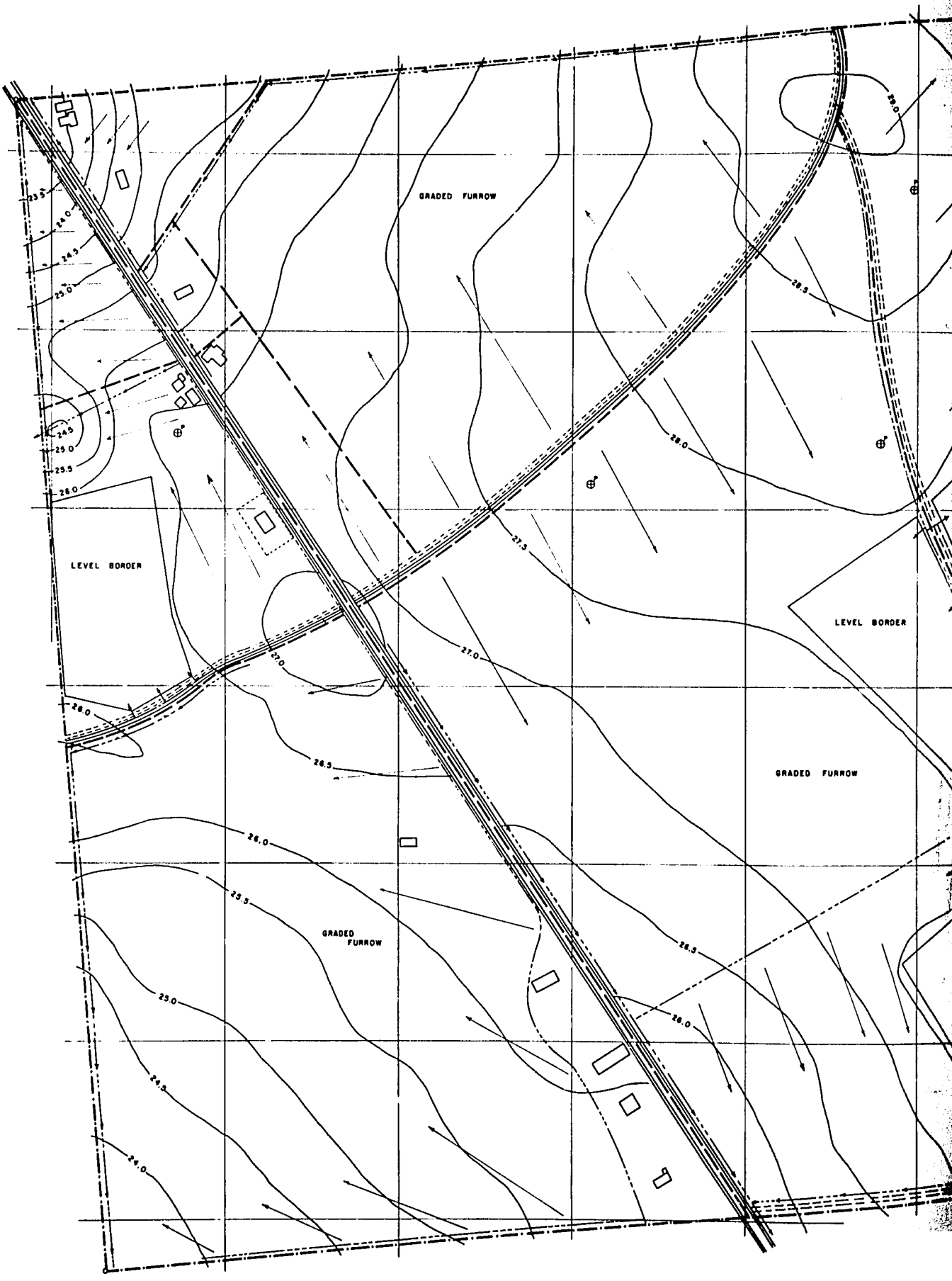
Sprinkler irrigation is being used widely throughout the world. It consists of conveying water through pipe under pressure and utilizing nozzles to spray water into the air. The water falls onto the soil similar to rain. This method of irrigation has been used successfully on most crops, except rice, and is particularly suited to soils with high intake rates, soils too shallow to be levelled, and especially for steep, irregular topography. Fertilizer and fungicides can also be applied through the system. In the past, the most serious constraints to sprinkler irrigation have been soils with low infiltration rates, wind, land use, and economics. These conditions are present on the Akkar Plain; soils are predominantly tight; ownerships are small with a wide variety of crops; and winds are prevalent, ranging in velocity to 60 km per hour. The weather is calm approximately 25 percent of the time. Windbreaks are required for tall growing crops and citrus.

Advanced technology in design is now providing wide flexibility in sprinkler equipment with good control of application rates and coverage. Therefore, it is believed that sprinkler irrigation would have application on the Akkar Plain. However, successful use of the system would require expert design and be custom-engineered to fit specific areas on the Plain. Since land ownership is small, it may be desirable to group several farms together under one sprinkler irrigation system and growing the same crop. This would also permit more efficient use of wheel-move or other mobile system and the larger the area sprinkled, the more economical in original and operational cost.

Although sprinkler irrigation is considered to have rather restricted use on the Akkar Plain, there are a number of important benefits associated with its use; namely, cooling when temperatures are 32°C or above; is adjustable to provide fine spray for germination of small vegetable seeds; provides efficient application of fertilizer and fungicides; and would free farm labor for other productive uses.

The cost of sprinkler irrigation is somewhat higher than other methods of irrigation described, but would eliminate some of the cost of land smoothing.

Topography of the Akkar Plain was taken at a 5 m contour interval and scale of 1:25,000, which is not adequate for laying out an irrigation system. A detailed survey was made of three representative tracts on the project. Each area comprised from 60 to 100 hectares and represented slopes and conditions most common to irrigation under the project. The area at Dakaka was selected as a model for detailed study, Figure AIII-6. An irrigation system was


GRADED FURROW
LEVEL BORDER
LEVEL BORDER
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GRADED FURROW
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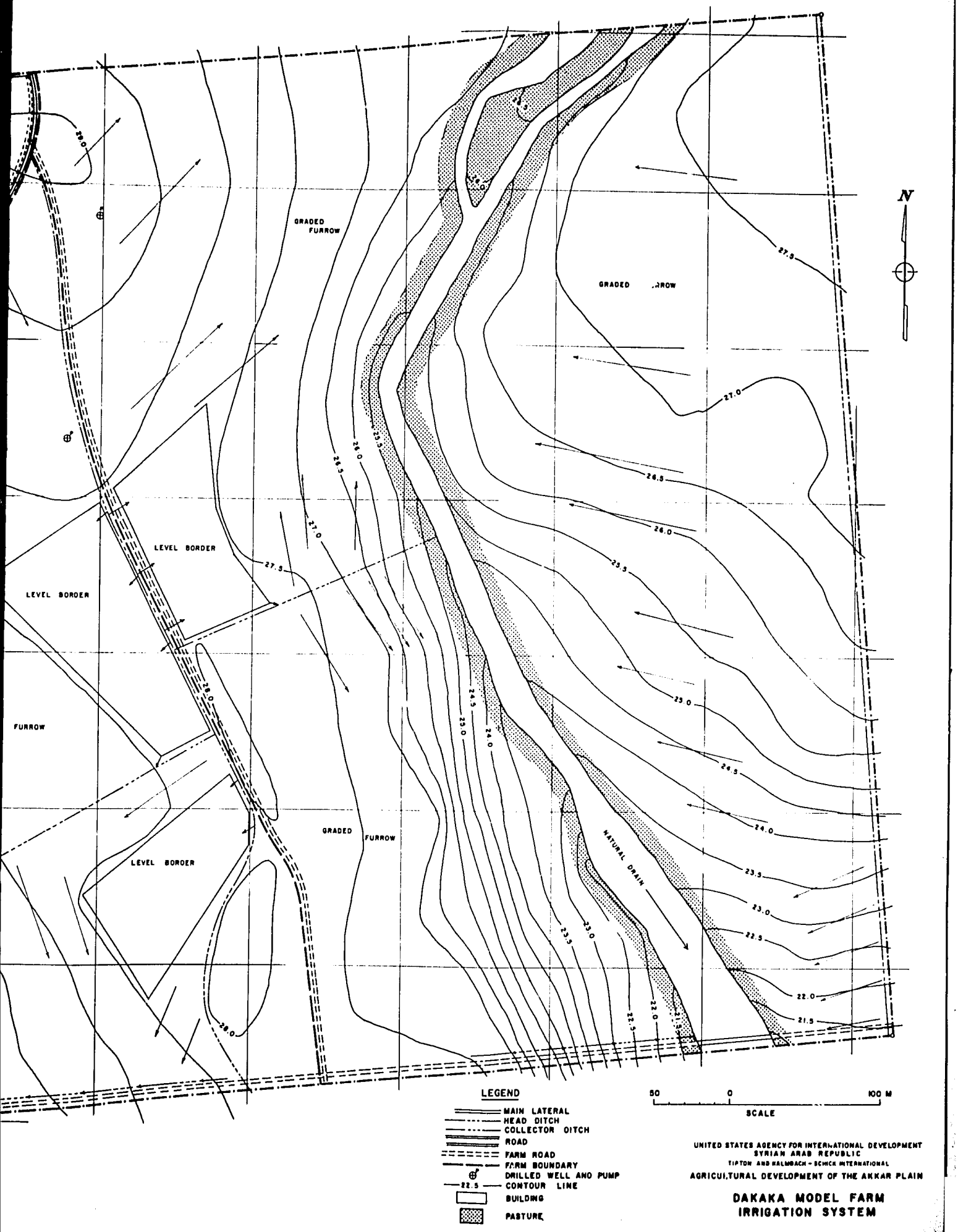
FIGURE AIII-6



designed for the area which utilizes the level border and graded furrow methods, Figure AIII-5. Land ownership plats or surveys were not available; therefore, the tracts were laid out to represent typical size ownerships and in accordance with topography. The estimated cost of on-farm irrigation is 2,496 S.P. per hectare, Table AIII-38. Field roads were relocated or added to provide:

(1) Ease of operating the irrigation system.

(2) Ready access to all areas of the farm.

(3) Transportation of products from the farm.

(4) Dryness and usability of the road.

The owner's tillage, planting and harvesting methods, and farm machinery to be employed must be resolved before final irrigation planning.

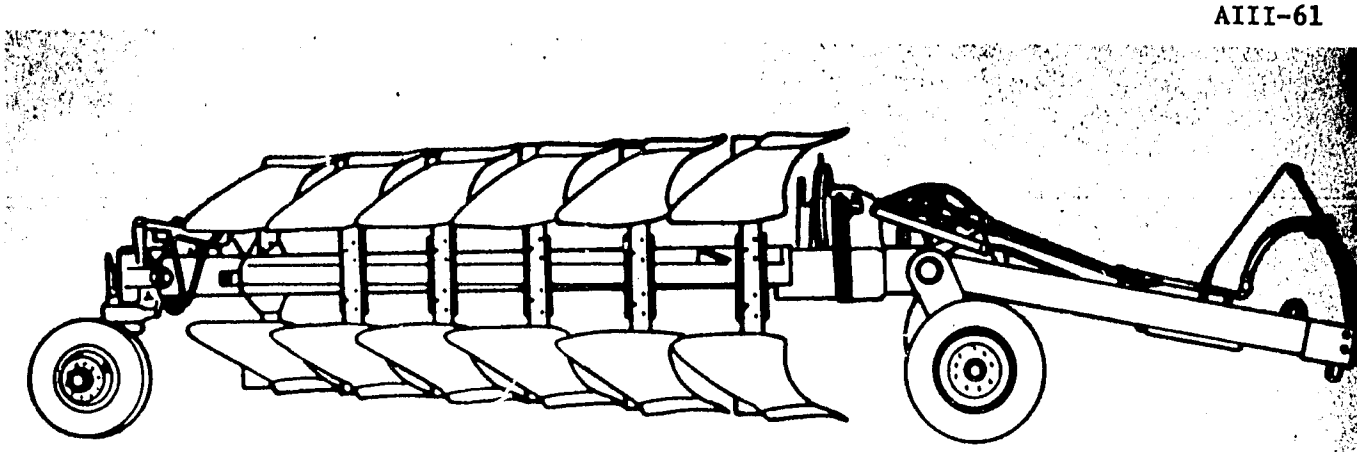
Tillage

Heavy clay soils on the Akkar Plain will require a wide variability in tillage management. Clay soils should be worked when the moisture content is near or slightly below optimum to avoid excessive clodding and development of undesirable soil structure. Realization of this is difficult since the small size of the farms does not justify the farmer owning all of the farm machinery needed. In this case, he will have to depend on custom work or obtaining equipment from the farmer cooperative, which may not be available to permit the farmer to work his land at the optimum time; therefore, tillage practices will vary.

Two-way moldboard plows are considered the most adaptable for use on the project, Figure AIII-7. This type of plow breaks up and loosens the heavy soils and eliminates the dead furrows. Plowing with the contour or topography would be desirable to facilitate surface drainage during the

Table AIII-38. On-Farm Irrigation Cost Equipment
Gated Pipe at Head of Farm

Per 60 hectares model farm	2,940 m = 49.0 m/ha.
Inlet Structures	8 @ 400 = $3,200 = $53.33/ha
8" Rigid Plastic Pipe	@ $2.40/ft = $7.87/m
Cost	$385.63/ha
Head Structure	53.33/ha
SUBTOTAL	438.96/ha
SHIPPING 20%	87.79
SUBTOTAL	526.75
CONTINGENCIES 20%	105.35
TOTAL	632.10 ≃ $640/ha



DRAWN TWO-WAY PLOW

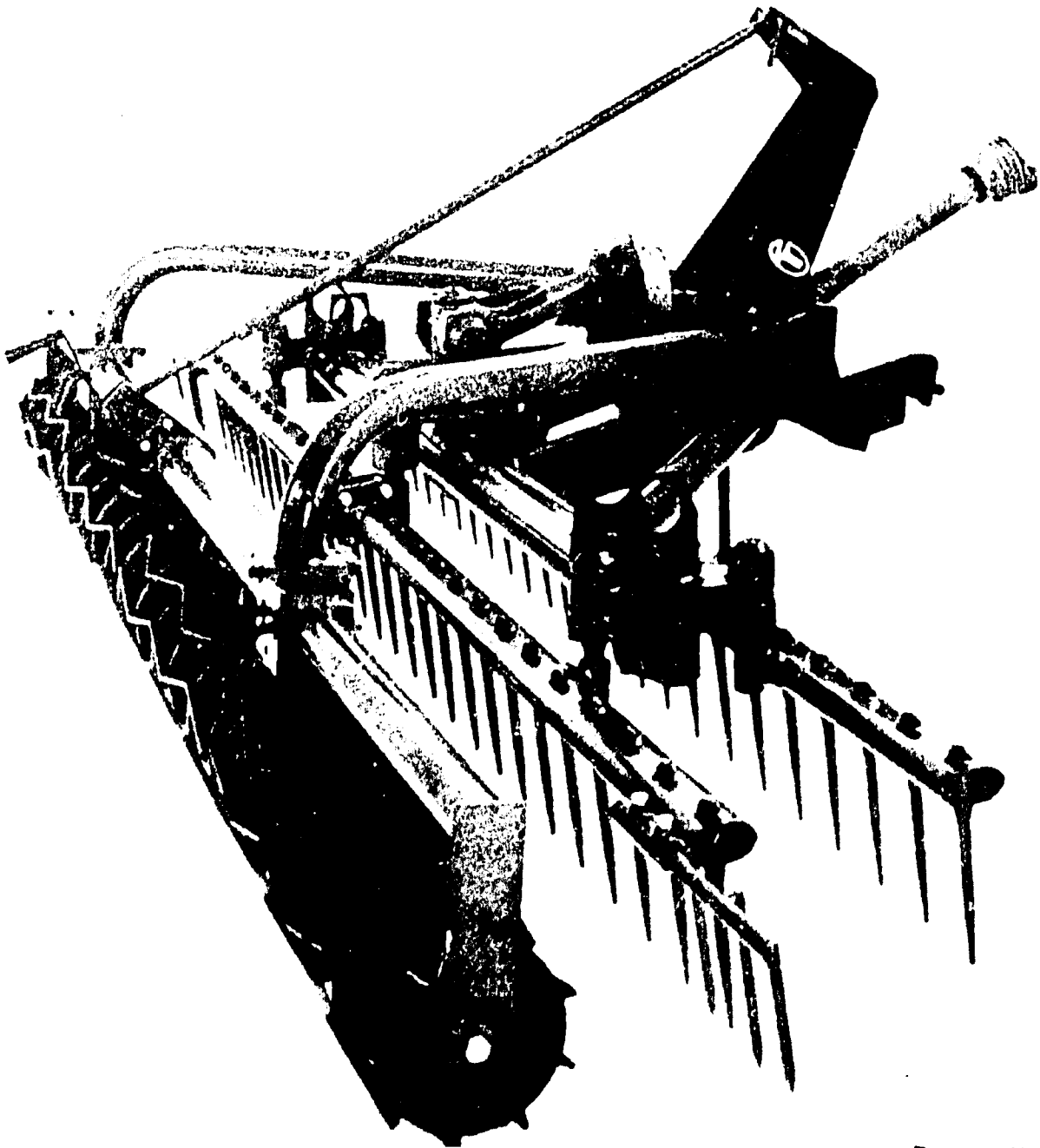
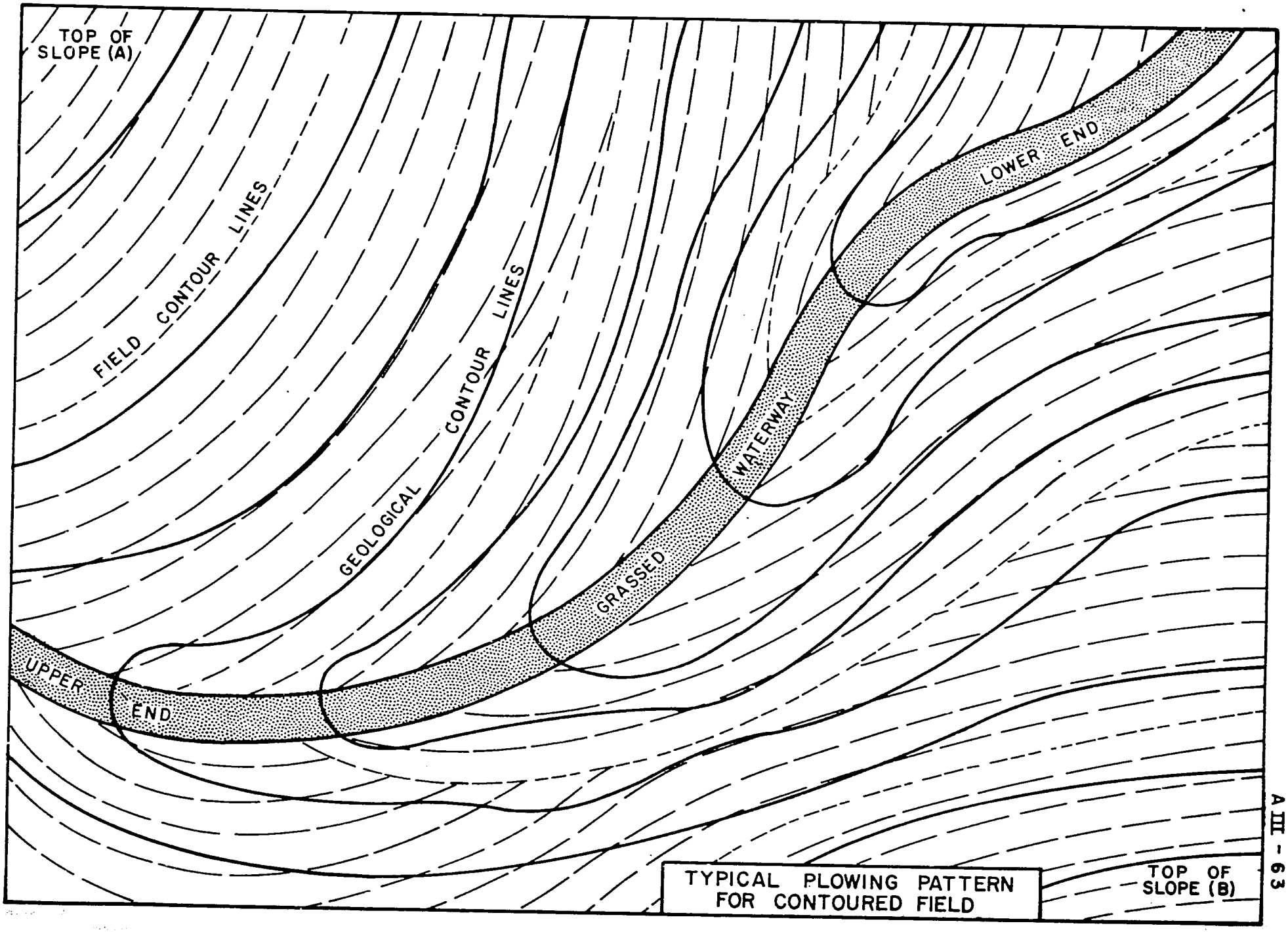


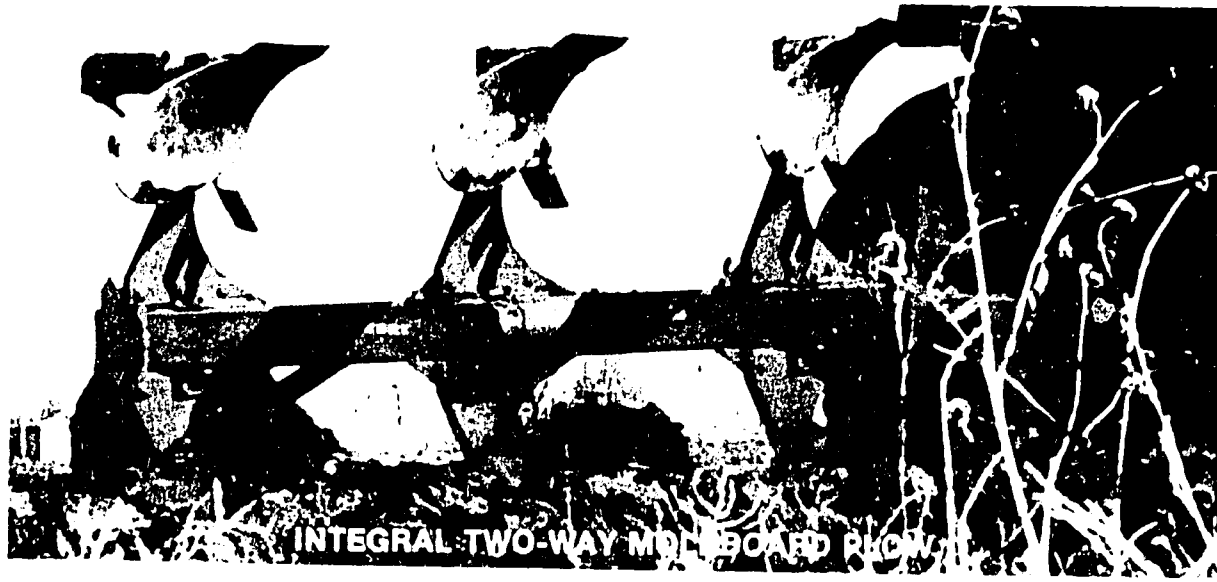
Figure AIII-7 POWER HARROW

season of high precipitation, Figure AIII-8. Clod buster attachments should be used on plows, with provisions for attachments which break clods while the soil is moist, and will usually eliminate one trip over the field with a disk or harrow, Figure AIII-9. Since formation of clods will be inevitable at times, a clod buster would be necessary. A power harrow, Figure AIII-7, or equivalent is recommended for seedbed preparation. This type of harrow loosens and breaks up the soil by employing a vertical and horizontal motion which also aerates the soil. The low draft and other characteristics of this type of harrow permits the farmer to get on the soil a week or two earlier than with other types of equipment and reduces the need for additional harrowing and levelling. On heavy soils, overmechanization causes compaction, which destroys structure and limits aeration.

Bed shapers and sled carriers, Figure AIII-10, can be employed as a basic implement for specialized row crops. Use of bed shaping attachments or listers can form precision beds for a large variety of row spacing and configurations. Attaching planting units for vegetables or other row crops permits shaping beds and planting in one operation. Dry soil is swept off by the shapers which permits planting directly in moist soil for rapid and high percentage germination. Shapers can also be used for weed control. Furrows between the rows are uniformly shaped which permits optimum flow and uniform distribution of irrigation water. Cultivating tools can also be attached to the shapers which permit minimum plant damage with efficient cultivation. When sled carriers are not used, cultivation and planting should be performed by equipment which employs listers in combination with



TYPICAL PLOWING PATTERN FOR CONTOURED FIELD



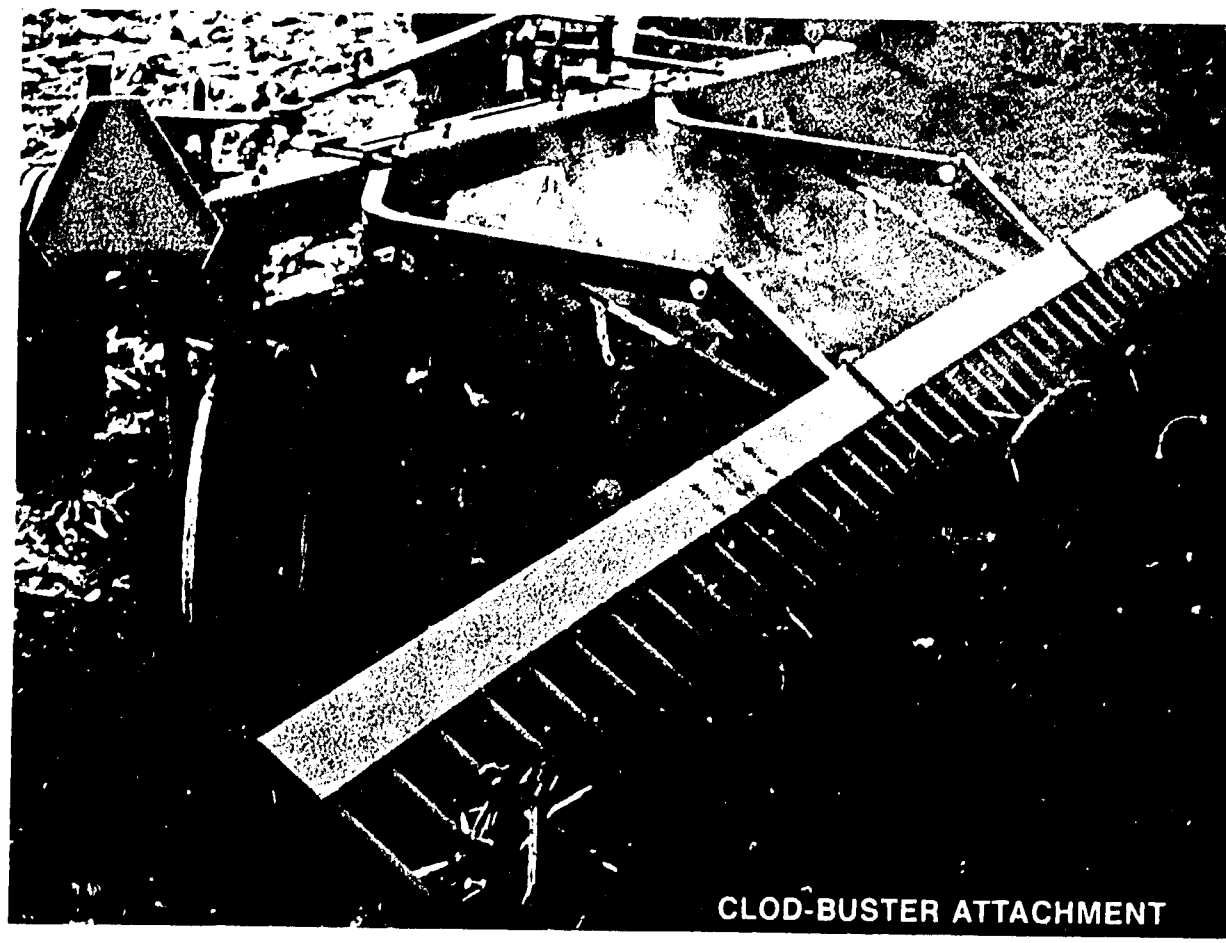
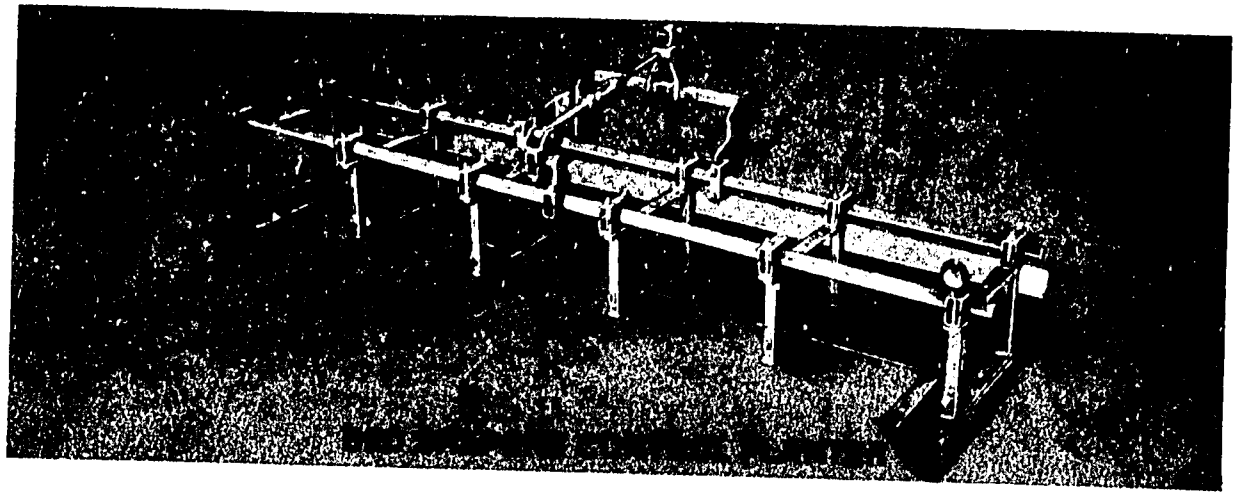


Figure AIII-9

–Bed-Shapers Provide Very Accurate Planter Control



–Cone or Sled Guides Provide Precision Guidance on Beds

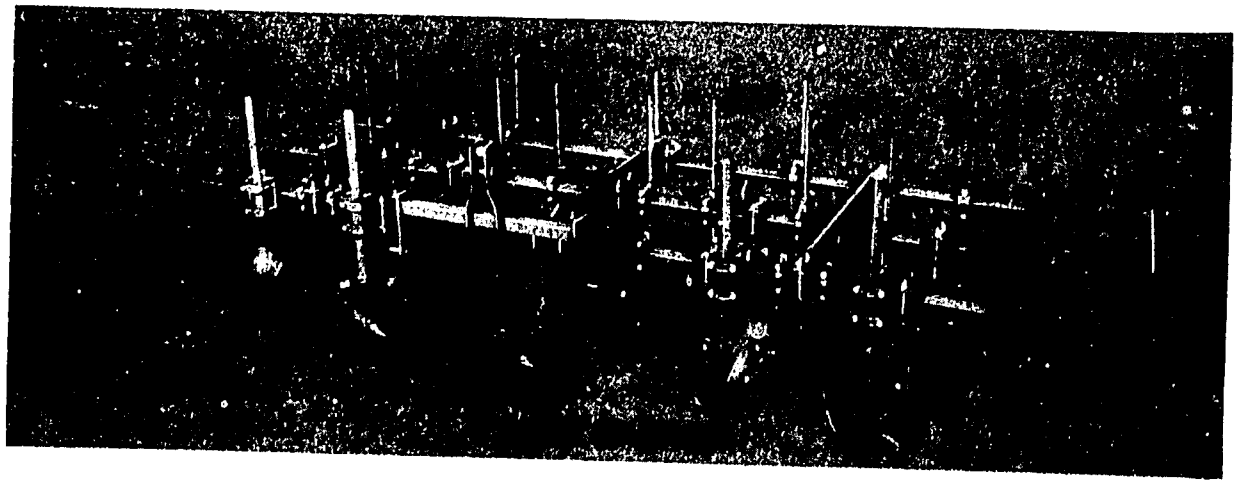


Figure AIII-10

the basic machine to properly shape and reshape the soil. This procedure also reduces the number of trips over the field and maintains good surface drainage conditions, Figure AIII-11. Profile planting would be useful on the Plain to protect seed and small plants from wind and rain, Figure AIII-12.

Small grains should be planted with tractor-drawn drills for uniform planting and good crop stands, Figure AIII-13. The common method of hand broadcasting seed on plowed, unharrowed ground and then covering the seed by a light 3 to 4-inch plowing results in some seed being buried too deep and some remaining on the surface. This results in poor, uneven stands.

Every three to five years deep plowing or chiseling should be done to prevent plow pans, to break up and blend the soil, and to restore aeration, Figure AIII-11. For field operation other than tillage, the soil should be as dry as possible.

Weed Control

Adequate weed control programs are a vital part of good farm management and are important factors in crop yield. To satisfactorily control the spread of weed seeds, the program must include primary and secondary tillage, good cultivation and planting practices, the use of herbicides, and general farm housekeeping which includes control of weeds along fence lines, ditchbanks, drains, and from fallow and unused or hard to get at areas. Chemical herbicides are required in conjunction with good tillage and planting practices for effective weed control. Well chosen herbicides applied at the recommended time and rate of application will kill most weeds without damage to crops.

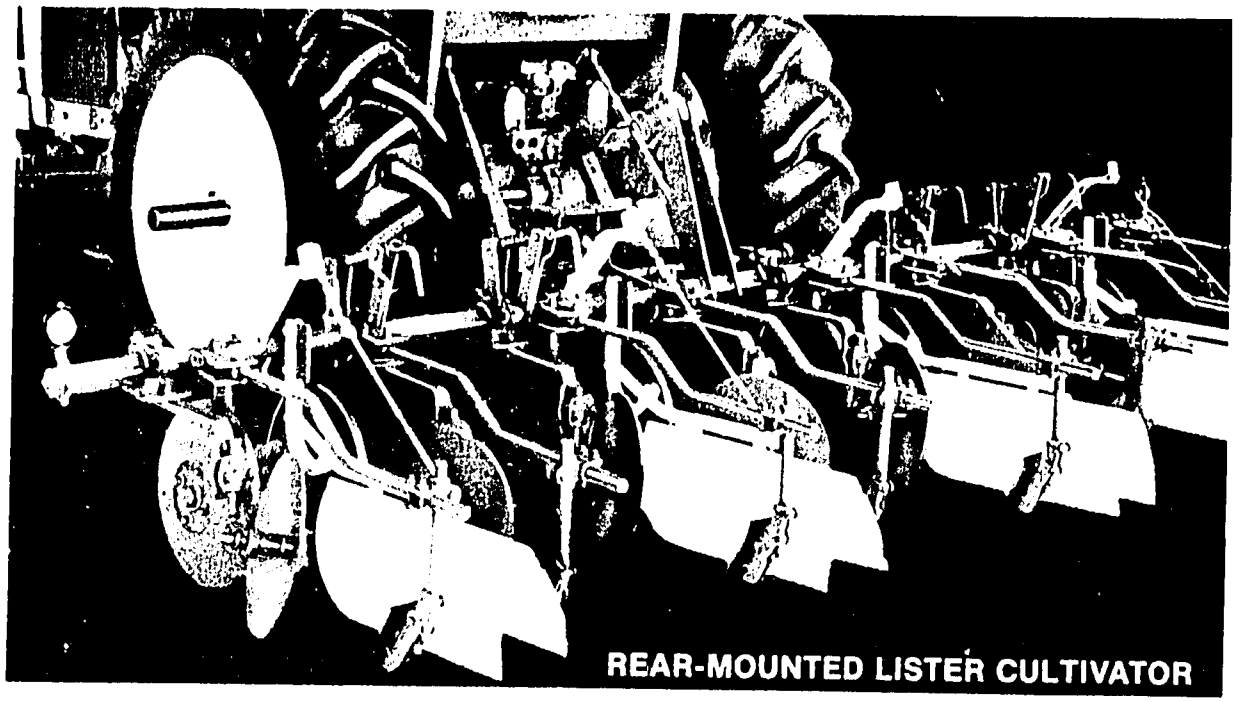


Figure AIII-11

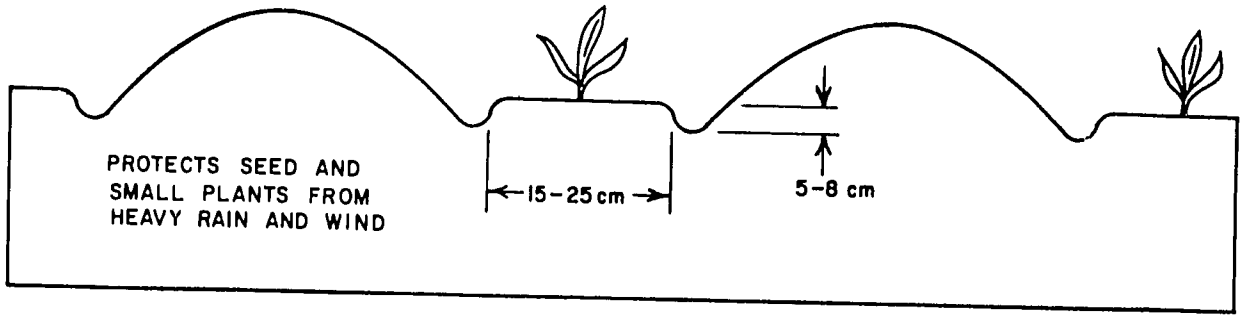
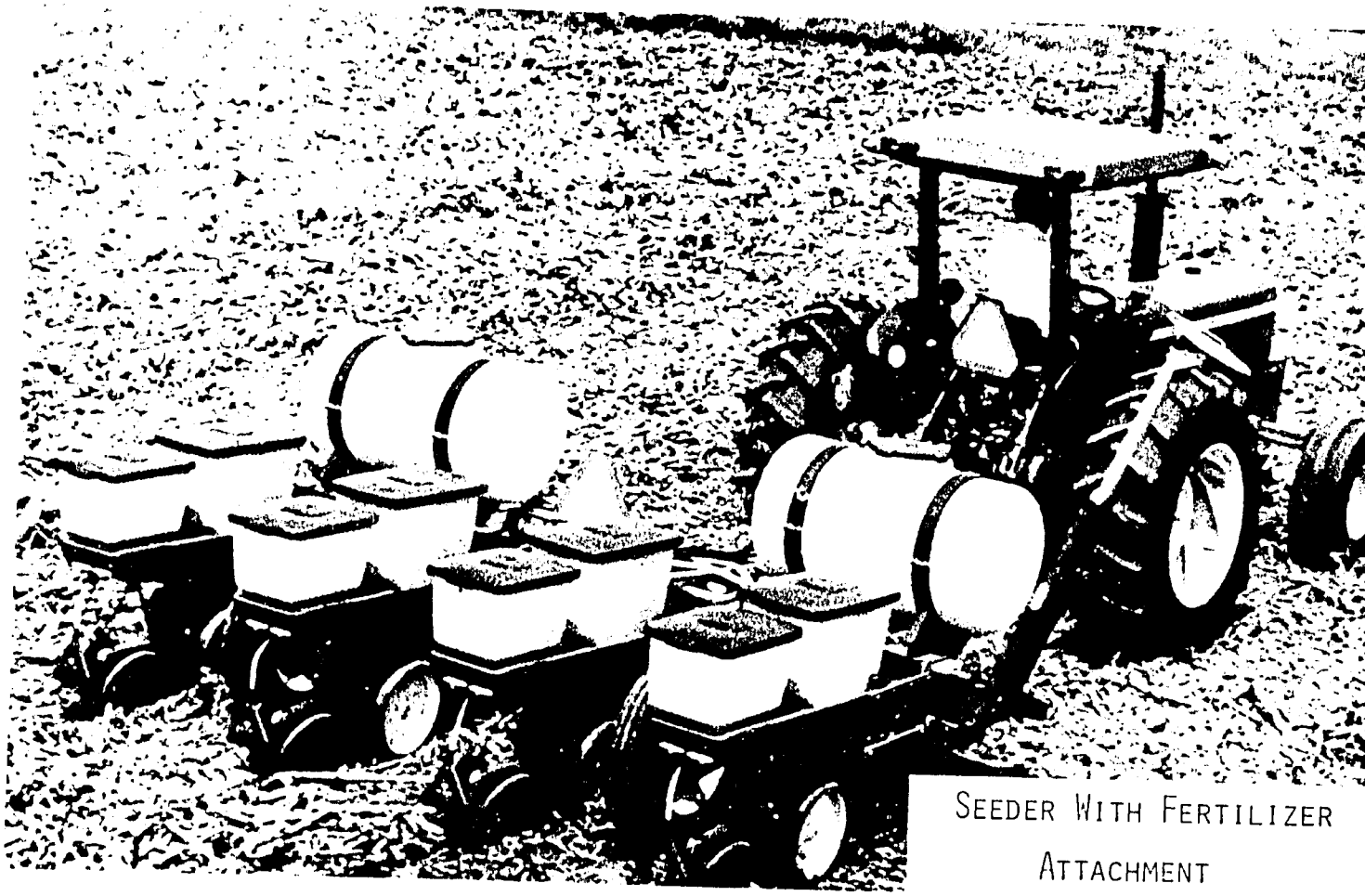
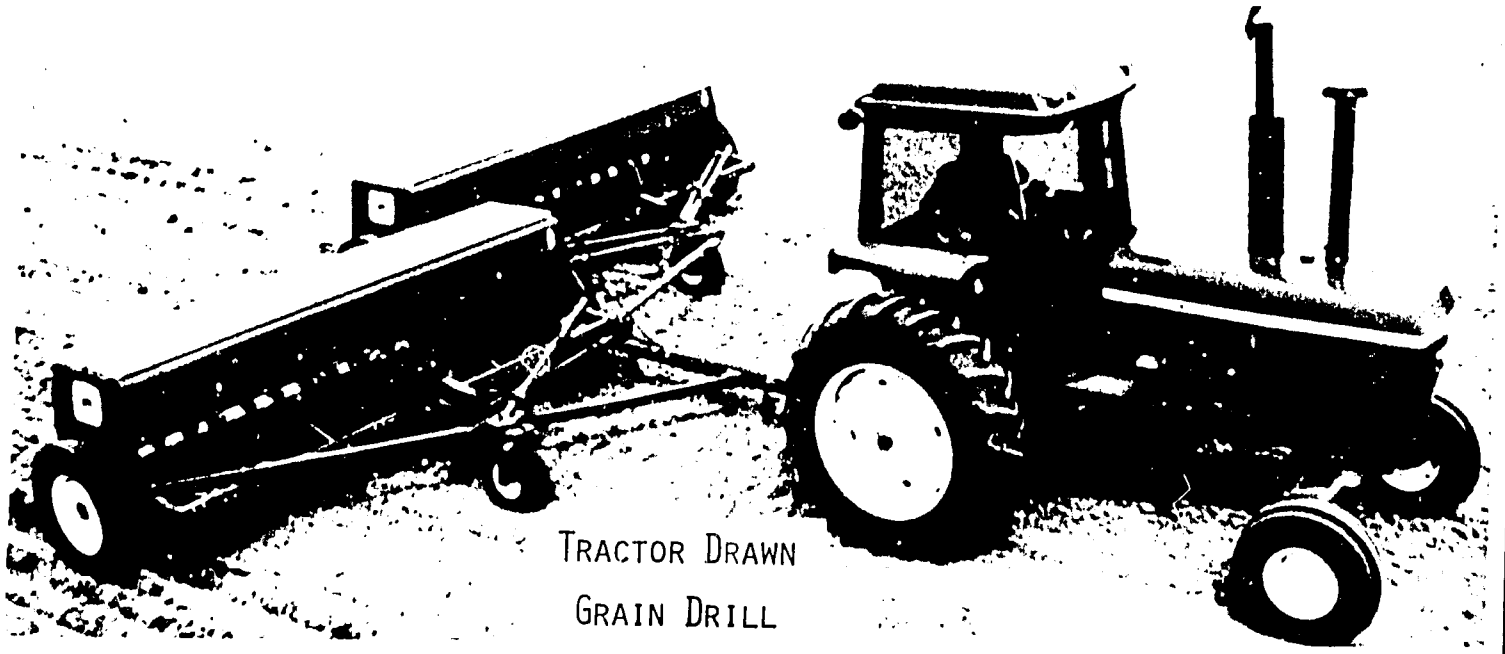


FIGURE AIII-12 PROFILE PLANTING



SEEDER WITH FERTILIZER ATTACHMENT



TRACTOR DRAWN GRAIN DRILL

Figure AIII-13