9.4 Water Economy

According to the report on Rahad Irrigation Project prepared in 1975, the total cost of the said project with an area of 126,000 ha amounts to US$239 million including contingencies.

The main crop produced in Rahad project is cotton, while in Abu Gasaba project, rice. The net production value of both crops can be approximately estimated as below;

Net Production Value per ha of Cotton and Rice

	Item	Cotton	Rice
1.	Anticipated yield (ton/ha)	0.4 (lint)	7.0 (milled)
2.	Financial price (£s/ton)	500	267
3.	Gross production value (£s/ha)	200	1,869
4.	Ratio of production value and production cost (%)	40 (assumed)	41 (proposed)
5.	Production cost (£s/ha)	80	766
6.	Project cost (£s/ha)	700	6,000 (proposed)
7.	Amortization of project cost(£s/ha)	30	256
8.	Net production value (£s/ha) 3.- (5 + 7)	90	847

As clarified in the above table, rice is decidedly superior to cotton in view of land productivity. The above calculation also indicates that an intensive investment in rice cultivation can correspondingly yield appropriate project returns.

Futhermore, net production value per unit water consumption of both crops can be evaluated as bolow;

Item	Cotton	Rice
1. Net production value (£s/ha)	90	847
2. Water consumption (m^3/ha)	9,300	21,200/1
3. Net production value per unit water consumption (£s/1,000 m^3)	9.7	40.0

/1: Net annual amount of irrigation water/15,600ha = 0.33 milliard m^3/15,600 ha

In water economic viewpoint, rice production is more feasible than cotton production as shown above. In Abu Gasaba project area, a large amount of water resourcws (0.25 milliard m^3) can be additionally saved by land reclamation as mentioned in 9.3. Therefore only 0.08 milliard m^3 or 5,100 m^3/ha equivalent will be consumed for irrigation. Consequently, instead of £s.40.0/1,000 m^3 in above table, the net production value per unit water consumption can be estimated at about £s.163 /1,000 m^3, about 17 times equivalent to the value of cotton. Hence, in Abu Gasava area, rice production is numerically superior to cotton production in view of water resource productivity as well as land productivity.

Table 9.1 Effective Rainfall

	Apr.		May		June		July		Aug.		Sept.		Oct.		
	0-15	16-30	0-15	16-31	0-15	16-30	0-15	16-31	0-15	16-31	0-15	16-30	0-15	16-31	
1956	0	0	0	0	20.0	12.0	53.9	43.0	11.4	34.4	68.1	19.0	0	0	
57	0	0	0	0	0	0	0	22.6	74.4	15.0	54.4	0	0	0	
58	0	0	0	9.0	0	20.2	54.1	82.0	36.5	50.0	23.2	36.0	0	0	
59	0	50.0	0	0	0	16.7	58.9	24.5	51.6	33.5	64.5	0	0	0	
60	0	0	8.3	0	0	0	24.8	0	15.1	43.9	44.8	8.0	0	0	
61	0	0	0	0	0	33.2	95.2	148.9	28.5	76.6	0	0	0	0	
62	0	0	0	0	0	47.0	35.6	50.1	82.0	30.3	9.2	0	21.0	0	
63	0	0	0	0	0	0	26.5	37.1	80.7	43.9	21.0	23.9	0	0	
64	0	0	0	0	50.0	9.0	5.0	32.0	10.0	81.0	66.5	0	0	8.2	
65	0	0	0	0	5.0	0	22.2	52.5	100.6	117.8	27.8	0	0	0	
66	0	0	8.8	12.0	21.2	0	0	8.7	35.6	50.0	19.0	0	5.6	0	
67	0	0	0	0	6.0	0	13.8	53.1	50.0	49.8	0	0	0	0	
68	0	0	0	0	94.7	0	43.5	7.5	15.3	27.7	49.9	0	0	0	
69	0	0	0	0	10.4	13.0	13.0	0	69.5	98.5	6.5	5.0	5.0	0	
70	0	0	0	0	0	0	0	21.0	57.2	37.5	36.5	0	29.0	0	
71	0	0	0	0	0	0	6.6	51.6	37.8	17.0	26.0	0	0	0	
72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
73	0	0	0	0	0	0	0	66.0	8.6	0	8.0	0	0	0	
74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
75	0	0	0	0	7.5	0	13.5	0	79.0	68.9	16.0	0	0	0	Total
Average	0	2.8	1.0	1.2	11.9	8.4	25.9	38.9	46.9	48.7	30.1	5.1	3.4	0.5	224.8
Distribution Ratio (%)	0	1.2	0.4	0.5	5.3	3.7	11.5	17.3	20.9	21.8	13.4	2.3	1.5	0.2	100.0
Basic Effective Rainfall	0	1.6	0.5	0.7	7.2	5.0	15.5	23.4	28.3	29.3	18.1	3.1	2.0	0.3	135

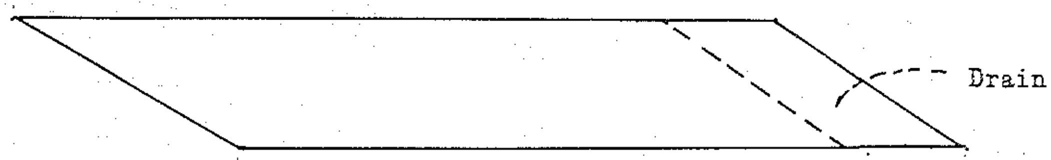
Table 9.2(1) Irrigation Water Requirement (1st Crop)

	Dec.	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.
Cropping Calender														
1. Consumptive Use of Water														
(1) Crop Coefficient (kc)				0.83	1.02	1.16	1.23	1.26	1.20	1.04	0.81			
					0.83	1.02	1.16	1.23	1.26	1.20	1.04	0.81		
						0.83	1.02	1.16	1.23	1.26	1.20	1.04	0.81	
(2) Average Crop Coefficient				0.83	0.93	1.00	1.14	1.22	1.23	1.17	1.02	0.93	0.81	
(3) Potential Evapotranspiration(mm)				114	114	126	126	129	129	122	122	111	111	
(4) Consumptive Use of Water(2)x(3)(mm)				95	106	126	144	157	159	143	124	103	100	
2. Percolation (mm)				7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	
3. Effective Rainfall (mm)				-	-	-	-	-	1.6	0.5	0.7	7.2	5.0	
4. 1 + 2 - 3 (mm)				102.5	113.5	133.5	151.5	164.5	164.9	150.0	130.8	103.3	102.5	
5. Crop Intensity to Total Area				1/6	3/6	5/6	1	1	1	1	5/6	3/6	1/6	
6. Pre-irrigation Requirement (mm)	20	20	20	15	15	15	-	-	-	-	-	15/2	15/2	15/2
7. Net Water Requirement (mm) 4 x 5 + 6	20	20	20	32	72	126	152	165	165	150	109	67	32	15
8. Diversion Water Requirement (mm) 7 /0.7/1	29	29	29	46	103	180	217	236	236	214	156	96	46	21

/1: Irrigation efficiency

/2: Pre-irrigation requirement for 2nd crop

Table 9.2(2) Irrigation Water Requirement (2nd Crop)

	Jul.	Aug.		Sep.		Oct.		Nov.		Dec.		Jan.	Feb.
Cropping Calender													
1. Consumptive Use of Water													
(1) Crop Coefficient (kc)	0.82	0.98	1.12	1.21	1.26	1.25	1.16	1.01	0.79				
		0.82	0.98	1.12	1.21	1.26	1.25	1.16	1.01	0.79			
			0.82	0.98	1.12	1.21	1.26	1.25	1.16	1.01	0.79		
(2) Average Crop Coefficient	0.82	0.90	0.97	1.10	1.20	1.24	1.22	1.14	0.99	0.90	0.79		
(3) Potential Evapotranspiration(mm)	92	80	80	92	92	93	93	111	111	107	107		
(4) Consumptive Use of Water(2)x(3) (mm)	75	72	78	101	110	115	113	127	110	96	85		
2. Percolation (mm)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5		
3. Effective Rainfall (mm)	23.4	28.3	29.3	18.1	3.1	2.0	0.3	-	-	-	-		
4. 1 + 2 - 3 (mm)	59.1	51.2	56.2	90.4	114.4	120.5	120.2	134.5	117.5	103.5	92.5		
5. Crop Intensity to Total Area	1/6	3/6	5/6	1	1	1	1	1	5/6	3/6	1/6		
6. Pre-irrigation Requirement (mm)	15	15	15	-	-	-	-	-	-	-	-		
7. Net Water Requirement 4 x 5 + 6	25	41	62	90	114	121	120	135	98	52	15		
8. Diversion Water Requirement (mm) 7 /0.7/1	36	59	89	129	163	173	171	193	140	74	21		

/1: Irrigation efficiency

Fig. 9.1 Comparison of Potential Evapotranspiration

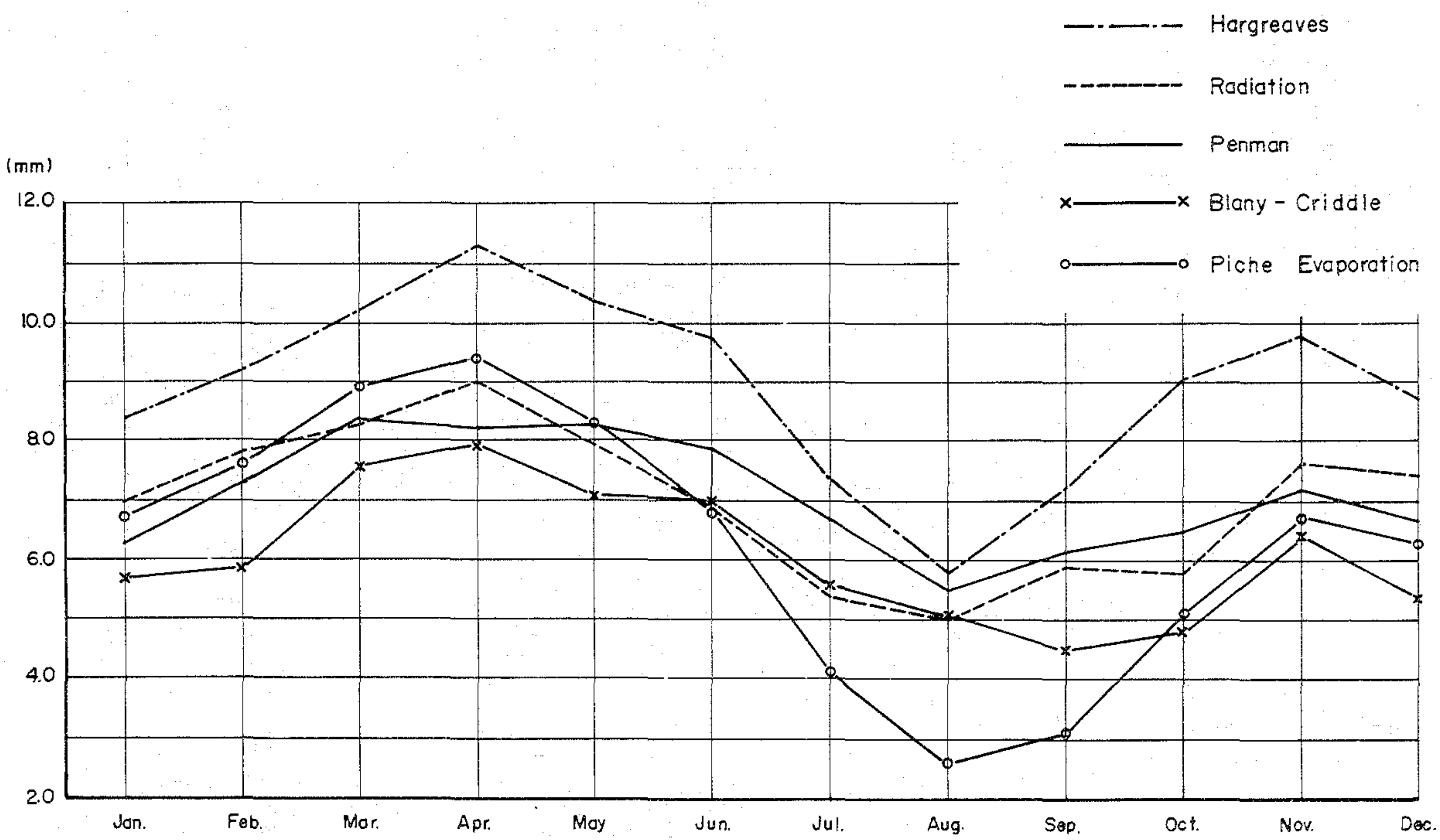


Fig. 9.2 Crop Coefficient Curve of Rice.

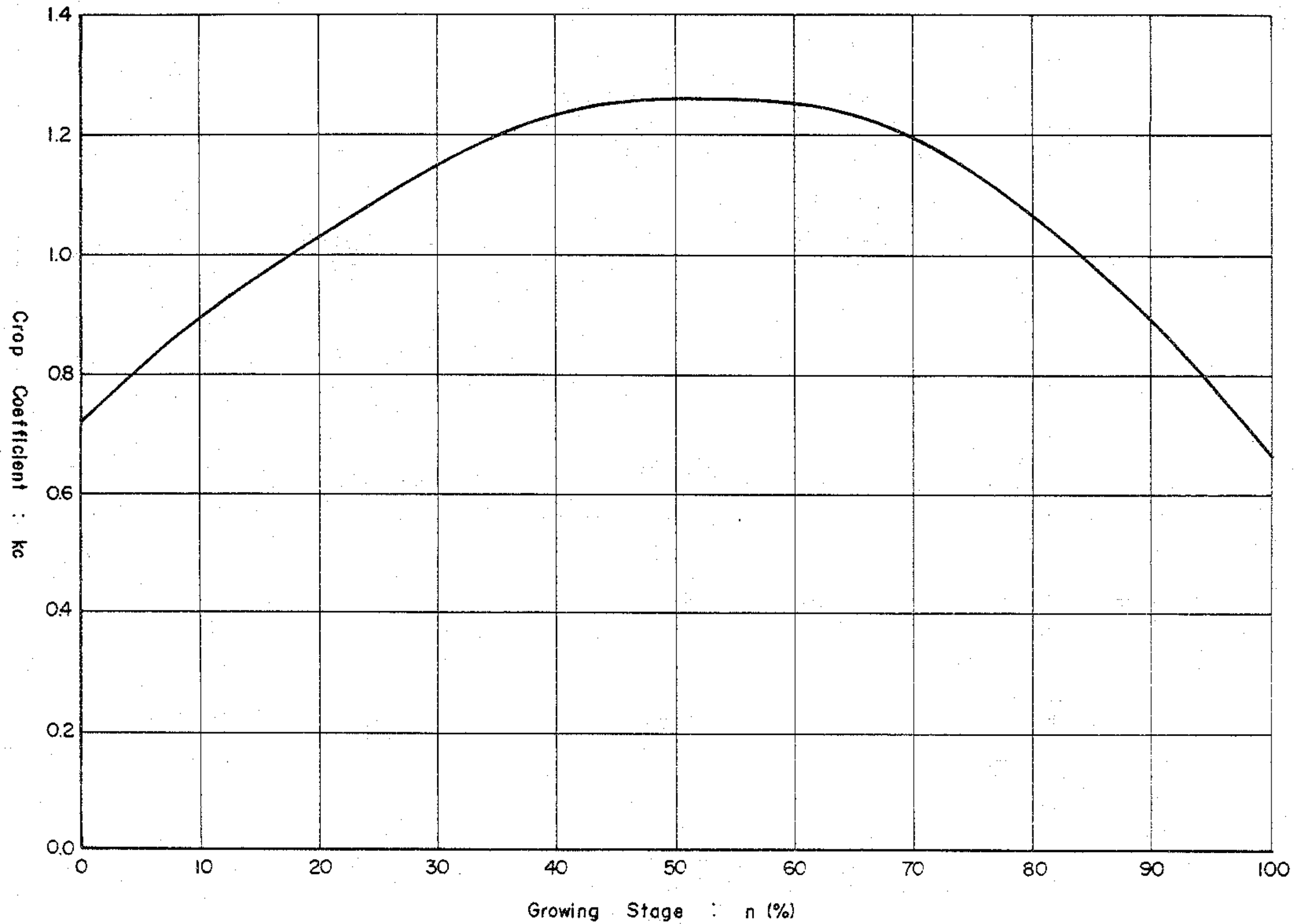


Fig. 9.3 Probable Distribution of Effective Rainfall

Year	Annual Effective Rainfall(mm)
1956	261.8
57	166.4
58	311.0
59	299.7
60	144.9
61	377.4
62	275.2
63	233.1
64	261.7
65	325.9
66	160.9
67	172.7
68	238.6
69	220.9
70	181.2
71	139.0
72	—
73	82.6
74	—
75	184.9

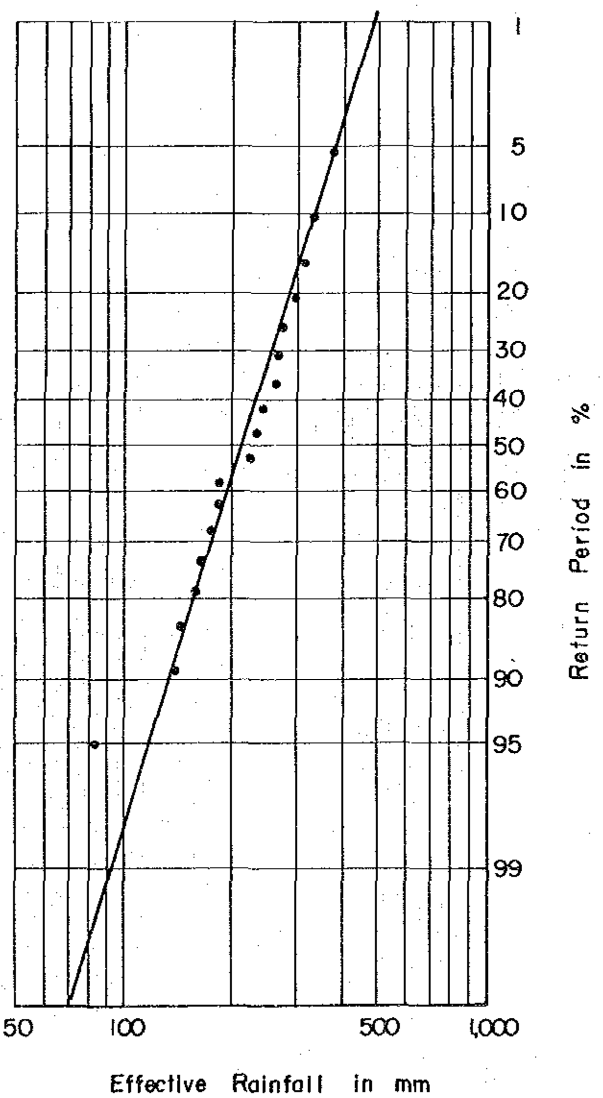


Fig. 9.4 Probable Distribution of Daily Rainfall

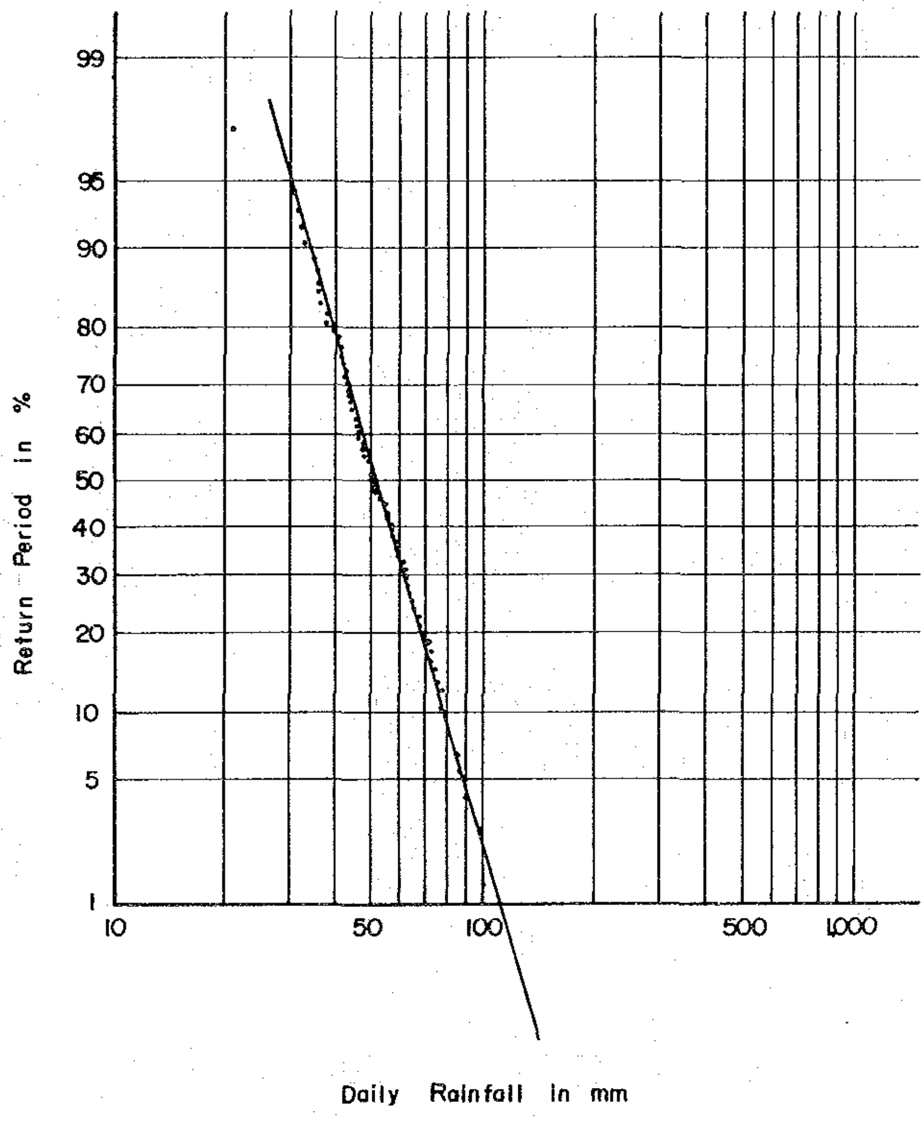
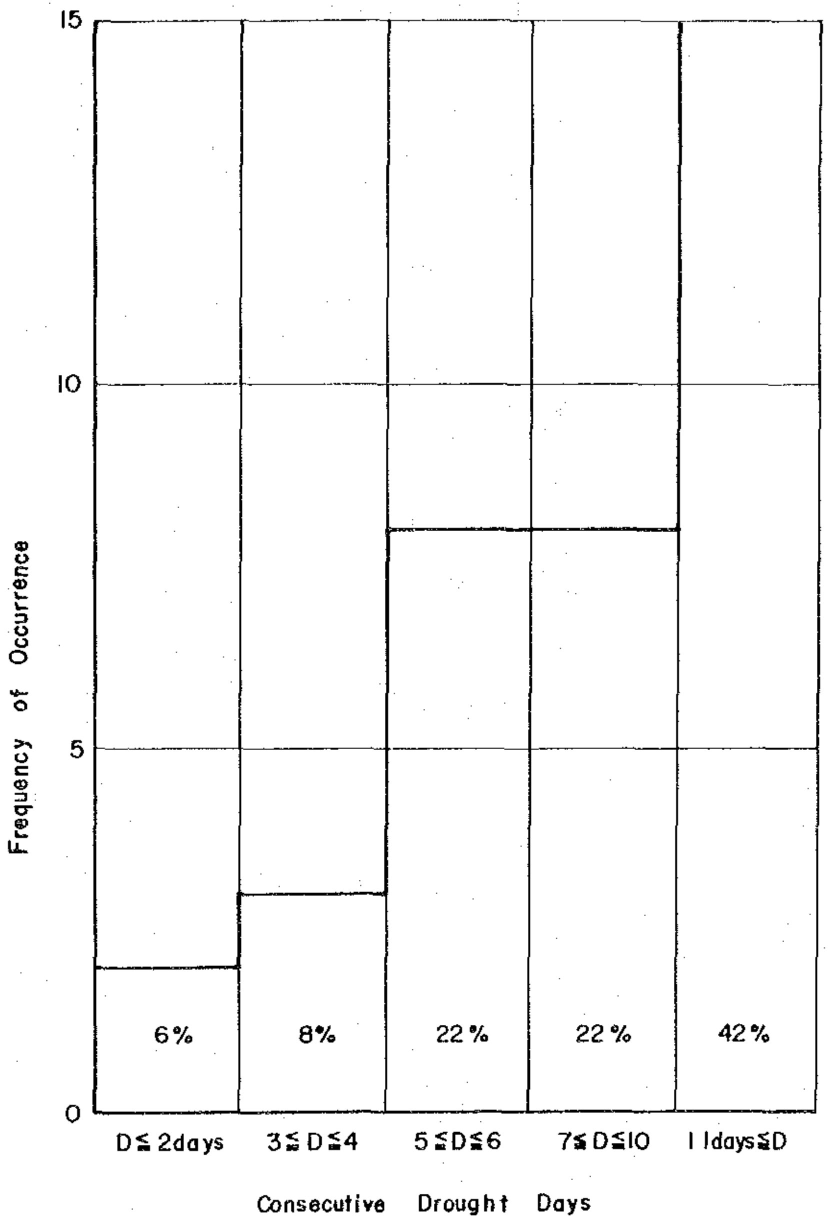


Fig. 9.5 Frequency of Consecutive Drought Day



Note : The Daily Rainfalls from 1955 to 1975 are Used.

ANNEX X

ENGINEERING STUDIES

ANNEX X

ENGINEERING STUDIES

Tables

Figures

Figures | Page

X. ENGINEERING STUDIES

10.1 Alternative Study of Irrigation and Drainage System

10.1.1 Alternative Plan

As mentioned in Annex XII, two basic alternative cropping patterns, viz. the single rice cropping pattern and double rice cropping pattern, are introduced in the project area from the agronomical viewpoints. Coupled with the introduced cropping patterns, six alternative plans are described hereinafter are prepared for the alternative study on the irrigation and drainage system in each tract of the project area.

Alternative-1 (for single rice cropping)

As far as the pattern of single rice cropping is proposed in each tract, a gravity irrigation system is technically feasible from the annual water-level fluctuation of the White Nile and the topographic condition in each tract. The Alternative Plan is subdivided into two sub-Alternative Plans as illustrated in Fig. 10.1.(1) to (2) according to the major irrigation system. Both sub-Alternative Plans can be briefly described as follows;

- Alternative-1.1 Gravity irrigation system, single intake-cum-single main canal system
- Alternative-1.2 Gravity irrigation system, multi-intakes-cum-multi-shorter main canal system

The major components to be proposed for the both Alternatives-1.1 and -1.2 comprise land reclamation with dikes, gravity major irrigation system, pumping drainage system and onfarm development work.

Alternative-2 (for double rice cropping)

In addition to the major components of the Alternative-1, a pumping station (with a dual purpose, namely, irrigation and drainage) is facilitated in each tract, to irrigate the first cropping rice during the low water season of the White Nile. The Alternative-2 is sub-divided into two sub-Alternatives which will be similar system with the Alternative-1, as illustrated in Fig. 10.1(3) to (4). Both sub-Alternatives can be briefly defined as follows;

- Alternative-2.1 Gravity and pumping irrigation system; single intake-cum-single main canal.
- Alternative-2.2 Gravity and pumping irrigation system; multi intakes-cum-multi shorter main canal

Alternative-3 (for double rice cropping)

The system of Alternative-2 will require sizable main canal to convey irrigation water with a gentle hydraulic gradient, due to the limited available hydraulic head for gravity irrigation and considerably large roughness of the unlined canals to be proposed in each tract.

Alternative-3 is prepared to improve such a hydraulic dis-advantage of Alternatives-1 and -2. Alternative-3 has a year-round pumping irrigation system to reduce the size of irrigation canals. The major components of Alternative-3 are the same as for Alternative-2, as schematically illustrated in Fig. 10.1.(5). Its specific feature is briefly described as follows;

- Alternative-3 Year-round pumping irrigation system; single intake-cum-single main canal

Alternative-4 (for double rice cropping)

Alternative-4 is prepared to improve the Alternative-3. In the Alternative-4, a number of small sized pumping stations is provided on the polder dikes so as to curtail the lengthy main canal, as shown in Fig. 10.1.(6). The major components are the same as for Alternatives-2 and -3. Its specific feature is briefly described as follows;

- Alternative-4 Year-round pumping irrigation system; multi intakes-cum-multi shorter major canal.

10.1.2 Study

(1) Cost estimate

Construction Cost

Main features, quantities and economic cost of major construction works in the six Alternatives are roughly estimated as summarized in Table 10.1 to 10.2.

Operation and Maintenance Cost

The O & M cost of pumping station is estimated based on the actual data on the existing pumping station in Ed Dueim.

The O & M cost of canal system is assumed as follows, considering the canal size and gradient;

- Alternative-1.2, -3 and -4
  1% of total construction cost of canal system
- Alternative-2.2
  2% of total construction cost of canal system
- Alternative-1.1 and -2.1
  2.5% of total construction cost of canal system

The O & M cost of pumping station and canal system is summarized as follows;

(Unit: 10^3£s)

	Alt.-1.1	Alt.-1.2	Alt.-2.1	Alt.-2.2	Alt.-3	Alt.-4
Pumping Station	220	220	580	580	930	1,000
Irrigation Facilities	1,000	390	1,090	870	440	590
Total	1,220	610	1,670	1,450	1,370	1,590

Replacement Cost

The useful life of pump, rice mill and farm machinery are shown below.

	Useful Life (Year)
Pump	25
Rice Mill	20
Farm Machinery	
- Double Cropping	8
- Single Cropping	10

The replacement cost is shown follows; (unit: 10^3£S.)

	Alt.-1.1	Alt.-1.2	Alt.-2.1	Alt.-2.2	Alt.-3	Alt.-4
Pump	1,820	1,820	3,720	3,720	3,720	9,380
Rice Mill	6,500	6,500	13,000	13,000	13,000	13,000
Farm Machinery	5,120	5,120	5,120	5,120	5,120	5,120

(2) Benefit estimate

The following assumption are made to estimate the net benefit per ha;

- The yield of single cropping rice is tentatively assumed at 4 tons of paddy rice per ha;
- The yield of double cropping rice is assumed at 10 tons paddy rice per ha per annum; 4 tons of paddy rice per ha at first cropping and 6 tons of paddy rice per ha at second cropping;
- Milling ratio is estimated at 70% of paddy rice;
- Economic price of milled rice is estimated at £S176 per ton less loading and port charge, storage charge, insurance premium and transportation cost from Port Sudan F.O.B.;
- Rice production cost is tentatively assumed at £S130 per ha for single cropping and £S310 per ha for double cropping; and
- **Negative benefit of grazing and vegetable cultivation are neglected.**

The net benefit is assessed as follows;

$$Bn = Y.m.Pg - Cp$$

where,
- Bn: net benefit (£S/ha)
- Y : yield of rice (ton/ha)
- m : milling ratio (70%)
- Pg: mill gate price (£S/ton)
- Cp: Production cost (£S/ha)

Single cropping: $Bn = 4^{t/ha} \times 0.7 \times 176^{£S/t} - 130^{£S/ha} = 363^{£S/ha}$

Double cropping: $Bn = 10^{t/ha} \times 0.7 \times 176^{£S/t} - 310^{£S/ha} = 922^{£S/ha}$

The gross benefit at the full development stage is estimated as shown below.

	Alt.-1.1	Alt.-1.2	Alt.-2.1	Alt.-2.2	Alt.-3	Alt.-4
Gross Benefit (10^3£S)	5,380	5,720	13,660	13,950	14,380	14,530

(3) IRR of each Alternative

On the basis of the economic construction cost and benefits estimated above, economic internal rate of return of each Alternative are calculated for the project life of 50 years after completion of the project constructed works. The period of implementation is 8 years.

The estimated IRR of each Alternative is shown below;

	Alt. -1.1	Alt.-1.2	Alt.-2.1	Alt.-2.2	Alt.-3	Alt.-4
IRR	less than 1%	1%	10.9%	11.6%	12.4%	9.2%

10.1.3 Conclusion

Based on the outcome of the alternative study, Alternative-3 is recommendable as a definite plan of irrigation and drainage system for the project area. Irrigation and drainage plan hereinafter will discussed on the basis of Alternative-3.

10.2 Flood Protection

10.2.1 Estimation of High Water Level

The polder dikes will be constructed along the boundary of each tract to prevent the project area from submerging by the flooding water of the White Nile during a period of 7 months from eary August to mid-February.

With full operation of the Jebel Aulia Dam, the high water level of the reservoir was initially maintained at EL. 377.20 m above MSL in 1942, and then tentatively adjusted to EL. 377.40 m above MSL from 1954 to 1956. The water level was temporarily raised to EL. 377.80 m above MSL from 1960 to 1964 and since 1965 initial operation criteria has been applied again. Therefore, the maximum high water level is estimated at EL. 377.74 above MSL using the data at the Ed Dueim station since 1966. (refer to Annex III)

10.2.2 Alignment of Dike along the White Nile

Four alternatives are prepared to finalize the dike alignment along the riverside of the White Nile as shown follows.

Alternatives	Ground Elevation proposed (m MSL)	Average Height of Dike (m)	Reclaimed Hectareage (ha)
1	374.20	4.5	3,210
2	375.20	3.5	3,180
3	375.70	3.0	2,850
4	376.20	2.5	2,300

The embankment cost and the anticipated benefit of each Alternative are roughly estimated and the benefit-minus-cost is compared as shown in Table 10.3. The correlation between the reclaimed hectareage and the (B-C) are illustrated in Fig. 10.2. From the above results, the polder dike along the riverside is aligned on the contourline of EL. 375.20 above MSL as far as possible.

10.2.3 Preliminary Design of Polder Dike

The extra embankment above the maximum high water level is indispensable for the settlement of dike foundation and the consolidation of embankment materials, and, furthermore, for some clearance to protect dikes from wave action in the White Nile.

The extra embankment for the settlement and the consolidation is estimated at 0.40 m, viz. above 10 % of net required height of the dike, from the result of soil mechanic test.

The scramble of wave to the polder dike is calculated as follows, based on SMB formula:

$$hw = 0.00086\ V^{1.1} \cdot F^{0.45}$$

where, hw: scramble of wave (m)
V: average wind speed during 10 minutes (m/sec)
F: fetch (m)

The average wind speed during 10 minutes is estimated at 15 m/sec from the climatic data recorded at the Ed Dueim station and the average distance to opposite river bank of the White Nile is estimated at 800 m on the topographic map. Therefore, the scramble of wave is calculated as below:

$$hw = 0.00086 \times 15^{1.1} \times 800^{0.45} = \underline{0.34\ m}$$

The total extra embankment of 0.74 m is required at least for the settlement, the consolidation and the scramble of wave. The crest elevation of dike proposed is EL. 378.70 m above MSL (about 1.0 m above the maximum high water), including a further clearance.

The crest width of 10 m is proposed, not from soil mechanic viewpoint but from traffic function of the main road installed on the top of dike.

The polder dikes are classified into three types, according to the height of dikes.

Type of Dike	Height of Dike
A	4.5 m
B	3.5 m
C	2.5 m

Internal and external side slopes of each type are proposed 1:2.0, based on the result of stability analysis as described in Annex IV. Berms with a width of 10 m to 12 m for the both side slope of the type are proposed from the stability viewpoint of dikes. (Refer to Annex IV) The typical cross section of each dike is illustrated in Fig. 10.3.

10.2.4 Embankment Materials and Borrow Pit

The materials have to be secured in the immediate vicinity of the site to reduce the embankment cost as much as possible. The soil from the borrow pit and the feeder channel, which are excavated along the dike alignment, is used as embankment materials of the polder dike. The borrow pit will be used as the main drainage canal.

10.3 Intake Structure and Pumping Station

10.3.1 Intake Structure

According to the hydrological data kept for the past 10 years at Ed Dueim, the lowest and the highest water levels of the White Nile are EL. 372.68 m above MSL and EL. 377.74 m above MSL, respectively.

An inlet channel for intake structure with a depth of 3.5 m and a bottom width of 4.0 m is excavated to divert irrigation water from the main course of the White Nile to the intake ponds during the low water season. The low water section of the channel is lined with wet rubble masonry from the operation and maintenance standpoints. The entire length of each channel is around 200 m on an average.

Intake structure is equipped with 2-barrel rectangular boxculvert of reinforced concrete and a regulator with steel slide gates each at inlet and outlet, as shown in DWG. 07 to 08. (Refer to ANNEX XX)

10.3.2 Pumping Station

(1) Delivery discharge

As already mentioned in the foregoing section, the pumping station in each tract is installed for dual purposes, namely, irrigation and drainage. The delivery discharge is estimated from the diversion requirement and the net irrigation hectareage of each tract, assumed pumping operation of 20 hrs/day; the irrigation water excessively pumped up due to the shortening of operation hour is regulated within the freeboard of main canals.

(2) Type of Pump

A pumping lift required in each tract varies from 2.5 m to 8 m, due to the seasonal fluctuation of the water level in the White Nile. The mixed flow type is recommendable from mechanical, geological and economical viewpoints. There are two types of mixed flow types of pump, vertical and horizontal axis. In view of the pump operation, the former type is advantageous to the latter, whereas from economical standpoint, the horizontal type is superior to the other. The mixed flow type with a horizontal axis, therefore, is proposed as the suitable pump type for each tract from geological conditions and economic standpoints.

(3) Arrangement of pump unit

Arrangement of a single unit of a large size is economically advantageous, whereas disadvantageous for emergency in the aspect of pumping performance.

The bearing capacity of foundation estimated by field penetration test is less than 20 t/m^2. The loading of the pumping station, therefore, has to be reduced by the arrangement of multi units, as far as possible; in this view, three pumping units each for Tract 1, 3 and 4, and five (5) units for Tract 2 are arranged.

(4) Bore

The bore of pump unit is estimated based on the following formula:

$$D \doteqdot 90 \sqrt{Q}$$

D : pump bore (mm)
Q : delivery discharge (m^3/min)

(5) Pumping lift

The maximum and minimum actual lifts of pump for irrigation are estimated at 6.5 m, 1.6 m, respectively, based on the water level fluctuation and the hydraulic head required to convey irrigation water into the terminal plots.

While, the maximum actual lift for drainage of 3.5 m is required during high water season of the White Nile; during the low water season, a gravity drainage is technically feasible.

The total lifts proposed are estimated by taking into account the head losses of pump unit with an actual lift.

(6) Prime mover

In general, the electric motor is more advantageous than diesel engine in every respect such as, initial cost, operation and maintenance cost, vibration, and influence on fundation, etc. As mentioned in Annex VI, however, no electric power is available in the project area at present. The use of electric motor in the project will require the extension of transmission line of a large capacity from Rabak, 150 km away from the project site. Diesel engine is, therefore, recommendable as prime mover of pumping unit in each station.

(7) Horsepower of engine

Horsepower of engine is calculated on the following formula:

$$Pw = 0.222\ r.H.Q.$$
$$P_p = Pw/\eta p$$
$$Pm = P_p(1 + \alpha)/\eta t$$

where, Pw: water horsepower (P.S.)

r: specific weight of liquid, 1.0

H: total lift (m)

Q: delivery discharge (m^3/min)

P_p: pumping horsepower (P.S.)

η_p: efficiency of pump

P_m: mover horsepower (P.S.)

α: allowance

η_t: efficiency of transmission

(8) Main features of pumping unit

Salient features of pumping unit mentioned above are estimated for each station and summarized in Table 10.4.

10.4 Irrigation Canal and Related Structures

10.4.1 Irrigation Canal Layout

General layout of canal system and layout of each tract are shown in DWG. 01 and 02 to 06 respectively.

The proposed canal system consists of Main irrigation canals, Irrigation laterals and Onfarm ditches. The irrigation water which is pumped up from the White Nile is delivered to the Onfarm ditch through Main irrigation canal and Irrigation lateral. Irrigation lateral branches off from the Main irrigation canal with approximate intervals of 2.0 km. The required water is distributed to the farm unit of 40 ha through Onfarm ditch which is diverted from Irrigation lateral with approximate interval of 400 m, as shown in Fig. 10.4.

Main irrigation canal and Irrigation lateral generally command the area which range from 700 to 3,200 ha and from 200 to 900 ha respectively. The command area of these irrigation canals in each tract are summarized as follows.

Command Area (ha)

Tract	Main Irri. Canal	Irri. Lateral
1	890 - 3,000	280 - 510
2	910 - 6,400	280 - 770
3	1,230 - 3,000	330 - 910
4	710 - 3,200	200 - 730

The lengths of irrigation canals for each of the respective tracts are estimated as follows.

Length (m)

Tract	Main Irri. Canal	Irri. Lateral	Onfarm Ditch
1	15,450	18,970	150,000
2-1 /1	12,350	21,680	160,000
2-2 /1	15,150	24,540	160,000

/1: Project area of Tract 2 is divided into 2 stages according to the implementation schedule.

(Cont'd)

Tract	Main Irri. Canal	Irri. Lateral	Onfarm Ditch
3	4,200	23,700	150,000
4	4,640	31,900	160,000
Total	51,790	120,790	780,000

The irrigation canal system, command area and proposed design discharge of each of the irrigation canals are shown in Fig.10.5.(1) to 10.5.(4).

10.4.2 Preliminary Design of Irrigation Canals

Irrigation canals in the whole project area are designed as unlined canals with trapezoidal section. The preliminary design of the irrigation canals has been made based on the basic design criteria described as follows.

(1) Design discharge

Design discharges for Main irrigation canals provide the maximum high water levels in the canals at the full pumping operation period. According to the assumed pumping operation method of 20 hrs/day, the excessive water should be stored in the Main irrigation canal during the full pumping operation period. The stored water should be used to cover the shortage of water delivered from the pumping station during the partially operated period of the pumping station.

Design discharges for Irrigation laterals and Onfarm ditches are calculated, based on the unit discharge of 1.85 ℓ/sec/ha which is mentioned in Annex IX.

Design discharges for irrigation canals are schematically shown in Figs. 10.5.(1) to 10.5.(4), Irrigation Diagrams.

(2) Permissible velocity

The maximum permissible velocity in unlined canals is decided in order to avoid the scouring of canal surface. The minimum permissible velocity is defined as the lowest velocity that does not cause silt depositing.

The permissible velocity of irrigation canals is in the range between 0.2 and 0.6 m/s, as summarized below.

Canals	Designed Velocity (m/sec)
Main Irrigation Canal	0.2 to 0.4
Irrigation Lateral	0.2 to 0.6
Onfarm Ditch	0.2

(3) Longitudinal slope

Considering the allowable water velocity and natural gradient of the ground surface, longitudinal slopes of Main irrigation canal and Irrigation lateral are designed to be within the range of 1/20,000 to 1/70,000 and 1/5,000 to 1/30,000 respectively. Longitudinal slope of Onfarm Ditches is estimated at 1/5,000.

(4) Side slope

The bank stability is analyzed based on the soil mechanical test to determine the stable side slope. The side slopes of 1:1.5 and 1:2.0 are applied to the design of Main irrigation canal. When the canal depth is less than 2.5 m, the side slope of 1:1.5 is safely used in the design of Main irrigation canal. In case of Irrigation lateral and Onfarm drain, the side slope of 1:1.0 is applied.

(5) Freeboard

Freeboard is decided so as to absorb the fluctuation of water surface due to the variation of actual roughness coefficient, conversion of velocity head to the static head and wave action caused by wind or canal structure operation.

The following empirical fomula is used as the base for determination of the freeboard.

$$D = 0.05\ d + \frac{V^2}{2g} + 0.15$$

where, D: Basic freeboard (m)
d: Hydraulic depth (m)
V: Velocity (m/s)
g: Gravitational acceleration (m/sec^2)

The proposed freeboards for Main irrigation canal and Irrigation laterals are estimated by adding the additional clearance of 0.5 m and 0.3 m respectively to the Basic Freeboard (D).

The freeboard for the Onfarm ditch is estimated at 50 % of the hydraulic depth.

(6) Hydraulic formula and roughness coefficient

Manning's formula is applied for hydraulic calculation of all canals.

$$V = \frac{1}{n} \cdot I^{1/2} \cdot R^{2/3}, \quad Q = A \cdot V$$

where, V: Velocity (m/sec)
n: Roughness coefficient
I: Hydraulic gradient
R: Hydraulic radius (m)
Q: Discharge (m^3/sec)
A: Flow area (m^2)

The roughness coefficient of 0.020 to 0.030 is generally used for the hydraulic calculation and design of unlined canals. In this project, the design roughness coefficient of 0.025 is recommended for the irrigation canals in consideration of the canal maintenance to be carried out periodically in the future.

Depending on the above criteria, monographs for the hydraulic calculation of irrigation canals are prepared as shown in Figs. 10.6.(1) to 10.6.(3)

Main features and typical cross sections of irrigation canals are shown in Table 10.5 and Fig.10.7, respectively.

10.4.3 Preliminary Design of Related Structures

The irrigation canals run across the roads at many points in the project area. Accordingly, many crossing structures like culverts will be needed. In addition to the culverts, turnouts and check structures will also be needed to distribute water and to secure steady water management.

The number of structures required in each tract is summarized below.

Structures (Nos.)

Tract	Turnout	Irri. Culvert	Check Structure
1	164	34	17
2-1/1	202	41	19
2-2/1	182	43	19
3	173	24	8
4	215	47	21
Total	936	189	84

(1) Turnout

The turnouts are provided to distribute the required water from the parent canal into the offtake canal.

In this project, the turnouts in the irrigation canal in which the water discharge is more than 0.4 m^3/sec are to be provided with the Parshall flume as a measuring device. The turnouts should be designed for accurate delivery with minimum head loss and for avoiding silt depositing. Accordingly, the permissible velocity in the turnout is, limited to be in the range of 0.5 m/sec to 1.0 m/sec.

The turnouts are divided into two types, Types A and B, to simplify and standardize the structural features for easy and quick construction.

Type A turnout

The Type A turnout consists of a slide gate with steel pier, an in-situ concrete conduit with rectangular section, a Parshall flume and a transition with gradually varied section at the downstream of the Parshall flume.

/1: According to the implementation schedule, the project area of Track-2 is divided into 2 stages.

Type A turnouts are provided in the Main Canals in which the **design discharge delivered into Irrigation Lateral ranges from 0.4 m^3/sec to 1.5 m^3/sec.**

Type A turnouts are divided into six subtypes depending on the discharge of the takeoff canal and the length of concreate conduit. The hydraulic and structural features of the respective type of turnouts are summarized below.

Subtype	Discharge (Q, m^3/sec)	Conduit length (m)	Width of Parshall flame (m)
A-1	$1.5 > Q > 0.6$	20.0	1.22
A-2	"	18.0	"
A-3	"	7.0	"
A-4	$0.6 > Q > 0.4$	20.0	0.49
A-5	"	18.0	"
A-6	"	7.0	"

Type B turnout

The Type B turnout consists of circular gate, a precast concrete pipe and a transition with gradually varied section at outlet of the concrete pipe. Type B turnouts are provided in the Irrigation laterals and the **water discharge delivered into the Onfarm Ditch** is 0.04 m^3/s. Type B turnouts are divided into 3 subtypes depending on the length of concrete conduit as shown below.

Subtype	Length of Conduit (m)
B-1	19.0
B-2	17.0
B-3	6.0

Detailed dimensions of each type of turnout are as shown in DWG. 14, and the number of the each type of turnout is summarized below.

Type	Subtype	Tract-1	Tract-2-1	Tract-2-2	Tract-3	Tract-4	Total
A	A-1	-	-	-	2	2	4
	A-2	4	5	4	-	-	13
	A-3	1	-	1	2	2	6
	A-4	-	-	-	-	1	1
	A-5	3	1	3	-	-	7
	A-6	-	-	-	1	1	2
B	B-1	6	-	7	18	20	51
	B-2	72	90	68	102	100	432
	B-3	78	106	99	48	89	420
Total		164	202	182	173	215	936

(2) Check structure

Check structures are proposed for the main canals and laterals to maintain the water level necessary for diversion of irrigation water. The design of the facilities is generally dependent upon the gradient of canals and the seasonal fluctuation of water requirement. The standardized interval between two check structures is 4 km for the main canal and 2 km for the lateral.

Check structure comprises a reinforced concrete flume and transitions with gradually varied section at both up and downstream of the flume; the flume is equipped with steel slide gates to check water surface in the irrigation canal. The inlet and the outlet of the structures are protected with dry rubble masonry. These structural features are shown in DWG. 15.

The check structures are classified into two types accroding to the design discharge of the structure.

Type A; This type is designed for a discharge greater than 5.0 m^3/sec.; it is provided with a double section concrete flume and two steel slide gates. This type is mostly installed in the main irrigation canal.

Type B; This type is smaller than Type-A; it has a single section concrete flume, equipped with a steel slide gate. This type is installed in the irrigation lateral.

Required number of the check structures in the project area is summarized below.

Numbers

Tract	Type A	Type B	Total
1	2	15	17
2-1	2	17	19
2-2	1	18	19
3	-	8	8
4	-	21	21
Total	5	79	84

(3) Irrigation culvert

The culverts in the project area are provided for road crossing. The irrigation culvert consists of an in-site concrete barrel with rectangular section or a precast concrete pipe and transitions with guadually varied section at the inlet and outlet of the conduit. The dry masonry is installed on the upstream and downstream of the culvert structure to protect the canal surface from scouring and erosion.

In designing the irrigation culverts, the velocity in the conduit which is less than 1.0 m/sec is adopted to avoid silt depositing in the conduit.

The irrigation culverts in this project are divided into three types to respond to the wide variation of the design discharge and also to simplify and standardize the structural features for easy and quick construction. Application and the characteristics of each type of the irrigation culverts are described as follows.

Type A

The design discharge for Type-A ranges from 2.5 m^3/sec to 6.0 m^3/sec. The concrete conduit with a length of 8 m is proposed for the Type-A culvert. The culvert of this type is mostly arranged in the main irrigation canal.

Type B

The conduit of this type is designed to have a concrete box barrel with single rectangular section; its conduit length ranges from 7 m to 10 m.

This type is further divided into six subtypes as shown below, dependent upon design discharge and conduit length;

Sub-type	Discharge (m^3/sec)	Conduit length (m)
B-1	$2.5 \geqq Q \geqq 1.5$	10.0
B-2	"	8.0
B-3	$1.5 > Q \geqq 0.8$	10.0
B-4	"	7.0
B-5	$0.8 > Q \geqq 0.5$	10.0
B-6	"	7.0

Subtypes B-1 and B-2 are provided in the main irrigation canal and other subtypes in the irrigation lateral.

Type C

The conduit of this type is proposed to have a precast concrete pipe, the proposed length of which ranges from 7 m to 10 m. Depending upon the design discharge and pipe length, this type is subdivided into three subtypes as follows:

Sub-type	Discharge (Q, m^3/sec)	Pipe length (m)	Diameter (mm)
C-1	$0.5 > Q > 0.25$	10.0	1,000
C-2	"	7.0	1,000
C-3	$0.25 > Q$	7.0	700

The dimensions of each type are as shown in DWG. 16. The number of the culverts in each tract is summarized below.

Type	Subtype	Tract-1	Tract-2	Tract 2-2	Tract-3	Tract-4	Total
A	-	1	1	-	1	2	5
B	B-1	-	-	1	1	2	4
	B-2	-	-	-	1	1	2
	B-3	-	1	1	-	-	2

(Cont'd)

Type	Subtype	Tract-1	Tract-2	Tract 2-2	Tract-3	Tract-4	Total
	B-4	2	14	8	2	11	37
	B-5	-	-	1	-	-	1
	B-6	4	5	4	1	5	19
C	C-1	-	4	3	-	-	7
	C-2	11	5	9	8	12	45
	C-3	16	11	16	10	14	67
Total		34	41	43	24	47	189

10.5 Drainage Canal and Related Structures

10.5.1 Drainage Canal Layout

General layout of the drainage canal system is shown in DWG. 01 and the drainage canal layout of each Tract is shown in DWG. 02 to 06.

The proposed drainage canal system consists of Main drainage canals, Drainage laterals and Onfarm drains. These drainage canals should be aligned at lower elevated portion in the project area. Accordingly, Main drainage canals in Tract 1 and 2 are aligned on the periphery of Um Jerr Island. In Tracts 3 and 4, the portions adjacent to the White Nile are selected to align the Main drainage canals.

Drainage water from farm unit of 40 ha caused by maximum daily rainfall of 79 mm and irrigation operation losses will be discharged into Onfarm drains and led to the pumping station by Drainage laterals and Main drainage canals, and then pumped out to the White Nile.

Onfarm drains branch off from the Drainage laterals with intervals of approximately 400 m and the Drainage laterals branch off from the Main drainage canals with interval of approximately 2.0 km by turns with the irrigation canals. The typical drainage system is shown in Fig. 10.4.

The length of the drainage canals in each tract is shown below.

	Length (m)		
Tract	Main Drain. Canal	Drain. Lateral	Onfarm Drain
1	17,000	19,090	75,000
2-1	15,200	16,900	80,000
2-2	11,900	22,250	80,000
3	15,500	20,500	75,000
4	13,700	24,500	80,000
Total	73,300	103,240	390,000

Catchment areas of Main drainage canal and Drainage lateral range from 730 ha to 7,770 ha and from 150 ha to 1,070 ha respectively. The catchment area of these drainage canals in each tract is summarized as follows.

	Catchment Area (ha)	
Tract	Main Drain. Canal	Drain. Lateral
1	780 - 3,450	190 - 540
2	990 - 7,770	220 - 930
3	730 - 3,600	240 - 1,000
4	920 - 3,800	150 - 1,070

The drainage canal system, catchment area and proposed design discharges of the drainage canals are shown in Figs. 10.8.(1) to 10.8.(4).

10.5.2 Preliminary Design of Drainage Canals

Drainage canals in the whole project area are designed as the unlined canal with trapezoidal section. When the canal depth is more than 5.0 m, berms 3.0 m wide are provided in the canal section.

The preliminary design of the drainage canals has been made based on the basic design criteria described below.

Decision of the canal capacity

The rain water should be stored in the paddy fields and all drainage canals and then pumped out to the White Nile as mentioned in Annex IX. Therefore, the capacity of the drainage canals is designed as storages according to the amount of surplus water which cannot be stored in the paddy fields. The storage capacity of drainage canals in each tract is shown below.

Storage Capacity (10^3 m^3)

Tract 1	Tract 2	Tract 3	Tract 4	Total
997	2,245	1,040	1,098	5,380

Design discharge

In designing the drainage structures, the delivery discharge due to the drainage pump operation is assigned as the design discharge. The delivery discharge at each pumping station ranges from 8.1 m^3/sec to 17.0 m^3/sec which has been studied in Annex IX.

Longitudinal slope

Considering the natural gradient of the ground surface and the role of the drainage canals mentioned above, longitudinal slopes of Main drainage canals and Drainage laterals are designed to be in the range of 1/3,500 to the level and of 1/3,000 to 1/15,000 respectively.

Side slope

The bank stability is analyzed based on the soil mechanical test to determine the stable side slope. Accordingly, the proposed side slope of 1:2.0 is adopted for Main drainage canals. In designing Main drainage canals, berms,3.0 m wide should be provided in the canal section when the canal depth is more than 5.0 m. In case of Drainage Laterals and Onfarm drains, the side slopes of 1:1.5 and 1:1.0 are applied respectively.

Water depth and Canal base width

To satisfy the required storage capacity, the water depth of 2.5 m and the canal base width of 5.0 m to 10.0 m are proposed in designing the Main drainage canals. From the same view point, the water depths of 0.5 to 1.5 m and 1.0 m, canal base widths of 1.0 to 5.0 m and 0.3 m are employed for the design of Drainage laterals and Onfarm drains respectively.

Main features and typical cross sections of Drainage canals are shown in Table 10.5 and Fig. 10.7 respectively.

10.5.3 Preliminary Design of Related Structures

The drainage canals run across the roads and the irrigation canal so that the many crossing structures like culverts will be needed. In addition to culverts, the junction structures will be provided to prevent the canal surface from scouring and erosion at the connecting point of two drainage canals.

Required number of those structures in each tract is summarized below.

Structures (Nos.)

Tract	Drain. Culvert	Junction
1	47	83
2-1/1	45	107
2-2/1	45	98
3	52	59
4	52	88
Total	241	435

(1) Drainage Culvert

The drainage culverts are provided for the farm road and canal crossing. The drainage culvert consists of an in-situ concrete barrel with rectangular section or a precast concrete pipe and concrete wing walls at inlet and outlet of the conduit. The protection with dry masonry should be installed at both up and downstream of the culvert.

To avoid silt depositing in the conduit, the design velocity in the conduit is assumed as 0.5 m/sec.

The drain culverts in the project are divided into four types, A, B, C and D, because of the wide variation in the design discharge of the drainage canals and for simplifying and standardizing the structural features for easy and quick construction.

The application and the characteristics of each type are described as follows.

/1: Project area of Tact 2 is divided into 2 stages according to the implementation schedule.

Type A

This type has two or three in-situ concrete barrels with a large rectangular section; the design discharge of this type is greater than 5 m^3/sec.

Type B

Type-B drainage culvert is arranged to cross the irrigation canal and the farm road; this type is designed for a discharge of 3.4 m^3/sec.

Type C

The design discharge of this type ranges from 0.6 m^3/sec to 3.0 m^3/sec.

It has the in-situ concrete barrel with a single rectangular section. This type is divided into three subtypes, depending upon the design discharge; the design discharge of types C-1, C-2, C-3 varies between 2.0 m^3/sec and 3.0 m^3/sec, 1.0 m^3/sec and 2.0 m^3/sec, 0.6 m^3/sec and 0.6 m^3/sec, respectively. These types of culverts are mostly arranged in the Drainage Laterals to cross farm roads and onfarm roads.

Type D

The design discharge, ranging from 0.2 m^3/sec to 0.6 m^3/sec, is applied for type-D. This type is provided with a precast concrete pipe in the Onfarm drain. Type D culverts are divided into two types according to the design discharge; design discharge of Types D-1 and D-2 range from 0.4 m^3/sec to 0.6 m^3/sec and from 0.2 m^3/sec to 0.4 m^3/sec respectively.

The dimensions of each type are as shown in DWG. 17. The number of the required drainage culverts is summarized as follows.

Type	Subtype	Tract-1	Tract-2-1	Tract-2-2	Tract-3	Tract-4	Total
A		1	2	-	-	1	4
B		-	-	-	-	1	1
C	1	1	-	2	-	1	4
"	2	13	18	16	6	11	64
"	3	7	4	7	4	3	25
D	1	8	5	5	5	3	26
"	2	18	16	15	37	31	117
Total		48	45	45	52	51	241

(2) Drainage junction

To protect the canal surface against scouring and erosion, the drainage junction is installed at the connecting point of two drainage canals. The drainage junctions are divided into three types, A, B and C, according to the water discharge in the minor canal, the difference of canal base elevation at the connecting point and the relationship with other structures. Application of each type is as shown below.

Type	Sub-type	Application	Note
A	A-1	$Q \geqq 0.5\ m^3/sec, H < 0.5\ m$	-
	A-2	$Q < 0.5\ m^3/sec, H \geqq 0.5\ m$	-
B	-	$Q < 0.5\ m^3/sec, H < 0.5\ m$	-
C	-	$Q \leqq 0.5\ m^3/s$	connected with a culvert

Note:
Q : Discharge in the minor drainage canal
H : Difference of canal base elevation

Main features of each type are described as follows.

Type A

The longitudinal slope of the minor canal at the connecting portion is made steeper to decrease the fall at junction. The modified longitudinal slope of 1/100 is used in designing Type A junctions. Thus, the base of the minor canal is kept at the same level as that of the base of the main canal in the design of subtype A-1 junctions. In case of subtype A-2, the fall is kept within 0.5 m.

The surface of the main drainage canal where the normal water flow is disturbed due to the connection of two canals is protected with dry masonry. And the portion of the minor canal where the velocity is increased due to the steepened longitudinal slope is also protected with dry masonry.

Type B

The minor canal is connected to the main canal without any structural modification. The surface of main and minor drainage canals where the normal water flow is disturbed due to the connection of two canals is protected with dry masonry.

Type C

The drop structure is provided at downstream of the culvert to avoid scouring and erosion. The energy of the drained water in the minor drainage canal is dissipated at the drop structure and then the water is led into the main drainage canal.

The structural features of the junction are as shown in DWG. 18 and the required number of drainage junctions in the project area is summarized below.

Number

Type	Type A-1	Type A-2	Type-B	Type-C	Total
1	-	-	75	8	83
2-1	14	7	86	-	107
2-2	7	7	84	-	98
3	8	7	35	9	59
4	24	5	59	-	88
Total	53	26	339	17	435

10.6 Road System

10.6.1 Layout of Farm Road

Roads in the project area are classified into the main road, farm road and onfarm road based on the respective function in the project. All weather road networks are required to provide farm-to-market and market-to-farm access to allow the truckage of project inputs and outputs and, furthermore, to facilitate the operation and maintenance of the irrigation and drainage system. The main road and farm road are paved with well compacted laterite gravel materials.

The main roads are aligned on the top of polder dikes and feeder channel dikes; supplementally they are planned to be constructed at somewhere near the center of each tract.

The farm roads are aligned along the irrigation laterals arranged at 2 km intervals, provided with inspection roads for the operation and maintenance of the said laterals.

Onfarm roads are arranged at 400 m intervals by turns with onfarm drains to be directly connected with the farm roads for the convenience of mechanized farming; farm machinery can be conveyed directly to each terminal plot without crossing other plots.

10.6.2 *Preliminary Design of Farm Road*

(1) Width

The width of the road is usually determined by taking into account the types of vehicles, traffic volume, construction cost, maintenance cost and future prospect of widening. The total widths of the main road, farm road, and onfarm road, inclusive of the shoulders on both sides are standardized as 10 m, 8 m, 7 m, respectively on the basis of large scaled and intensive mechanization plan proposed in the project (refer to ANNEX XIII); the effecive widths of the main road and farm road, 7 m, 6 m, respectively. The width of the inspection road of 3 m in total is proposed for small scaled vehicles to inspect the irrigation laterals.

(2) Height

The main road, except the one proposed on the top of dike has an embankment of 50 cm above the existing ground surface including extra embankment for anticipated settlement of foundation; the farm road and the onfarm road have an embankment of 30 cm, due to the access of the farm machinery to the farmland.

(3) Profile

Roads must be cambered to provide the surface drainage. The percentage of camber of 3% is proposed for all roads in view of the pavement method mentioned hereinafter.

No side ditch for drainage of rain water is provided on most of the roads except for inspection roads, since irrigation and/or drainage canals are aligned along both sides of the roads. The inspection road has a side-ditch on the side where the farm road is aligned.

(4) Pavement

The pavement material has to be chosen based on the local condition of the project site. The laterite pavement with a thickness of 20 cm is proposed for the main road and the farm road, taking the size of vehicles, traffic volume and construction cost into accunt; no pavement, on the onfarm road.

The typical cross section of each road is illustrated in Fig. 10.9.

10.7 Onfarm Development

10.7.1 Layout of Ditches, Drains and Roads

Onfarm ditches and onfarm drains are separately aligned from the viewpoints of operation and maintenance of the terminal system and of water management. The ditches are proposed for construction along onfarm roads by turns with onfarm drains, and the onfarm drains in parallel with the onfarm roads.

Such alignment of the terminal system as mentioned above has definite advantages as described below.

- Irrigation water is fully controllable and equal amount of irrigation water can be supplied to each terminal plot;
- Excess water in each terminal plot can be released quickly into the main drainage canal; and
- Each plot is directly linked with the farm road which has a major function of transporting the farm inputs and outputs.

A typical layout of paddy fields proposed for the project is illustrated in Fig 10.4.

10.7.2 Size and Shape of Plot

The size and shape of plot exert much influence on the farming practice, pest control, farm management and the project cost in a long run. Careful attention should be paid to the items below when deciding the size and shape of the terminal plot:

- Operational efficiency of farm machinery
- to minimize the construction cost of onfarm development as little as possible; and
- to minimize as little as possible the land reduction ratio to be estimated from the size and the density of onfarm facilities.

To determine the optimum size and shape of the terminal plot, an alternative study is made hereinafter.

(1) Alternatives

In due consideration of local conditions of farming management, farming practice and labour sources in the Sudan, the size of plot of 0.4 ha to 1.0 ha is recommendable.

In this view, four Alternatives are prepared for the study on the "optimum size and shape of plots."

Alternative	Size (ha)	Shape (m x m)
1	0.4	30 x 133
2	0.6	35 x 171
3	0.8	40 x 200
4	1.0	45 x 222

(2) Construction cost

The work volumes of onfarm development, such as the construction of ditches, drains, roads, onfarm structures and the levelling work are figured out as shown in Table 10.6. The construction cost is estimated as shown below.

	Alt.-1	Alt.-2	Alt.-3	Alt.-4
Construction Cost (US$/ha)	1,490	1,390	1,340	1,370

(3) O & M cost of farm machinery

Unit operation cost is tentatively estimated as shown below.

- Unit cost per hr of 75 P.S. tractor

Fuel	7.8 ℓ/hr x 0.095 £S/ℓ	= 0.741 £S
Miscellaneous	30% of fuel	= 0.222
Operator	0.189 x 3.00	= 0.567
Labour	0.083 x 1.00	= 0.083
	Total	1.613 £S/hr

- Ploughing hour per ha

  $T = T' E$

  Where, T : operation hour per ha

  T': basic operation hour per ha, 1.6 hr/ha

  E : operation efficiency at length of run 200 m

  E_1: soil coefficient 1.30

  E_2: operation coefficient 0.95

  E_3: shape coefficient 1.00

  T = 1.60 hr/ha x 1.30 x 0.95 x 1.00 = 1.976 hr/ha

Therefore, operation cost = 1.613 £S/hr x 1.976 hr/ha = 3.187 £S/ha

Unit depreciation cost is also estimated as shown below.

- Depreciation rate of machinery (75 P.S tractor) 0.033 %/hr
- Maintenance rate 0.0092 %/hr
- Delivery cost at project site (75 P.S tractor) 5,050 £S
- Depreciation cost per hr 5,050 x (0.033 + 0.0092) = 2.13 £S/hr
- Depreciation cost per ha = 2.13 x 1.976 = 4.209 £S/ha

Basic O & M cost of farm machinary for double cropping comprises the operation cost and the depreciation cost as shown below.

(3.187 + 4.209) x 2 = 14.792 £S/ha

Based on the "land consolidation criteria for paddy field in Japan," the ploughing efficiency for each Alternative is estimated as follows, on the assumption of the length of run-width rate.

Alternative	Size (ha)	Efficiency (%)
1	0.4	75
2	0.6	85
3	0.8	90
4	1.0	92

The relative efficiency is converted from the above table as shown below, since the basic operation hour is estimated on the basis of the length of run of 200 m.

Alternative	Length of Run (m)	Relative Efficiency (%)
1	133	83
2	171	94
3	200	100 (basic)
4	222	102

O & M cost of farm machinery is finally calculated by multiplying the ploughing efficiency by the basic O & M cost, as shown below.

	Alt.-1	Alt.-2	Alt.-3	Alt.-4
O & M cost of Farm Machinery (£S/ha)	17.8	15.7	14.8	14.5
- do - (US$/ha) /1	45	40	38	37

(4) Comparision of each Alternative

Alternative -3 is the cheapest in alternatives on construction cost. Alternative -3 and -4 are cheaper than the other alternatives on O & M cost of farm machinery. From these viewpoints, Alternative -3 is recommendable. But it has a considerably long length of run. The plot recommended, therefore, must be managed by subdividing it into two or three subplots with tentative ridges, to achieve precise water control at early growing stage of paddy crops.

10.7.3 Land Levelling

The hilly area at 377.2 m above MSL or more are excluded from the levelling work. The farm surface undulation in each terminal plot should be within 10 cm after completion of the onfarm development work.

10.7.4 Rotational Irrigation Practice at Onfarm Level

The onfarm operations such as pre-irrigation, land preparation and sowing have to be completed within 45 days.

/1 : Exchange rate of £S = US$ 2.55 is tentatively used.

Each minor turnout commands area of 40 ha (50 plots x 0.8 ha) as illustrated in Fig. 10.4. One tractor with relevant accessories is able to carry out the above mentioned operations on 400 ha within 45 days. The said operations on 40 ha commanded by each turnout, therefore, will be completed within 4.5 days. In this view, 4 day-rotational irrigation practice is proposed at onfarm level; 10 ha or 12.5 plots, out of the respective 50 plots will be irrigated day by day.

10.8 Compensation for Existing Schemes (Feeder channel)

So far, 246 pumping schemes all together have been developed in the area along the boundary of the project area, out of which 28 schemes are being operated by the public corporation, and the remaining 218 small scaled schemes by private sectors. At present, total irrigation water drawn into the said schemes is about 18 m^3/sec (or 120 million m^3 annually in total capacity) from the vast Gasaba swamps inundated during high water season of the White Nile. In order to divert the irrigation water from the White Nile to all the existing schemes after the completion of the project, dikes of feeder channels 2.5 m high on an average are proposed at the site shifted back to appropriate distance from the existing pumping station as shown in Fig. 10.10. Two inlets for the channels are proposed in the vicinity of Araki Island and Golli villages, respectively. From the hydraulic viewpoint, west side inlets may not function sufficiently to provide stable water supply to the existing schemes, since the channels are extending more than 50 km from north to south.

In order to dispel such a hydraulic uncertainty, two inlet channels are supplementally proposed to divert the irrigation water from the White Nile into the feeder channels, in connection with the demarcation of Tracts-2, -3 and -4.

Table 10.1 Main Features and Construction Quantities of Each Alternative

(x 10^3 £S)

Works	Unit	Alt. 1.1	Alt. 1.2	Alt. 2.1	Alt. 2.2	Alt. 3	Alt. 4
(1) Irrigation Canals							
Embankment	m^3	777,000	532,700	777,000	1,145,600	1,276,200	663,300
Excavation	m^3	1,702,600	167,000	1,702,600	447,500	274,100	43,600
(2) Drainage Canals							
Embankment	m^3	481,900	481,900	481,900	481,900	481,900	481,900
Excavation	m^3	5,812,500	5,812,500	5,812,500	5,812,500	5,812,500	5,812,500
(3) Farm Road							
Embankment	m^3	964,100	964,100	964,100	964,100	964,100	964,100
Laterite	m^3	282,600	282,600	282,600	282,600	282,600	282,600
(4) Polder Dike							
Embankment	m^3	3,973,100	3,973,100	3,973,100	3,973,100	3,973,100	3,973,100
Laterite	m^3	168,300	168,300	168,300	168,300	168,300	168,300
(5) Feeder Channel							
Excavation	m^3	1,645,200	1,645,200	1,645,200	1,645,200	1,645,200	9,398,100
(6) Pump Station							
Excavation	m^3	-	-	478,800	478,800	478,800	478,800
Irrigation pump	Nos.	-	-	4	4	4	26
Drainage pump	Nos.	4	4	-	-	-	-
(7) Related Structures							
i) Turnout	Nos.	936	923	936	936	936	923
ii) Irrigation culvert	Nos.	189	187	189	189	189	187
iii) Check Structure	Nos.	84	78	84	84	84	78
iv) Intake	Nos.	-	32	-	30	-	-
v) Drainage Culvert	Nos.	241	241	241	241	241	241
vi) Junction	Nos.	435	435	435	435	435	435

Table 10.2 Construction Cost of Each Alternative

($\times 10^3$ £S)

Works	Alt. 1.1	Alt. 1.2	Alt. 2.1	Alt. 2.2	Alt. 3	Alt. 4
1) Civil Works						
Irrigation Canals	3,380	2,370	3,380	3,000	2,720 m	2,120
Drainage Canals	5,200	5,200	5,200	5,200	5,200	5,200
Farm Road	2,140	2,140	2,140	2,140	2,140	2,140
Polder Dike	5,730	5,730	5,730	5,730	5,730	5,730
Feeder Channel	1,160	1,160	1,160	1,160	1,160	6,580
Pump Station	2,580	2,580	5,490	5,490	5,490	13,290
Onfarm Development	13,050	13,460	13,050	13,320	13,730	13,880
Miscellaneous	6,660	6,560	7,250	7,260	7,330	9,860
Sub-Total	39,900	39,200	43,400	43,300	43,500	58,800
2) Processing facilities	9,000	9,000	18,000	18,000	18,000	18,000

Table 10.3 Benefit and Cost of the Dike Construction of Each Alternative

	Alt.-1	Alt.-2	Alt.-3	Alt.-4
1. Elevation to be located (MSL)	374.20	375.20	375.70	376.20
2. Average height of Dikes (m)	4.5	3.5	3.0	2.5
3. Reclainable acreage (ha)	3,210	3,180	2,850	2,300
4. Embank. volume per m (m^3)	73.94	47.44	36.15	23.50
5. Total Embank. volume	739,400	474,400	361,500	242,100
6. Embank. Cost (£s)	1,109,100	711,600	542,300	363,200
7. Yield of milled Rice (ton)	22,500	22,260	19,950	16,100
8. Total Net Benefit (£S)	2,407,500	2,381,800	2,134,700	1,722,700
9. (Benefit) - (Cost)(£S)	1,298,400	1,610,200	1,592,400	1,359,500

Note: (1) Unit yield for milled rice of 7 ton/ha and net benefit of 107 £s/ton are tentatively assumed.

(2) Typical cross section of the dike is assumed as illustrated below.

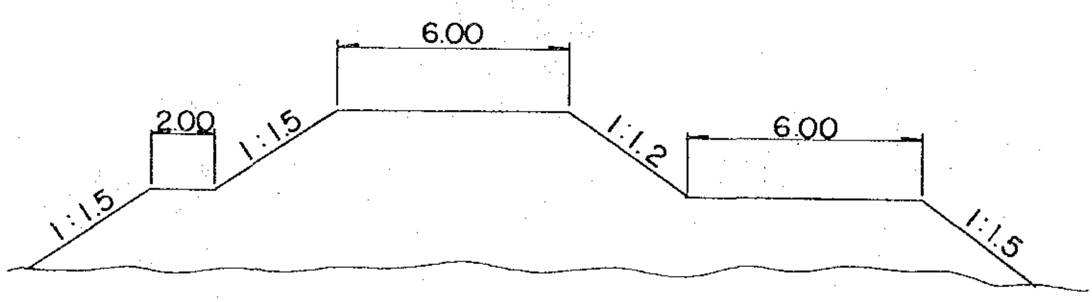


Table 10.4 Main Features of Pumping Station

Items	Unit	Tract - 1	Tract - 2	Tract - 3	Tract - 4	Total
1. Command Area	ha	3,000	6,400	3,000	3,200	15,600
2. Delivery Discharge	m^3/sec. (m^3/min.)	6.72 (403)	14.28 (857)	6.72 (403)	7.08 (425)	34.8 (2,088)
3. Pumping Bore	mm	1,000	1,100	1,000	1,000	-
4. Nos. of Unit	Nos.	3	5	3	3	14
5. Actual Head	m	6.44	6.44	6.44	6.44	-
6. Total Head	m	7.50	7.50	7.50	7.50	-
7. Type of Pump	-	Mixed Flow with Horizontal Axis	- do. -	- do. -	- do. -	-
8. Prime Mover (Nos.)	-	Diesel Engine (3)	- do. - (5)	- do. - (3)	- do. - (3)	-
9. Gross Power (Unit output)	P.S	990 (330)	2,100 (420)	990 (330)	1,050 (350)	5,130

Table 10.5 Typical Cross Section of Canals

Items	Unit	Irrigation Canal			Drainage Canal		
		Main	Lateral	Onfarm Ditch	Main	Lateral	Onfarm Drain
1. Bottom Width	m	3.0 to 7.0	1.0 to 3.0	0.3	5.0 to 10.0	1.0 to 5.0 (5.0 or 10.0)	0.3
2. Side Slope	-	1 : 2 1 : 1.5	1 : 1	1 : 1	1 : 2	1 : 1.5	1 : 1
3. Top Width of Bank							
Right Bank	m	2.0	1.5	1.0	2.0	1.50	1.0
Left Bank	m	3.0	3.0	1.0	Farm Road	1.50	1.0
4. Berm Width	m	-	-	-	3.0	-	-
5. Hydraulic Depth	m	1.0 to 3.0	0.4 to 1.5	0.35	2.5	0.5 to 1.5 (2.5)	1.0 (0.9)
6. Longitudinal Slope	-	1/20,000 to 1/70,000	1/1,500 to 1/30,000	1/5,000	1/3,500 to level	1/2,000 to 1/15,000	1/5,000
7. Velocity	m/sec.	0.20 to 0.40	0.20 to 0.60	0.20	-	0.20 to 0.85	0.30

* Parenthesized numbers are main type.

Table 10.6 Main Features and Construction Quantities for Onfarm Development

Works	Unit	Alt. 1	Alt. 2	Alt. 3	Alt. 4
(1) Irrigation Lateral					
Excavation	m^3/ha	1.4	1.3	1.3	1.3
Embankment	m^3/ha	22.6	22.1	21.9	21.8
(2) Onfarm Ditch					
Excavation	m^3/ha	2.9	2.4	2.0	1.8
Embankment	m^3/ha	225.4	181.5	154.0	140.6
(3) Drainage Lateral					
Excavation	m^3/ha	43.7	42.8	42.3	42.2
Embankment	m^3/ha	5.9	5.8	5.7	5.7
(4) Onfarm Drain					
Excavation	m^3/ha	104.6	79.6	67.5	67.2
Embankment	m^3/ha	41.8	31.8	27.0	26.9
(5) Farm Road					
Embankment	m^3/ha	10.3	10.1	10.0	10.0
(6) Onfarm Road					
Embankment	m^3/ha	94.7	69.5	57.3	57.1
(7) Land Leveling					
Earth Works	m^3/ha	332.0	428.0	500.0	555.0

Fig. 10. 1. (1) ALTERNATIVE 1 - 1 (Single Crop)

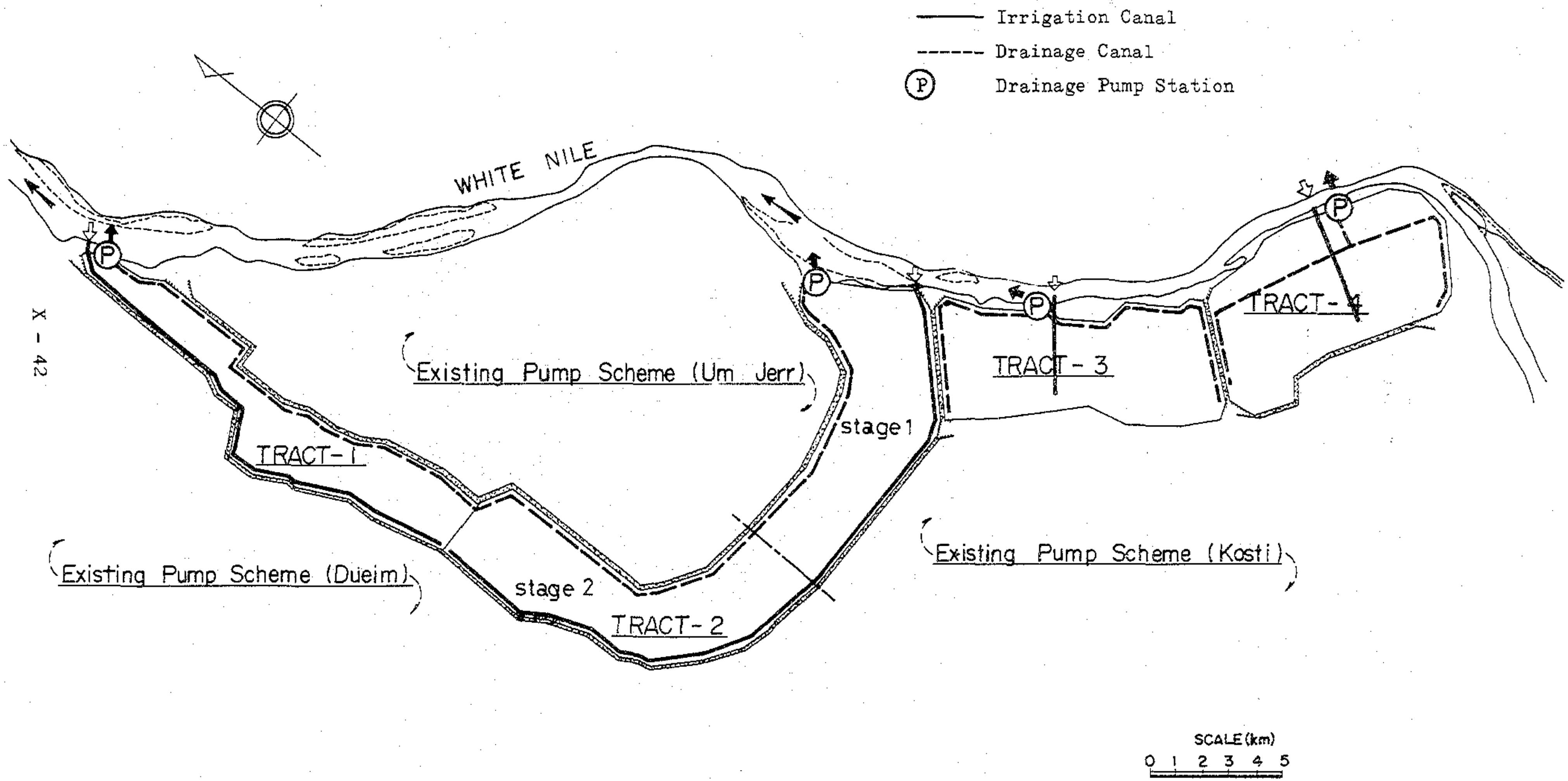


Fig.10. 1. (2) ALTERNATIVE I - 2 (Single Crop)

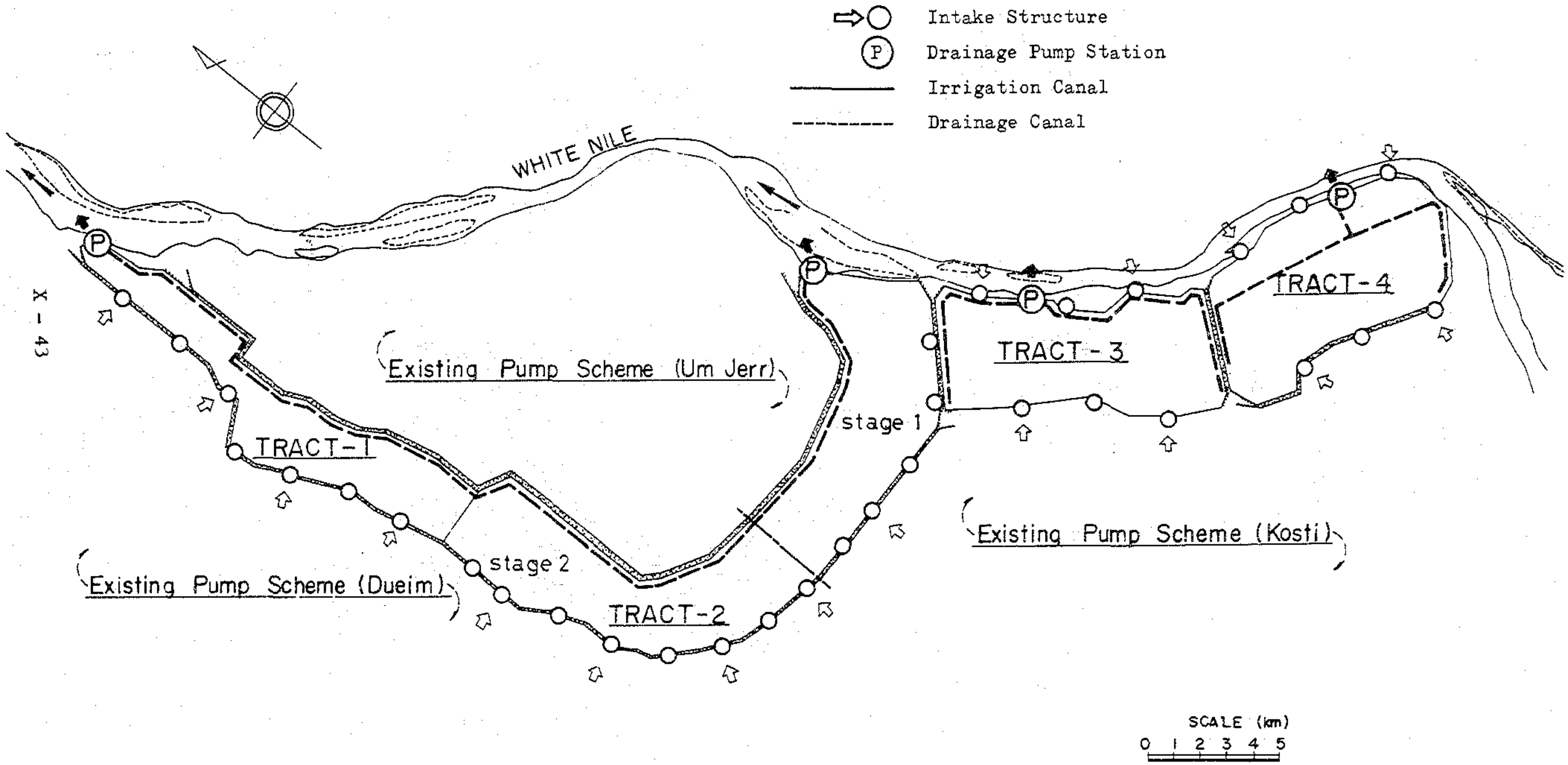


Fig.10. 1.(3) ALTERNATIVE 2-1 (Double Crop)

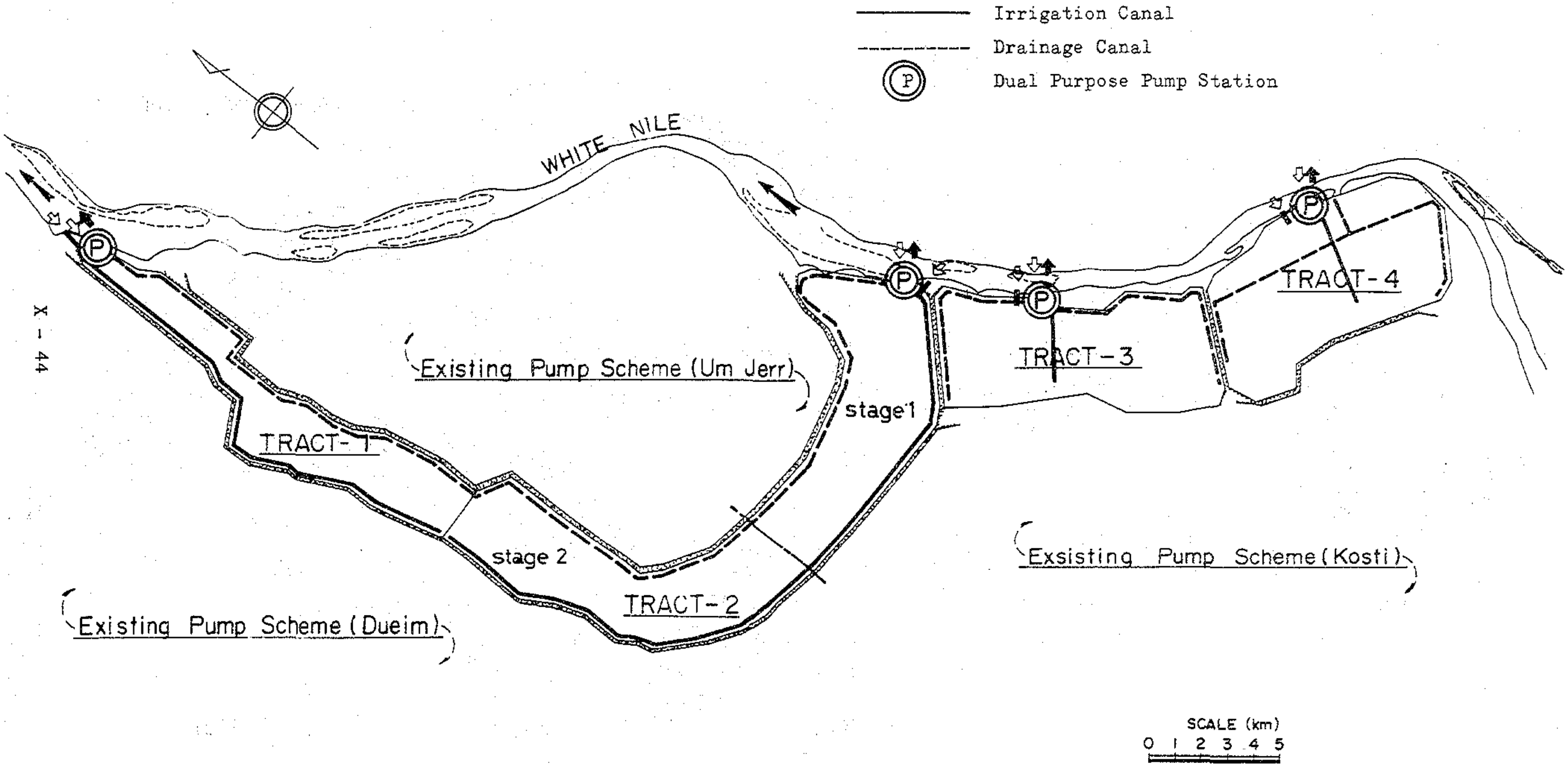


Fig. 10. 1.(4) ALTERNATIVE 2-2 (Double Crop)

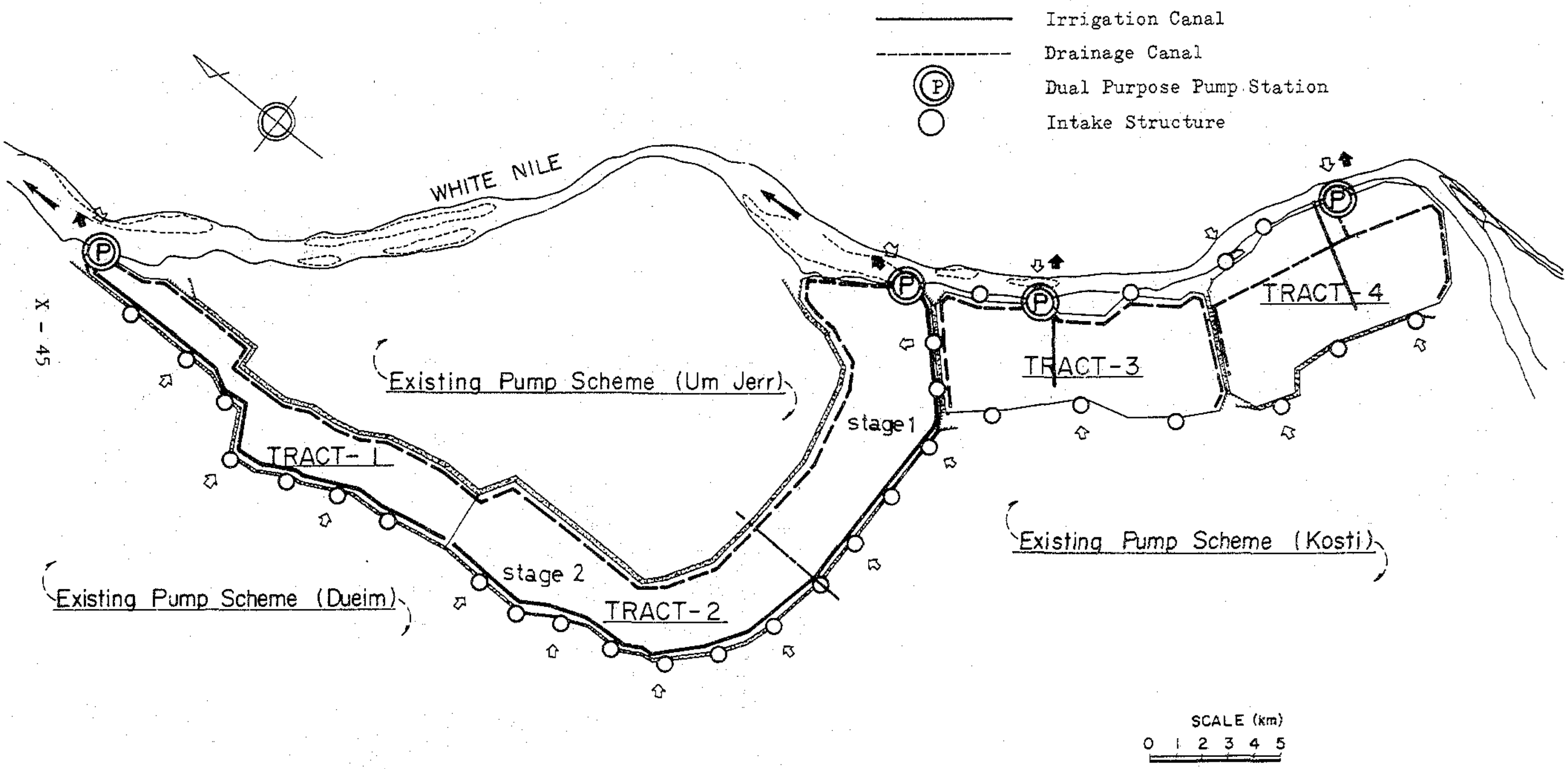


Fig. 10.1 (5) ALTERNATIVE 3 (Double Crop)

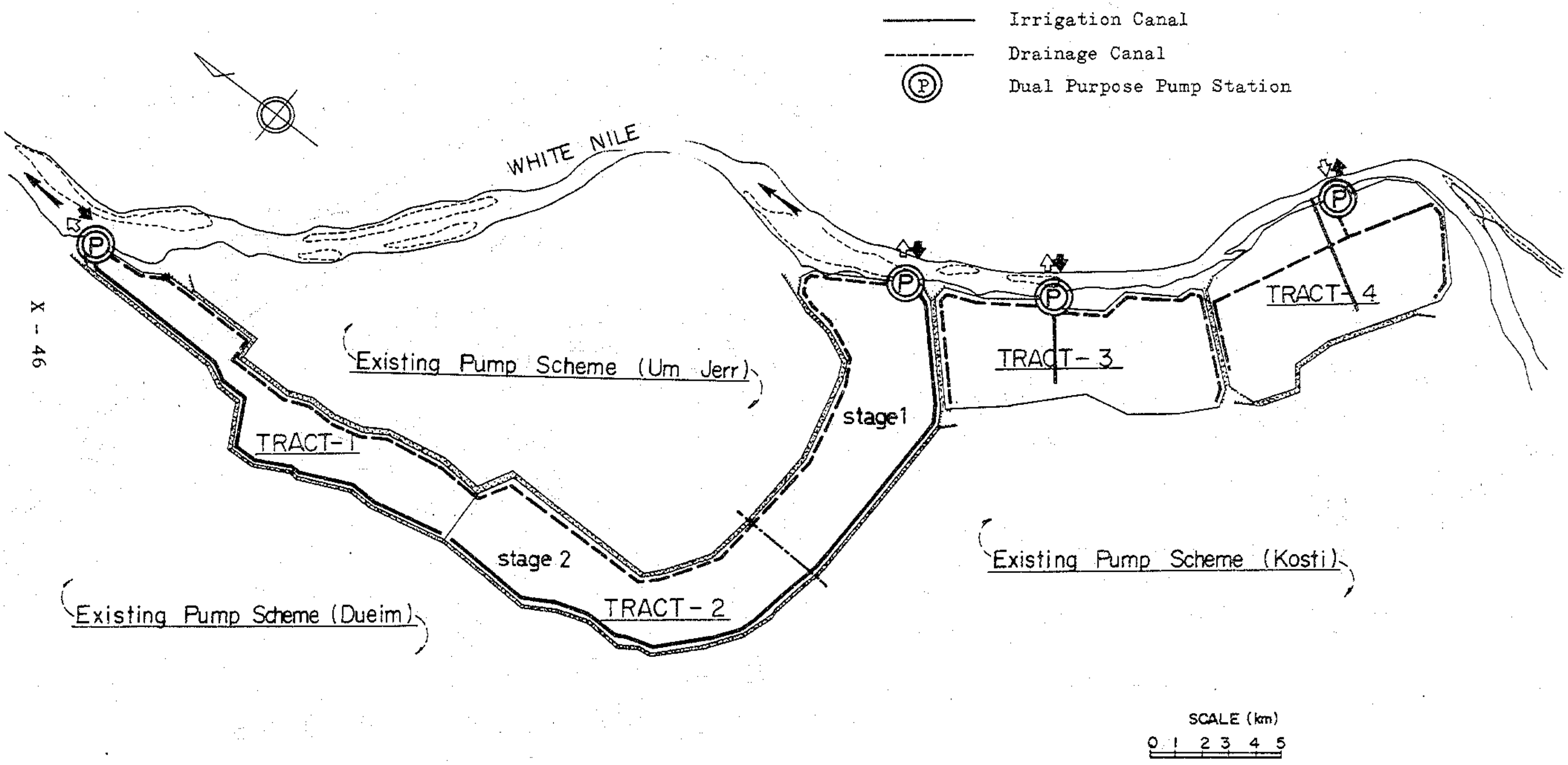


Fig. 10. 1. (6) ALTERNATIVE 4 (Double Crop)

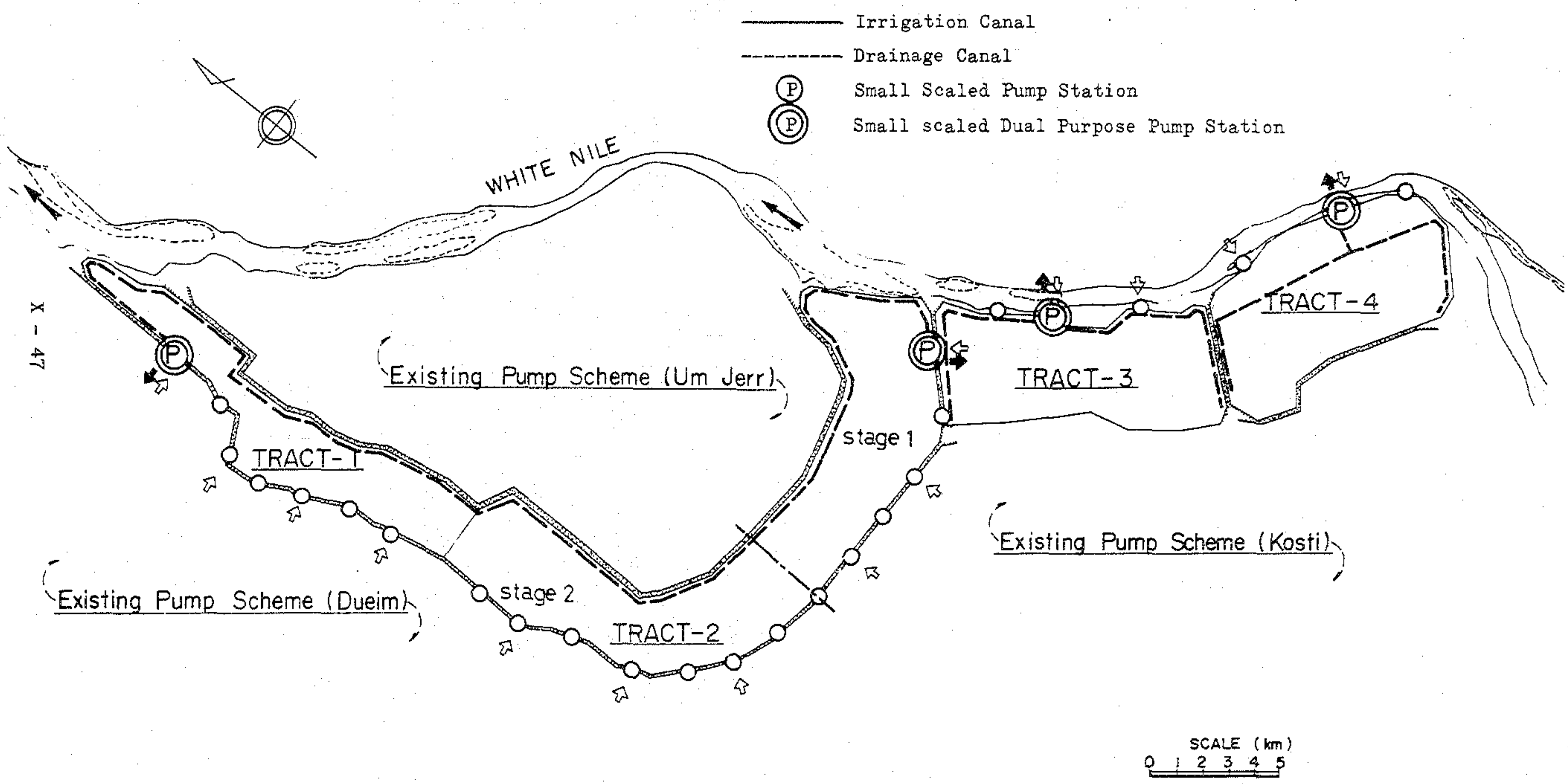


Fig. 10. 2 Relationship between Developed Area — (B-C)

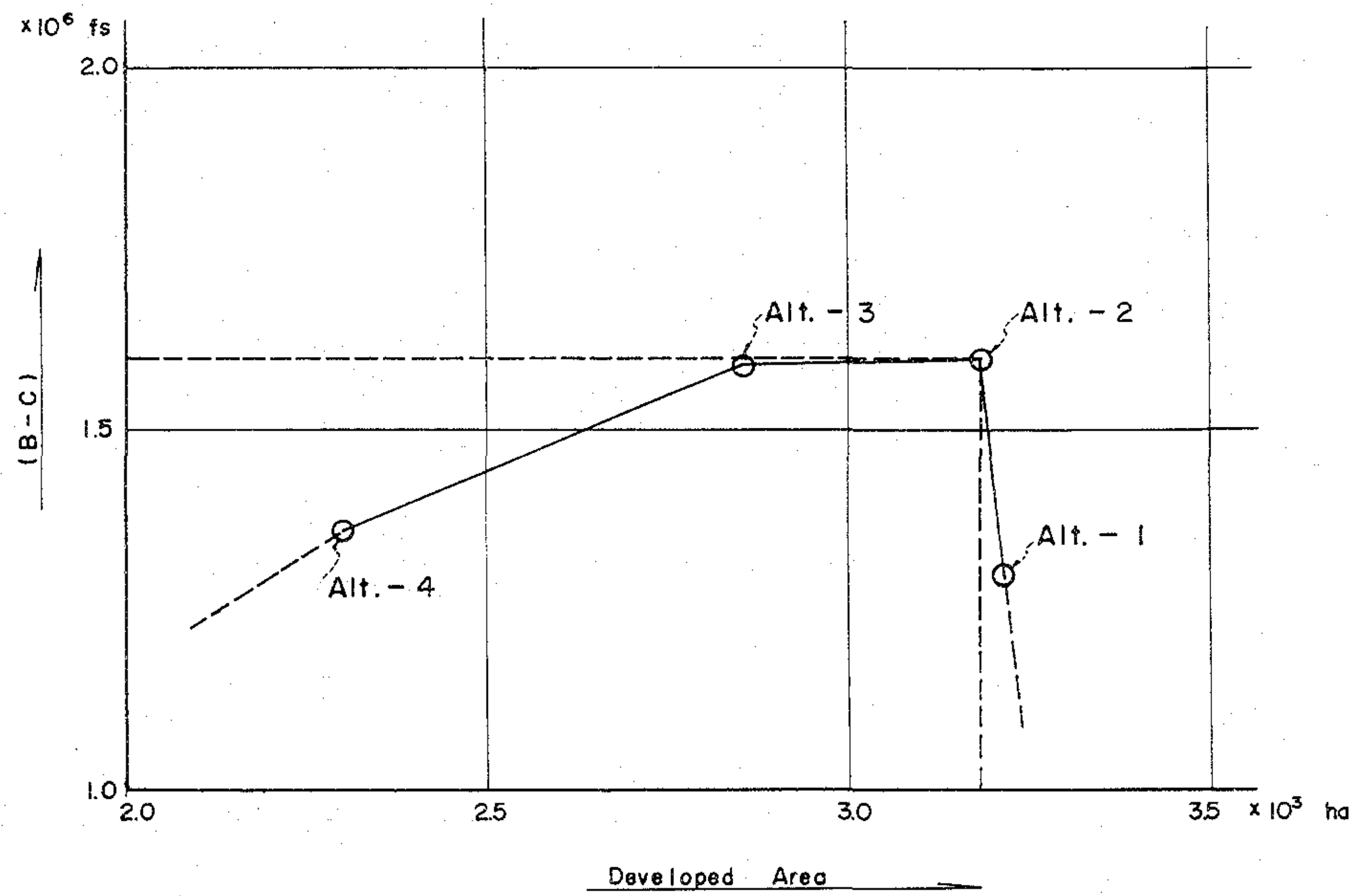


Fig.10.3 Typical Cross Section of Polder Dike

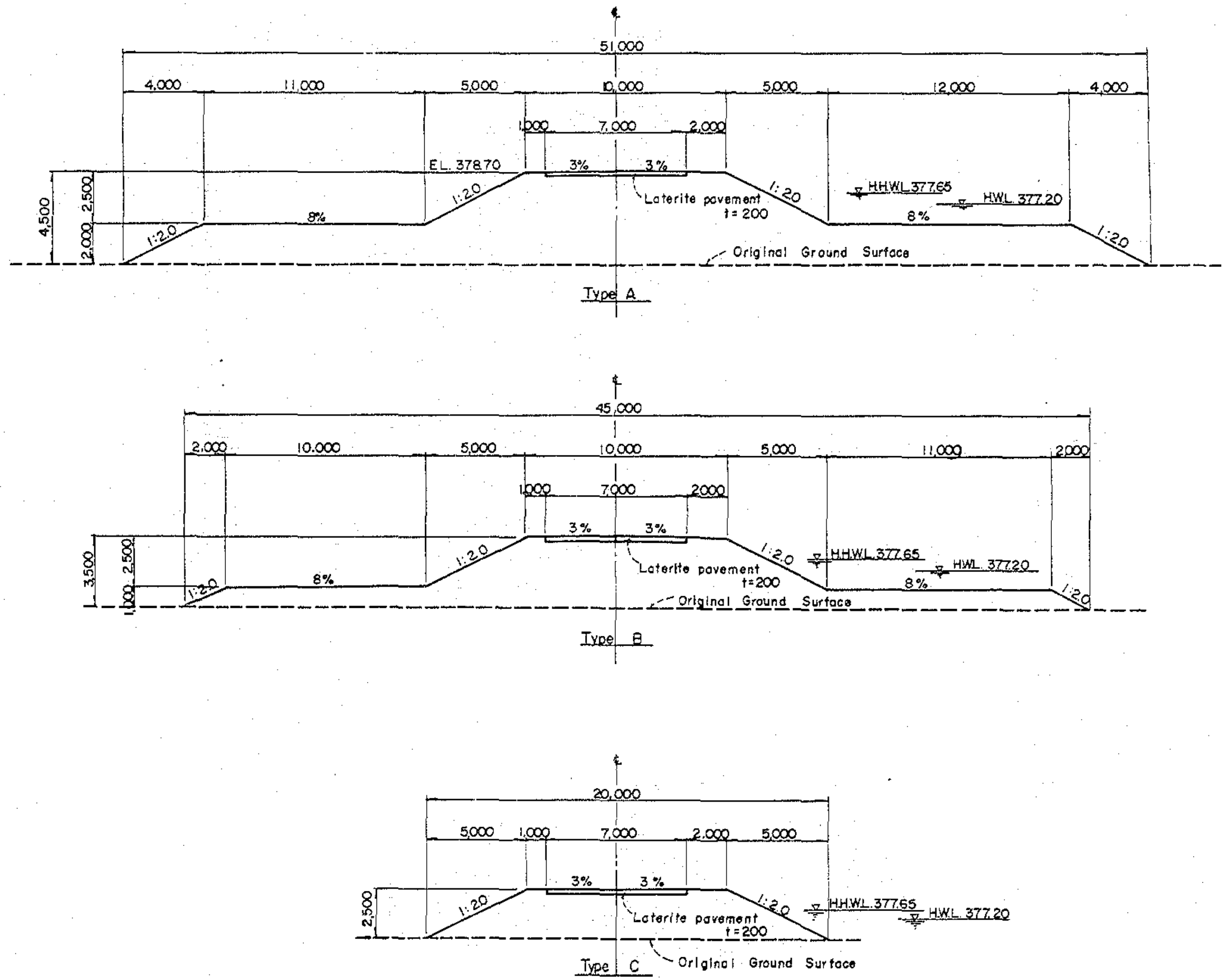


Fig.10.4 Typical Layout of Farm Unit

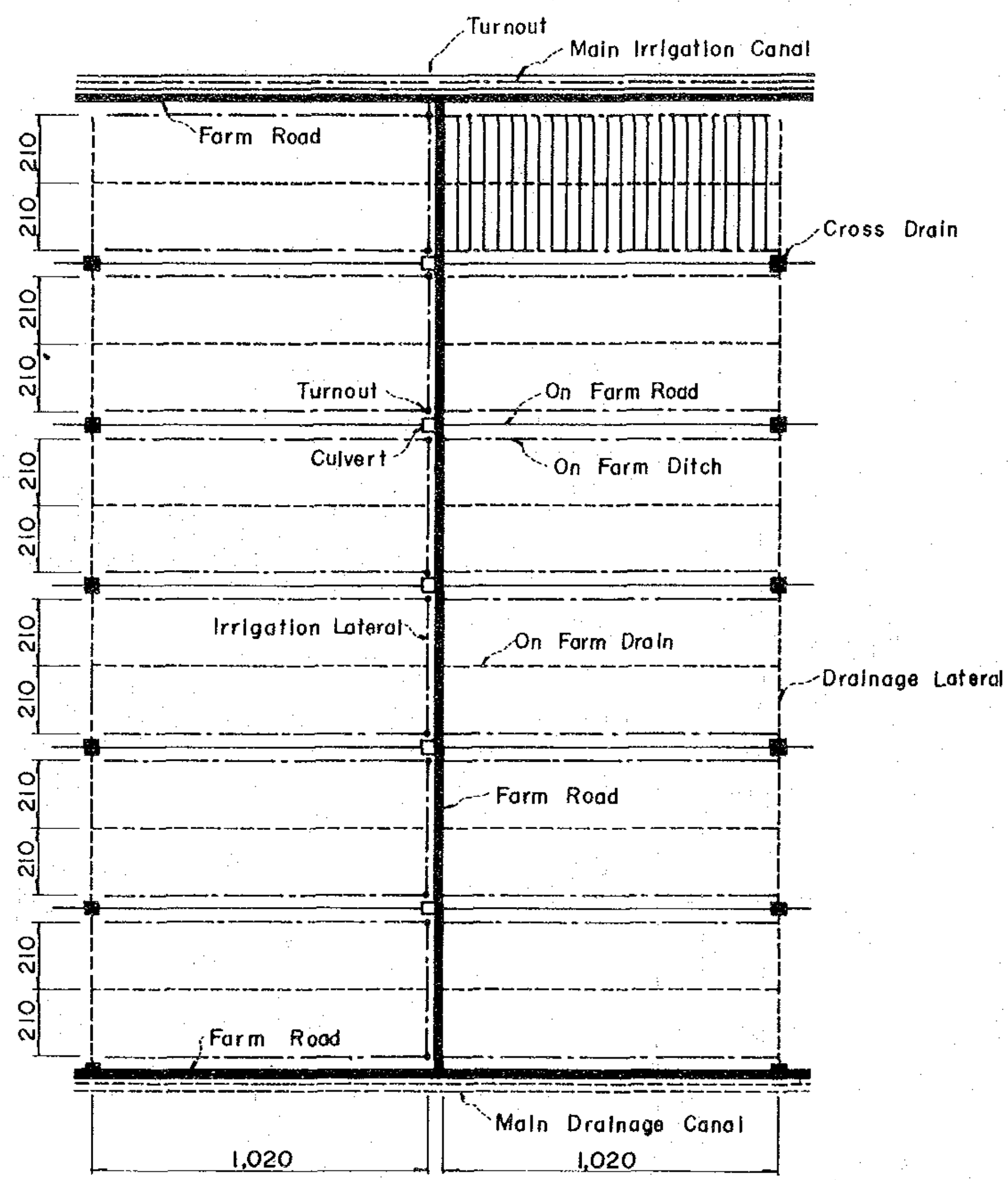


Fig. 10.5 (1) Irrigation Diagram for Tract - I

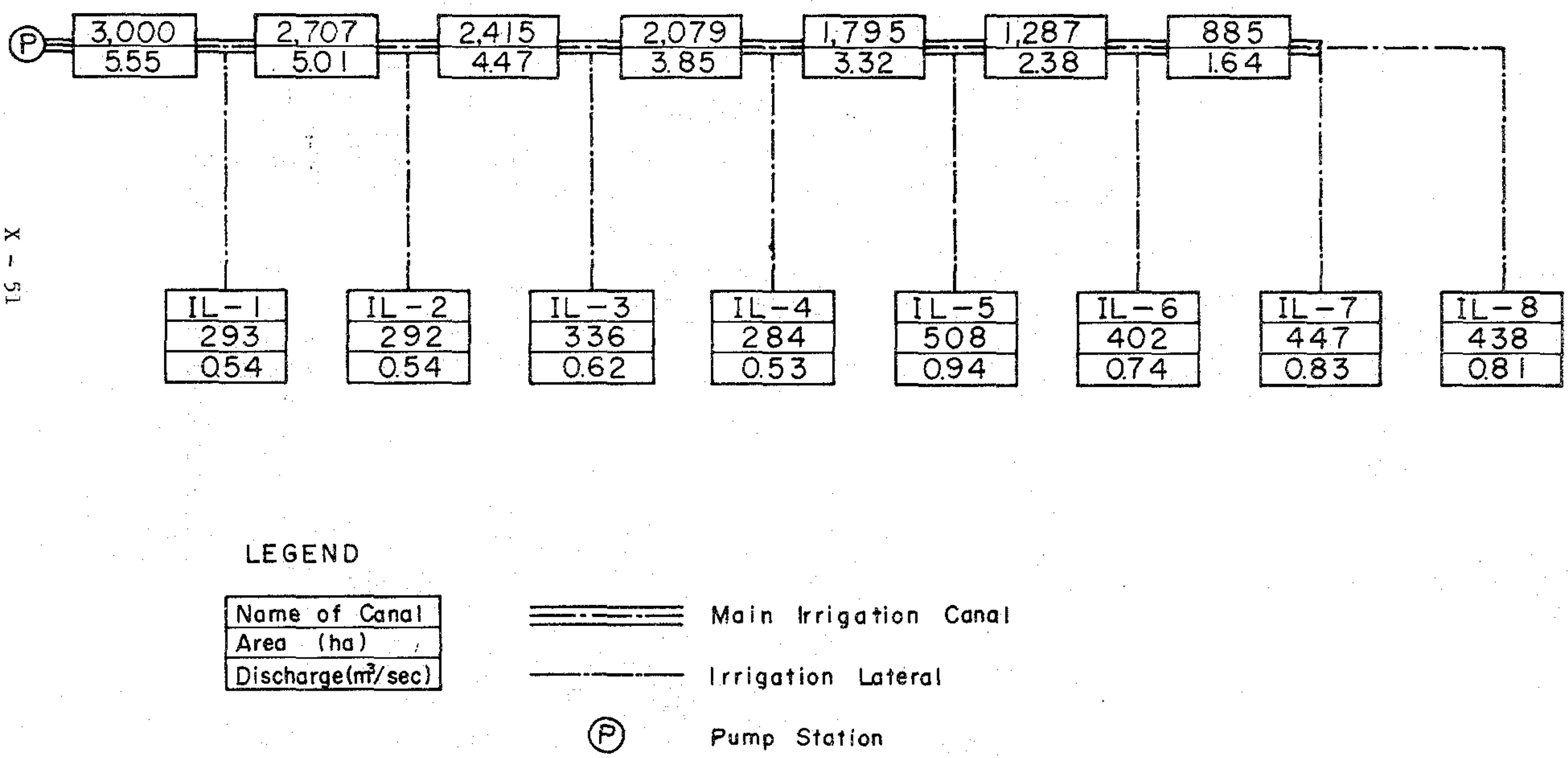


Fig. 10. 5 (2) Irrigation Diagram for Tract - 2

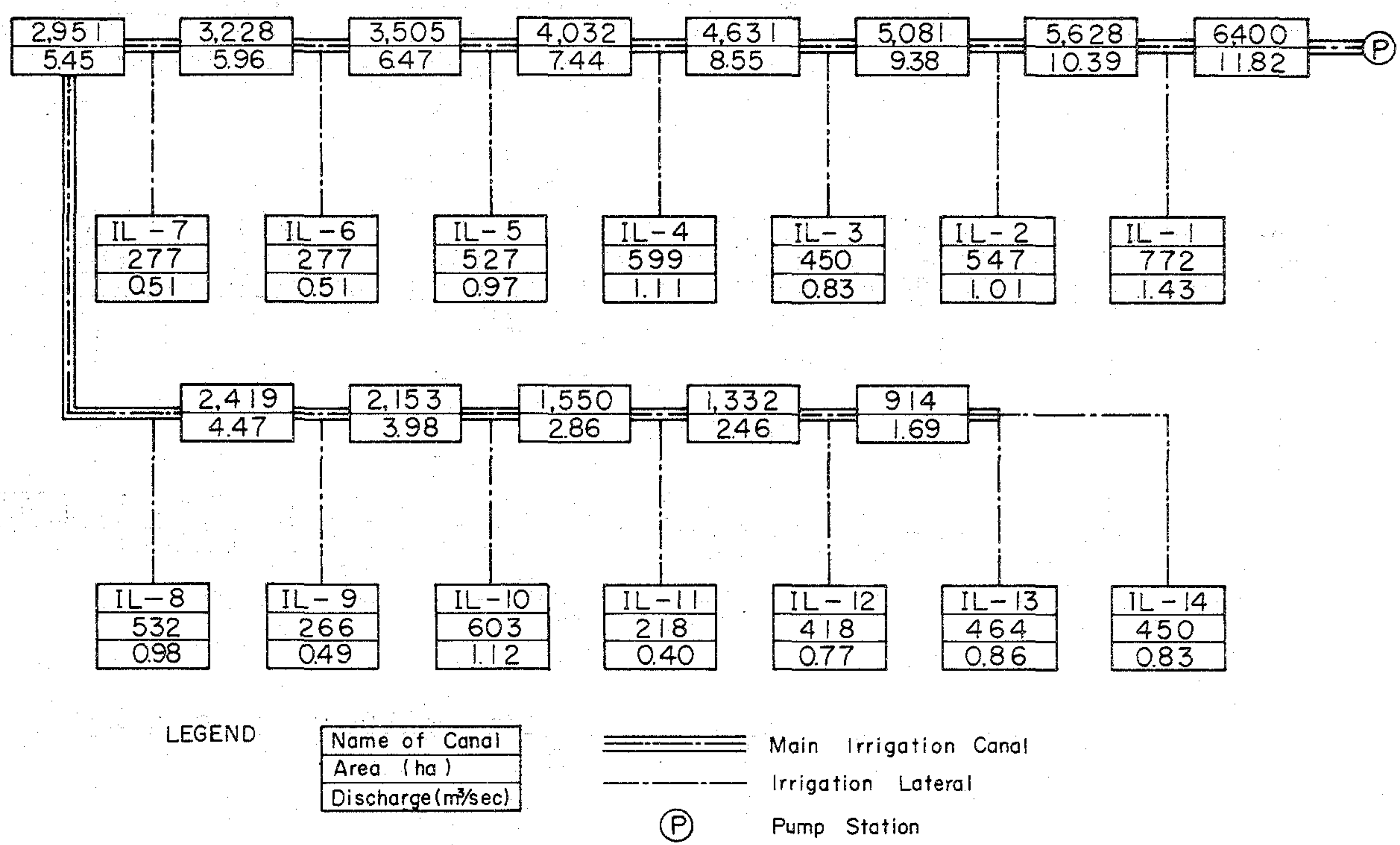


Fig.10.5 (3) Irrigation Diagram for Tract - 3

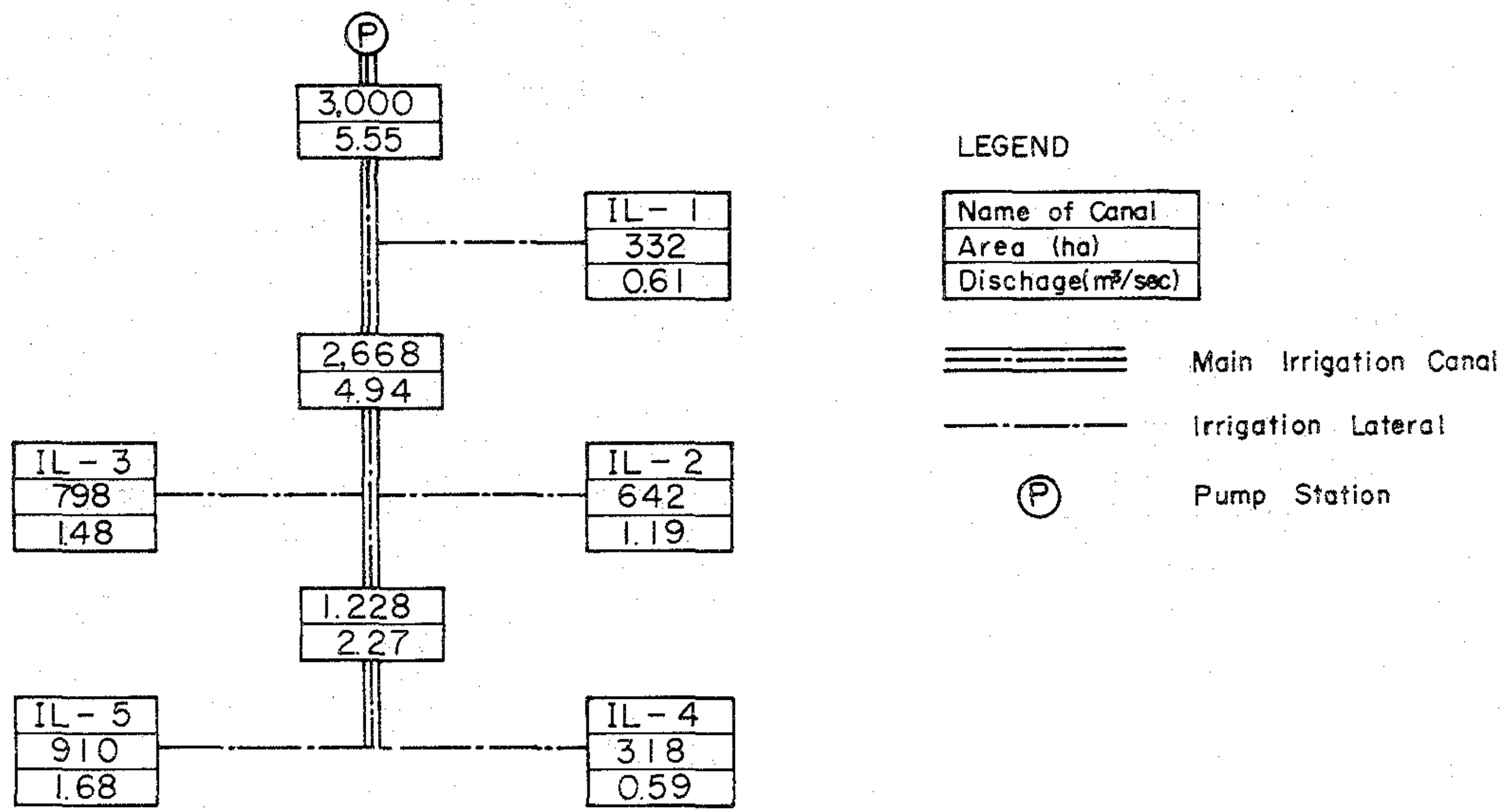


Fig. 10.5 (4) Irrigation Diagram for Tract - 4

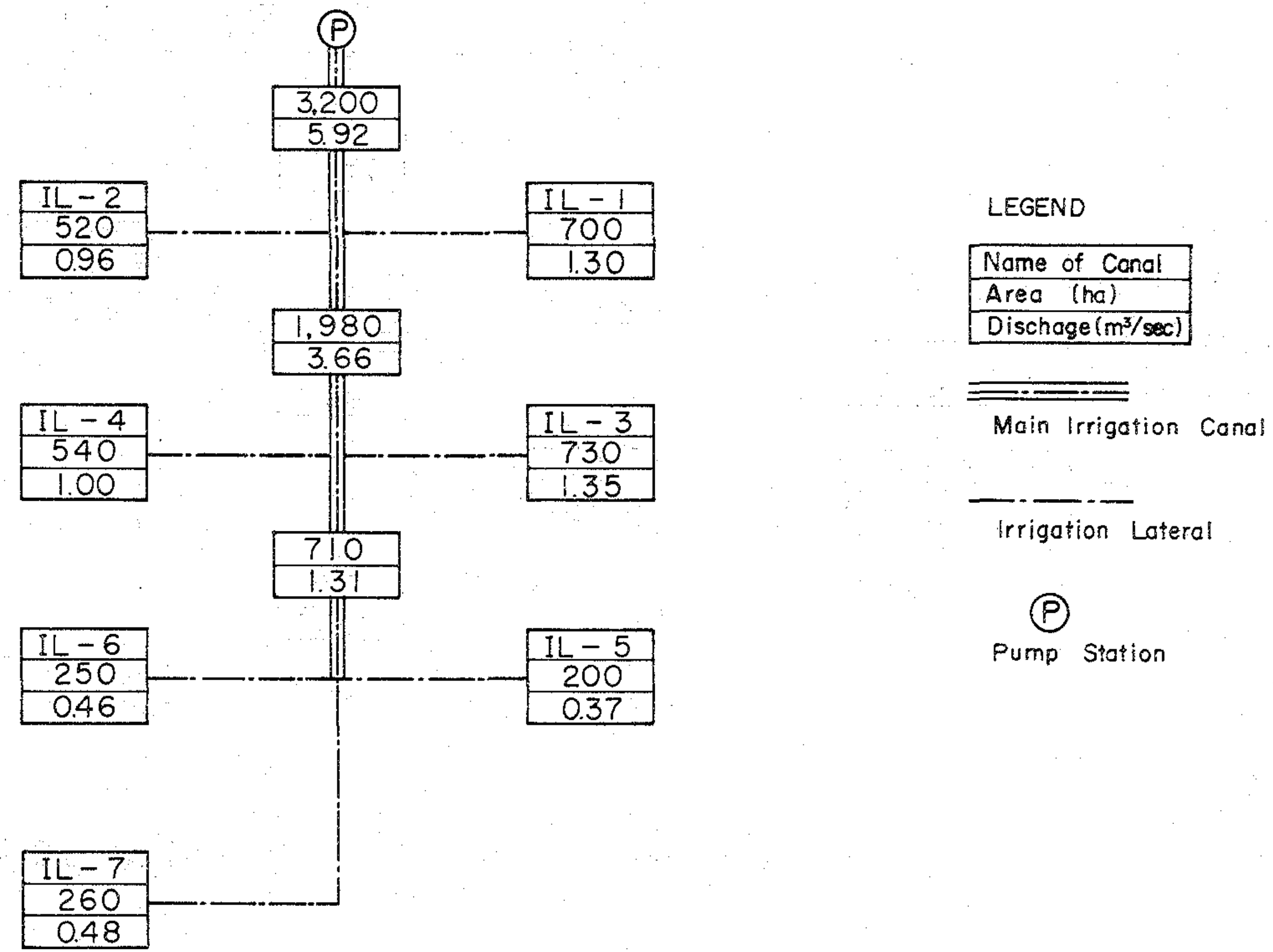
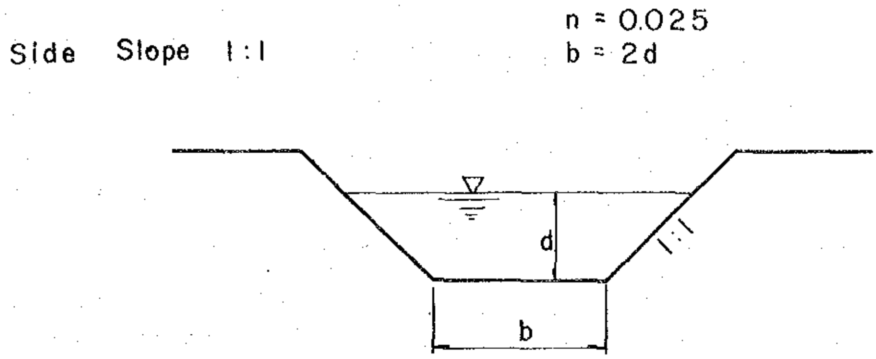


Fig.10.6 (I) Determination of Canal Dimension



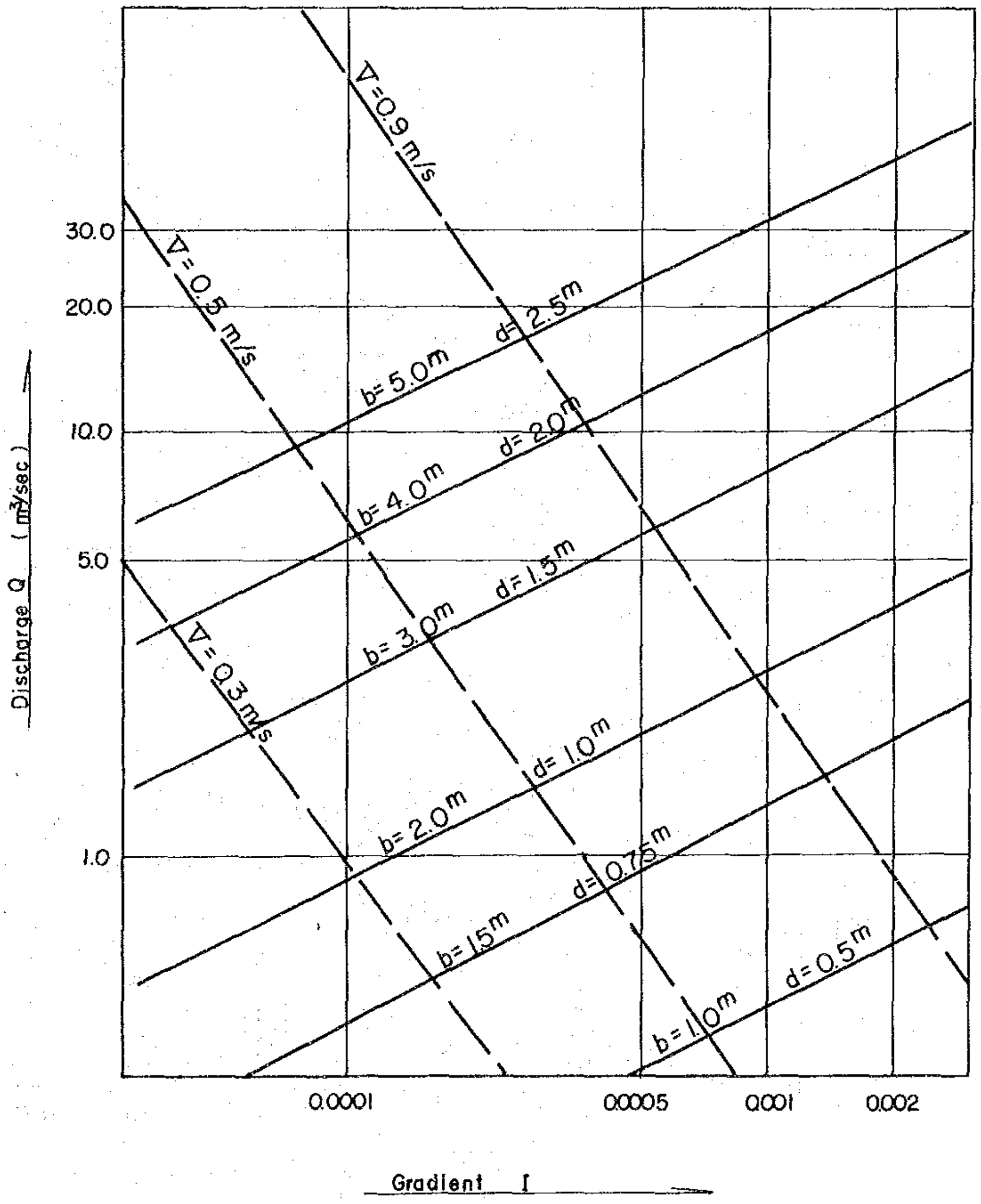


Fig.10.6 (2) Determination of Canal Dimension

Side Slope 1 : 1.5

n = 0.025
b = 2d

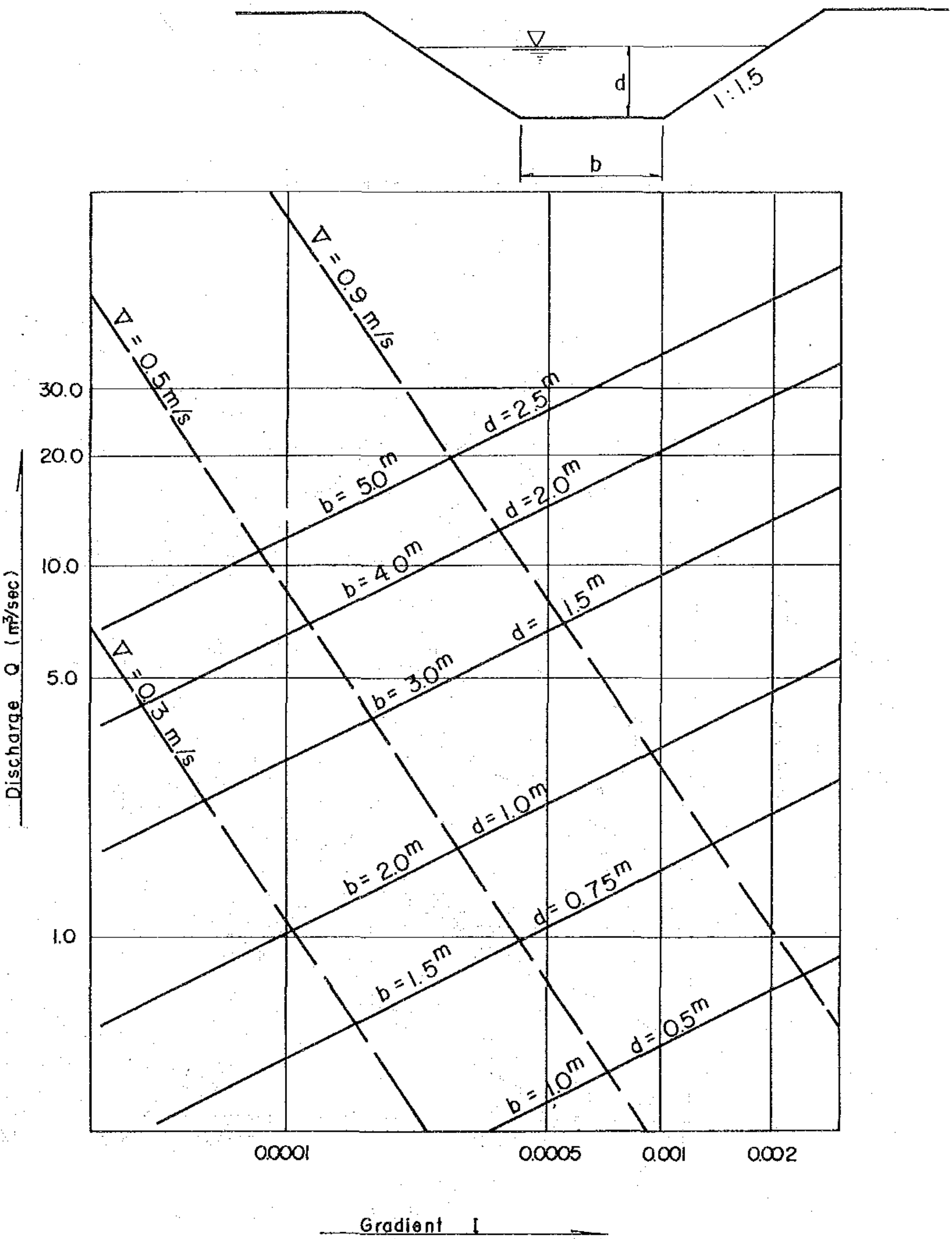


Fig.10.6 (3) Determination of Canal Dimension

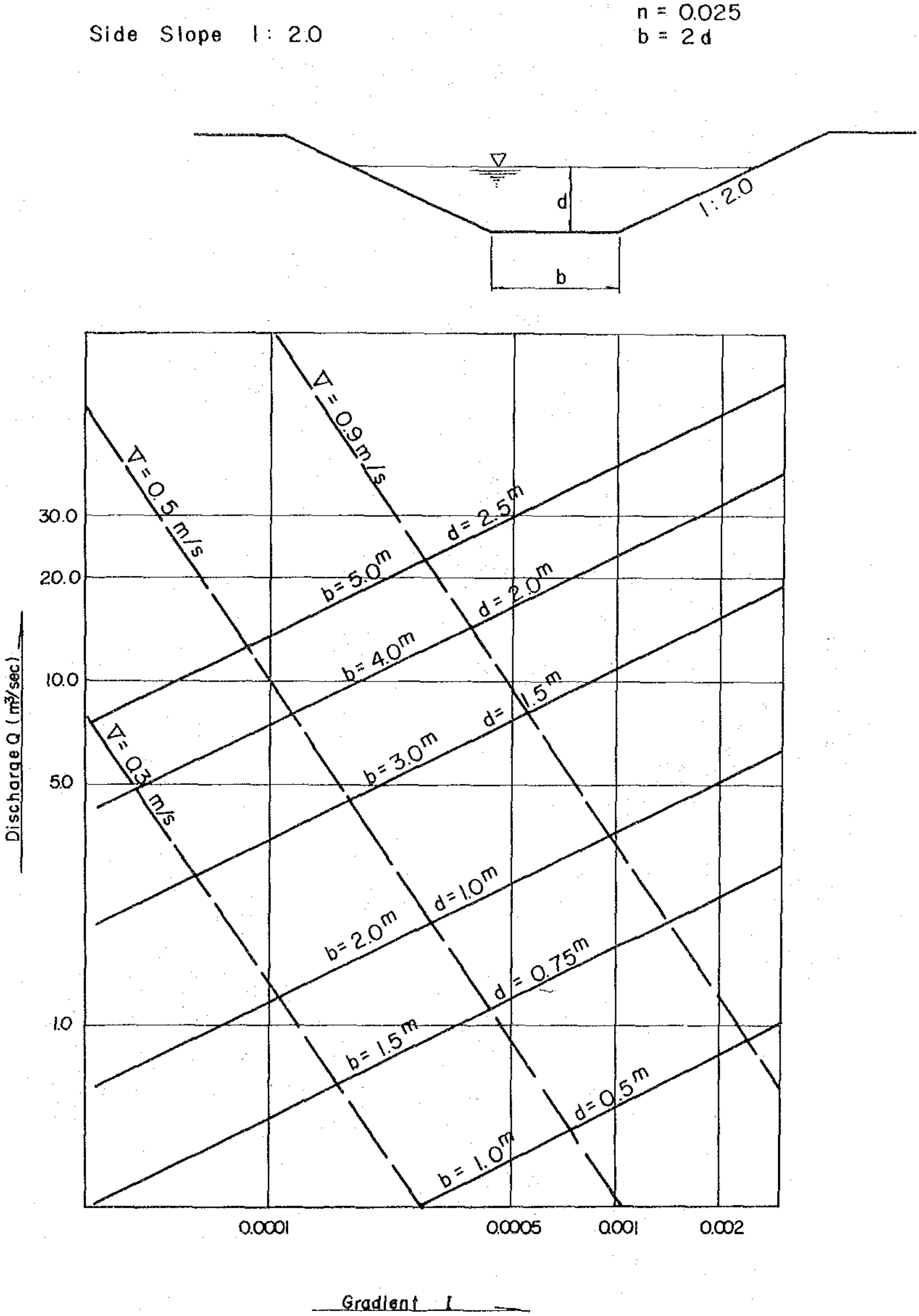


Fig.10.7. Canal & Road Section

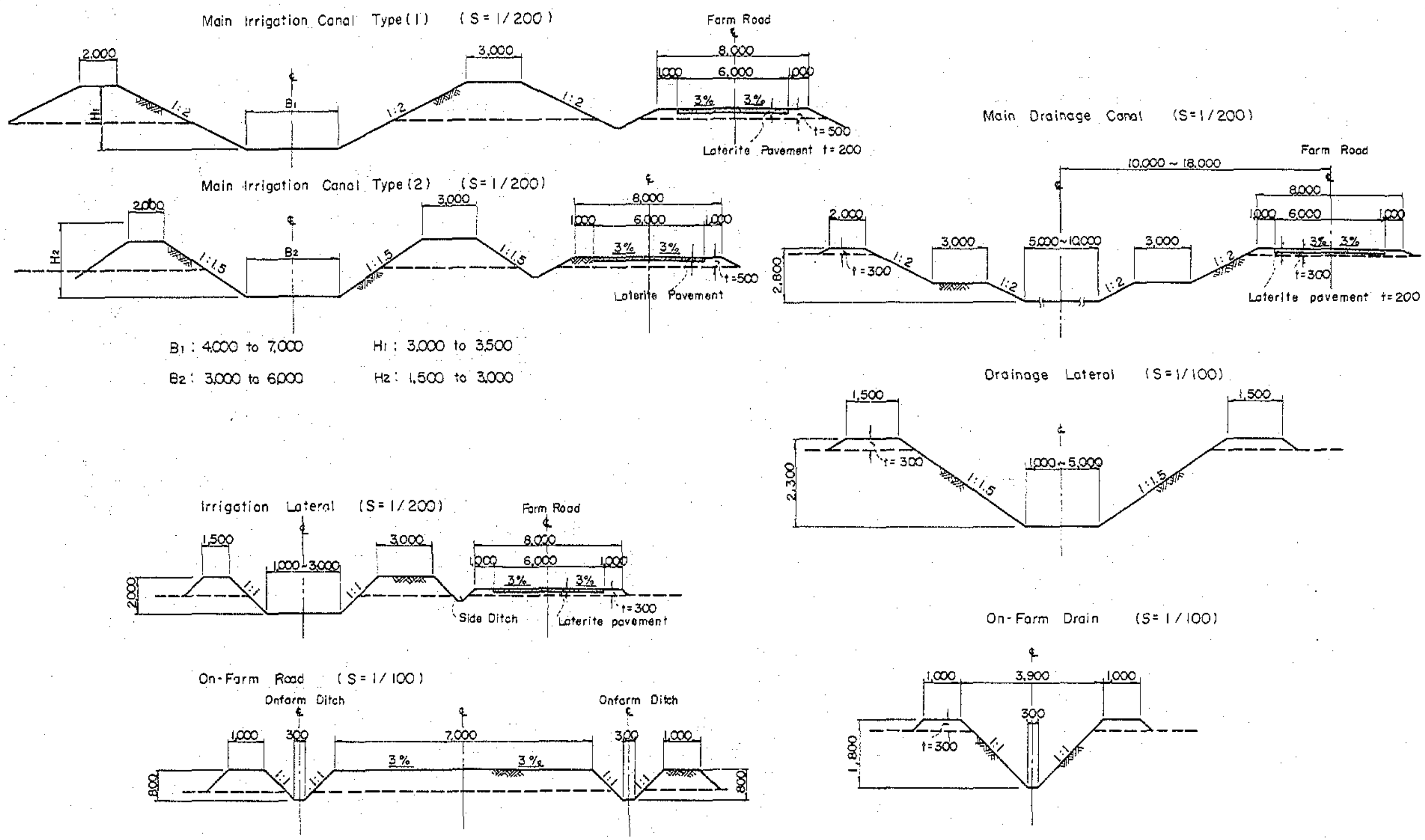


Fig. 10. 8 (1) Drainage Diagram for Tract - 1

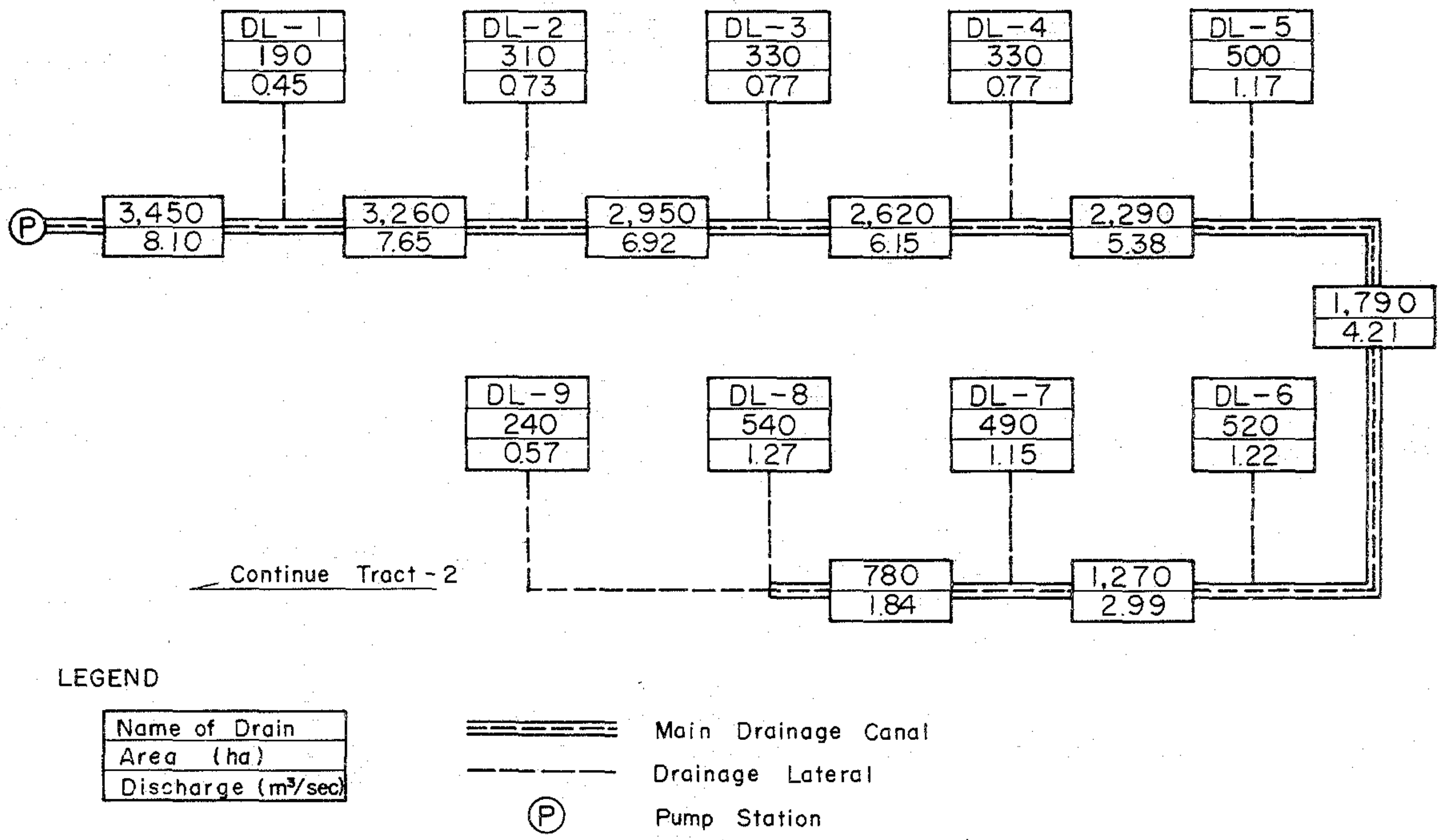


Fig. 10.8 (2) Drainage Diagram for Tract – 2

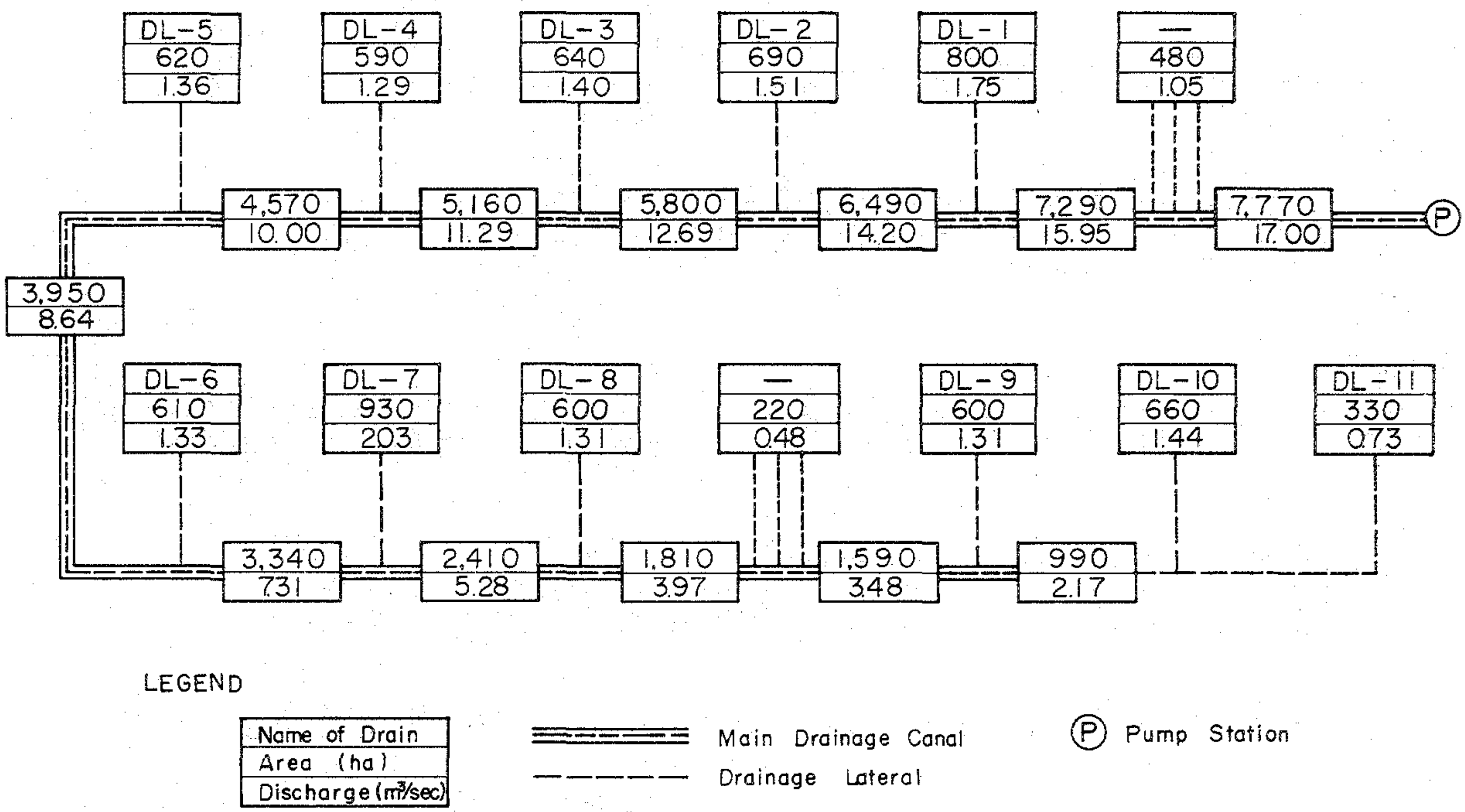


Fig.10.8.(3) Drainage Diagram for Tract - 3

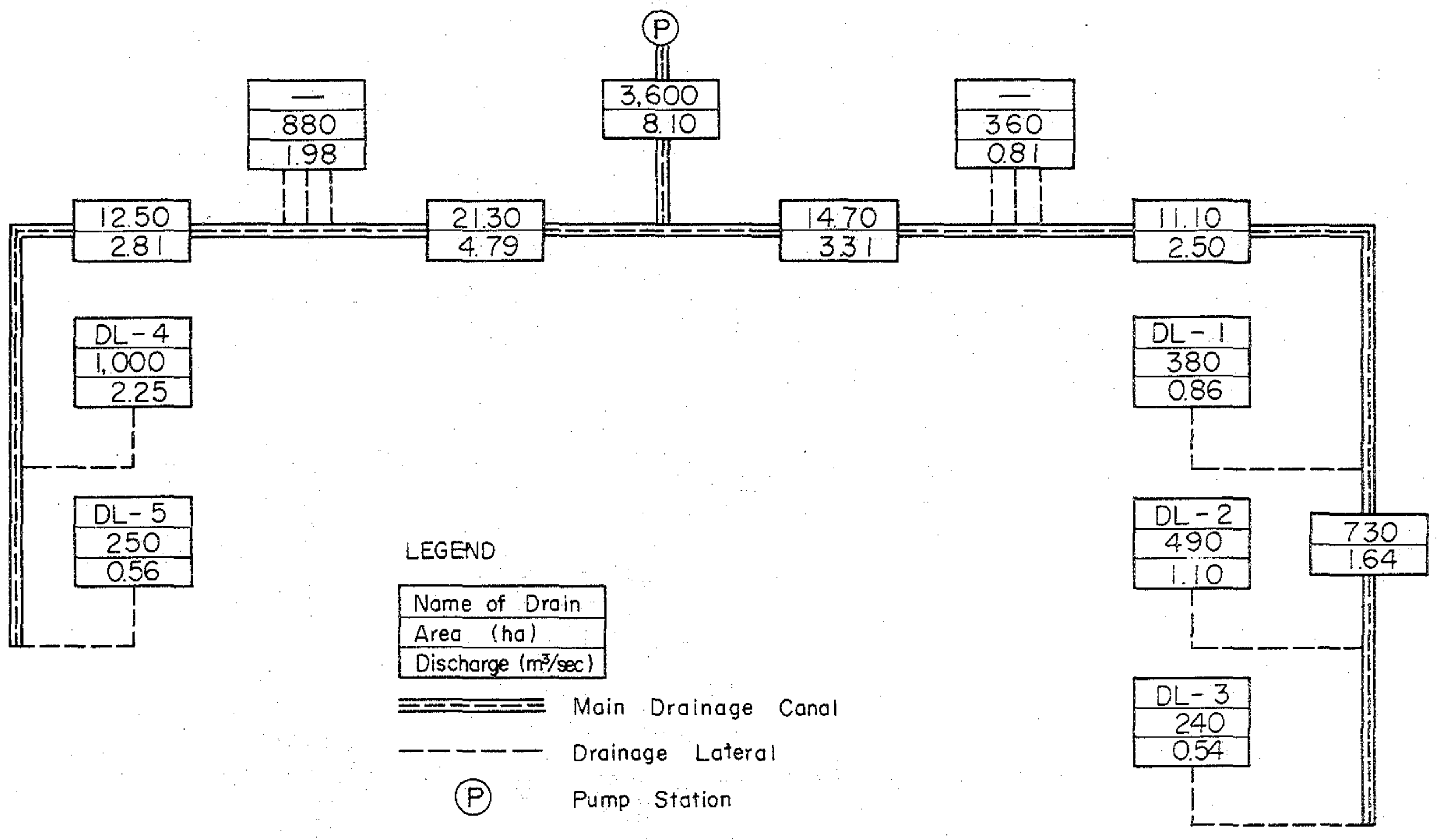


Fig.10.8 (4) Drainage Diagram for Tract - 4

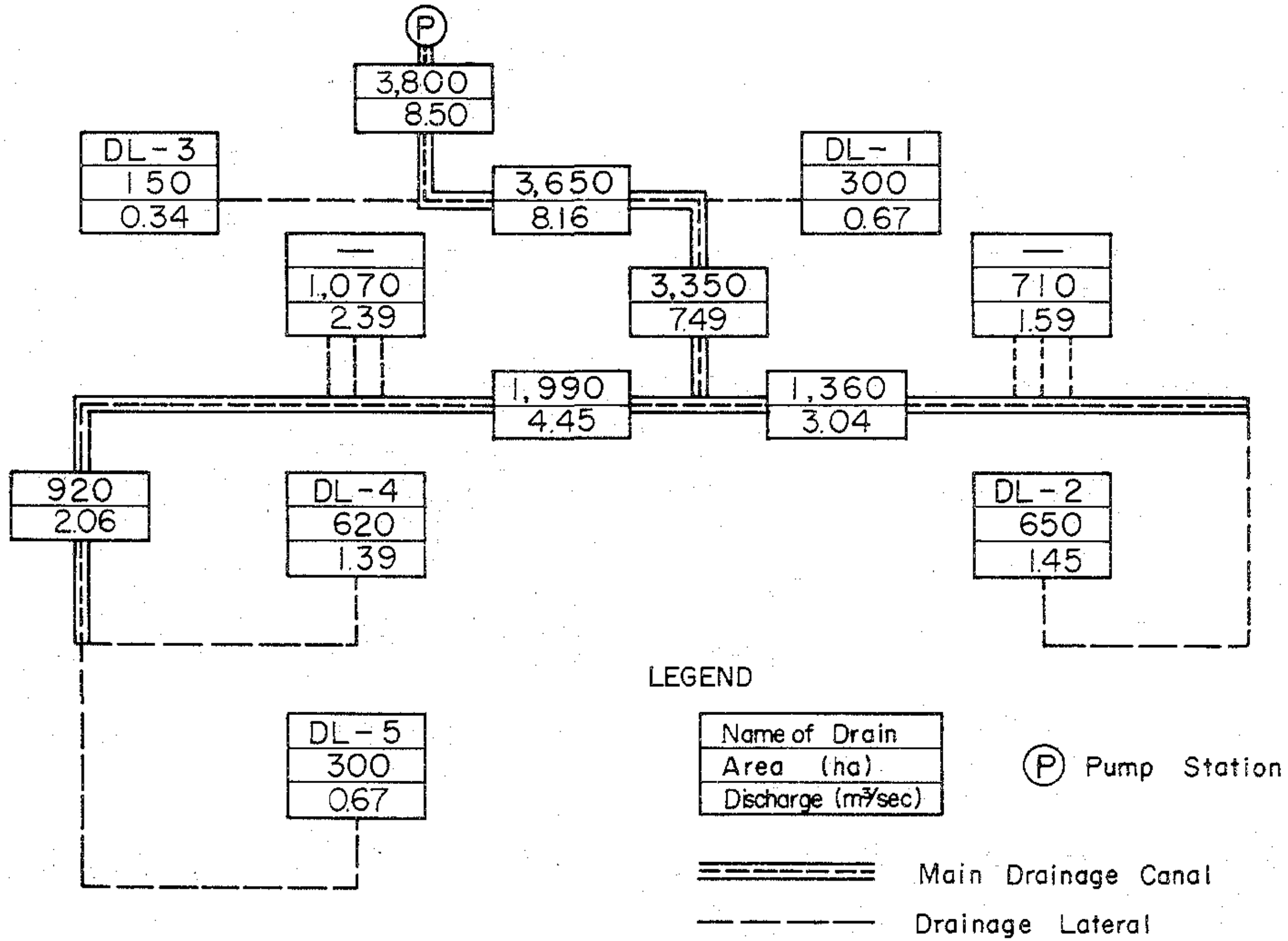
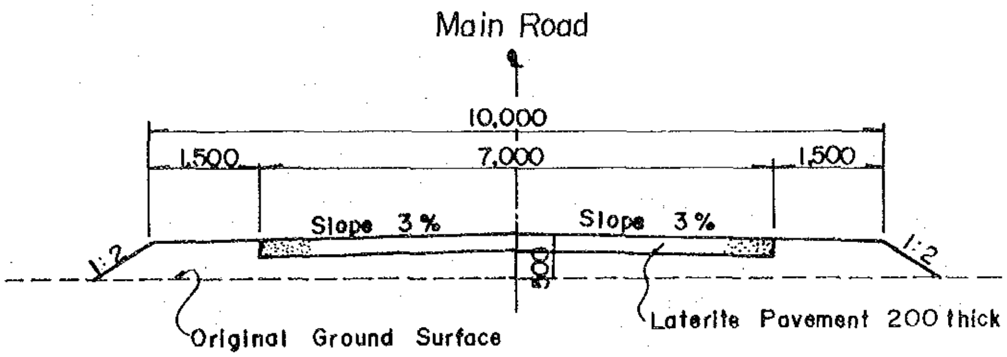
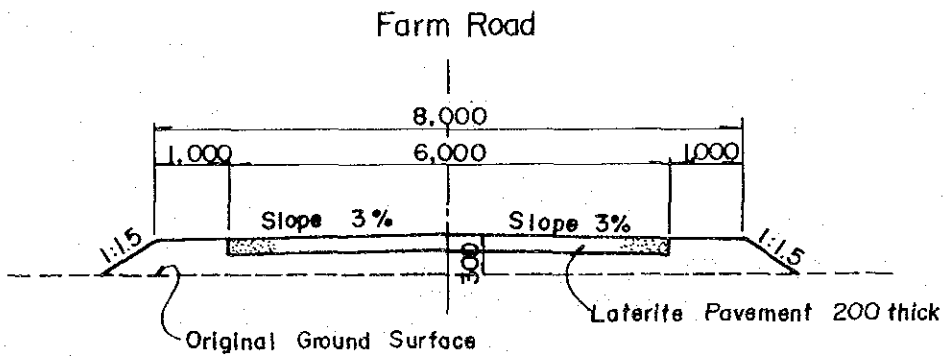


Fig. 10.9 Typical Section of Roads





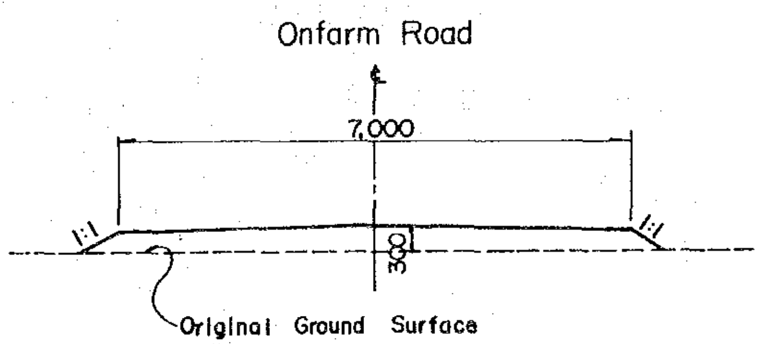
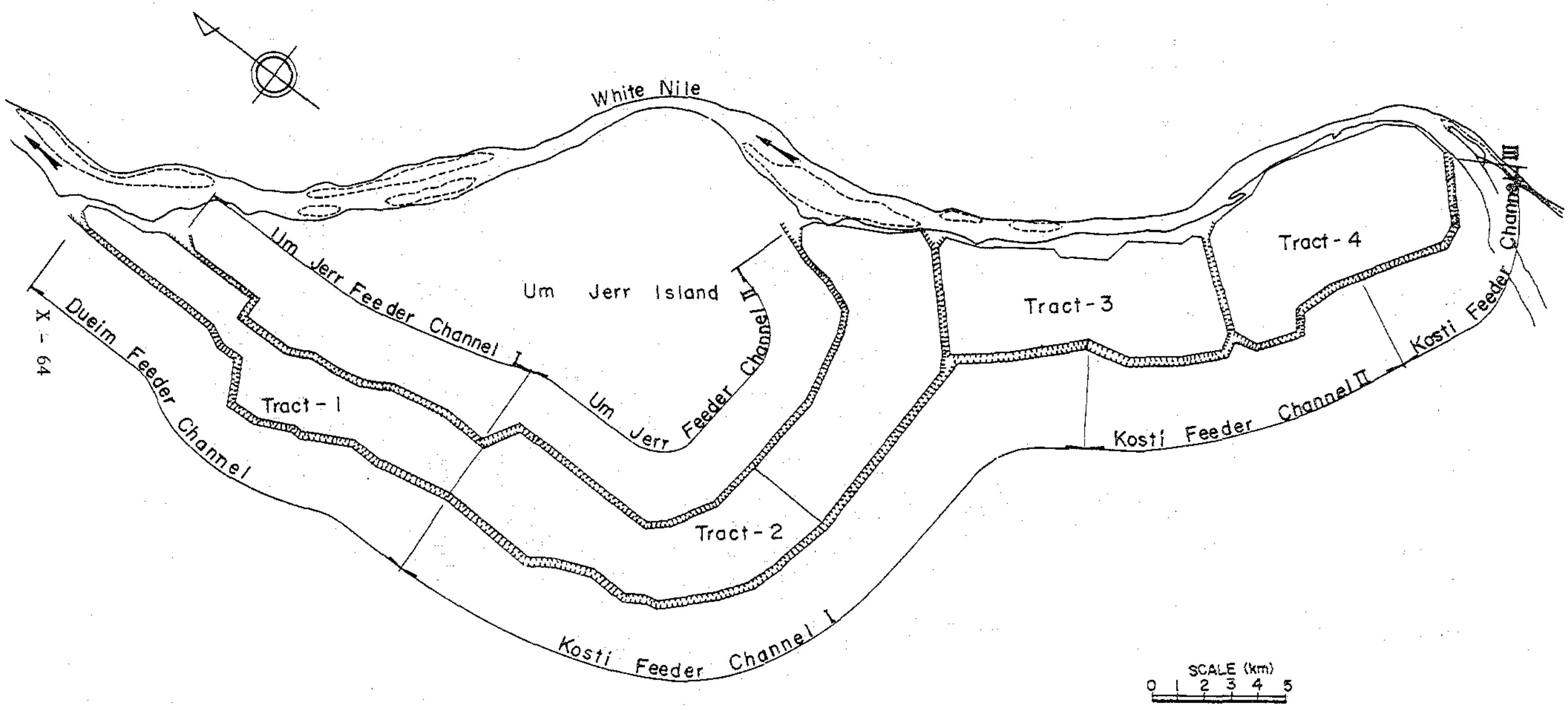


Fig.10.10. Feeder Channel for Existing Pump Scheme



ANNEX XI

IMPLEMENTATION SCHEDULE AND CONSTRUTION PLAN

ANNEX XI

IMPLEMENTATION SCHEDULE AND CONSTRUCTION PLAN

Tables

Figures

XI. IMPLEMENTATION SCHEDULE AND CONSTRUCTION PLAN

11.1 Construction Plan and Schedule

The implementation schedule for the whole project is given in Fig. 11.1. The implementation of the whole project is divided into four phases. Phase 2 is further subdivided into two stage. The area to be developed in each phase is summarized as shown below:

	Area		Schedule of Construction From	To
Phase-1	3,000 ha	(7,143 fedds)	Apr. 1980	Dec. 1981
Phase-2				
stage-1	3,200 ha	(7,619 fedds)	Apr. 1981	Jun. 1983
stage-2	3,200 ha	(7,619 fedds)	Apr. 1982	Jun. 1984
sub-total	6,400 ha	(15,238 fedds)		
Phase-3	3,000 ha	(7,143 fedds)	Apr. 1983	Jun. 1986
Phase-4	3,200 ha	(7,619 fedds)	Apr. 1984	Jun. 1986
Whole project	15,600 ha			

The time required for all construction work of the project is estimated at around eight (8) years including the time necessary for the preparatory works. The construction of the whole works could be completed by the end of June 1986.

The annual workable day for the earth-embankment is limited to about 100 days from the water surface fluctuation of the White Nile (Table 11.1). About 320 days are assumed for the earth-moving work inside the polder, based on the rainfall data covering the period of past ten years. The workable days for concrete work are limited to about 260 days, excluding two months during the hottest season (April to May). One month is exculded from the workable days on account of the Ramadon every year.

Table 11.2 shows the detailed estimation of the workable days.

1) Preparatory works

Prior to commencing the main construction works, it is necessary to complete such preparatory works as aerial photo mapping, detailed design, procurement of construction equipment and materials, land acquisition and buildings etc. The topographic maps of 1/50,000 with 0.5 m interval revised in the feasibility stage are still insufficiently accurate to proceed the detailed design. Shooting and subsequent mapping of the project area on a scale of 1/5,000 are required to be prepared before the commencement of detailed design. Providing that the shooting will be commenced from June 1978, the mapping will be completed in March 1979. Detailed design works including canal and road alignment survey as well as preparation of tender documents will commenced immediately after completion of the mapping. Because of the limited field survey period, the design works will be carried out in stage wise. It is planned that administrative facilities such as office, quarters and laboratories will be constructed in parallel with the engineering works for the first phase.

The procurement of construction machinery, pump equipment and construction materials for the first phase will be started in August 1979 in due consideration of the anticipated manufacturing and delivery terms. Land acquisition should be made before the commencement of the main civil works.

2) Major construction works

The construction of polder dike, main drainage canal and feeder channels for Phase-1 will be initiated concurrently from the middle of April 1980 when the area will have been dried from the flooding. Embankment materials for the polder dike are mainly employed from excavated materials of drainage canal and feeder channel. The dike will be completed within 5 months. The earth works will be carried out mainly by bulldozers, backhoes, excavators.

As soon as the major works of polder dike were finished, the construction of main irrigation canal and main drainage canal will be commenced and followed by drainage laterals, main road and farm roads.

The works for main irrigation canal and laterals for first phase will be completed by end of February and March 1981 respectively, those for the drainage laterals by end of August 1981 and those for the main and farm roads by end of April 1981.

Construction of foundation works for pumping station for the first phase scheme will be commenced in May 1980 and followed by building works. Installation of pump equipment will be made after the delivery of the equipment and it will be completed by the end of June 1981.

Phase 2, 3 and 4 will follow after the completion of Phase-1 under a similar schedule as shown in Fig. 11.2 to 11.5.

3) Onfarm development works

Onfarm works including works for onfarm irrigation ditches and drains, onfarm roads as well as land preparation will take critical pass for the implementation so that the construction works will be carried out continuously from the beginning, May 1980, to the completion of the project, June 1986. Onfarm works for first phase will be completed by the end of December 1981.

After completion of the major civil works, the most of the earth moving equipment will be transferred for the use in construction of onfarm facilities for both Phase-3 and 4 which will be completed by the end of June 1986 accordingly.

4) Processing and storage facilities

Construction works of buildings for rice processing plant and storage for the first phase scheme will be started from September 1980. Installation of rice mill equipment and other facilities will be made after the completion of buildings and be completed end of August 1981. Those of Phase-2, 3 and 4 will be installed in stage wise according to the progress of major civil works.

11.2 Construction Quantities, Materials and Equipment

The major construction quantities and materials required for the construction works are summarized in Table 11.3 and 11.4. The number of major construction machinery to be needed by contractors are roughly estimated as listed in Table 11.5.

Table 11.1 Workable Days for Dike Embankment

	Beginning of Low Water Season	End of Low Water Season	Workable Days
1976	4th May	4th Aug.	92
75	23rd Apr.	6th Aug.	105
74	20th Apr.	5th Aug.	107
73	19th Apr.	8th Aug.	111
72	17th Apr.	7th Aug.	112
71	23rd Apr.	5th Aug.	104
70	22nd Apr.	7th Aug.	107
69	24th Apr.	31st Jun.	98
68	6th May	1st Aug.	87
67	6th May	5th Aug.	91
	Average		101

Note: Data on water surface fluctuation of the White Nile during past ten years.

Table 11.2 Workable Days for Earth-moving Works

Conditions for Estimate

1) Daily rainfall (mm)	0 - 4	5 - 15	16 - 30	Over 31
2) Duration of rainfall (day)	0	0.1	0.1	0.3
3) Waiting time after rainfall (day)	0	1.0	1.5	2.0

Estimation of Workable Days

1) Rainfall (Frequency/month)

Daily Rainfall	J	F	M	A	M	J	J	A	S	O	N	D	Total
5 - 15 mm	0	0	0	0	0	1	2	3	1	0	0	0	7
16 - 30 mm	0	0	0	0	0	0	1	1	1	0	0	0	3
Over 31 mm	0	0	0	0	0	0	1	1	0	0	0	0	2

	J	F	M	A	M	J	J	A	S	O	N	D	Total
2) Duration of rains (days)	0	0	0	0	0	0.1	0.6	0.7	0.2	0	0	0	1.6
3) Waiting time (day)	0	0	0	0	0	1.0	5.5	6.5	2.5	0	0	0	15.5
4) Duration of suspention (day)	0	0	0	0	0	1.1	6.1	7.2	2.7	0	0	0	17.1
5) Fast month (Ramadon)									28				
6) Workable days (day)	31	28	31	30	31	29	25	24	0	31	30	31	321

Note: Workable days for concrete works are limited to 260 days, excluding two months during the hottest season (April and May).

Table 11.3 Construction Quantities

No.	Works	Unit	Quantity
1.	Clearing and stripping	ha	4,600
2.	Excavation common	m^3	14,047,000
3.	Embankment	"	13,538,000
4.	Backfilling	"	54,000
5.	Concrete for structure	"	19,900
6.	Concrete pipe	m	13,720
7.	Gate and hoist	ton.	360
8.	Reinforcement bar	ton	1,530
9.	Laterite pavement	m^3	551,000
10.	Land levelling	"	3,900,000
12.	Installation of pump	Nos.	14

Table 11.4 Construction Materials

No.	Item	Unit	Quantity
1.	Portland cement	P.C.S.(50kg/p.c.s)	131,600
2.	Reinforcement bar	ton	1,530
3.	Structural steel	"	110
4.	Gate and hoist	"	360
5.	Gravel for concrete	m^3	17,900
6.	Sand for concrete	"	9,000
7.	Laterite materials for road	"	551,000
8.	Fuel	kℓ	26,000
9.	Lubricant	ton	740

Table 11.5 Construction Machinery

No.	Machinery	Description	Required Number
1.	Bulldozer	21 ton	20
2.	"	15 "	10
3.	"	15 "	2
4.	Rake dozer	22 "	3
5.	Backhoe	1.2 m^3	18
6.	"	0.6 "	12
7.	Tractor shovel	2.2 "	10
8.	"	1.4 "	8
9.	Dragline	0.8 "	20
10.	"	0.6 "	10
11.	Clamshell	0.8 "	1
12.	Motor scraper	21 "	3
13.	"	11 "	10
14.	Motor grader	11 ton	5
15.	"	7 "	10
16.	Type roller	20 "	8
17.	"	14 "	5
18.	Crawler crane	25 "	1
19.	Diesel hummer	2.5 "	1
20.	Truck crane	10 "	1
21.	"	5 "	2
22.	Concrete plant	30 m^3/hour	1
23.	Aggregate plant	-	1
24.	Screening plant	-	1
25.	Agitator truck	6 m^3	2
26.	"	3 "	2
27.	Dump truck	11 ton	30
28.	Ordinary truck	11 "	10
29.	"	6 "	5
30.	Fuel tanker	10 kℓ	4
31.	Grease car	6 ton	2
32.	Water tanker	-	2

No.	Machinery	Description	Required Number
33.	Generator with diesel engine	-	5
34.	Drainage pump	-	10
35.	Miscellaneous equipment (Welder, Concrete mixer, Concrete vibrator, Compresser, etc.)		L.S.

Fig. 11.1 Implementation Schedule for Whole Project

Item	Unit	Quantity
1. Preparatory Works		
-1 Shooting and Mapping	ha	50,000
-2 Engineering Services	ha	15,600
-3 Procurement of Equipment	L.S.	—
-4 Land Acquisition	ha	95
-5 Administrative Facilities	Nos.	6
2. Major Construction Works		
-1 Dike	m	154,690
-2 Pumping Station	Nos.	4
-3 Main Irrigation Canal	m	51,790
-4 Irrigation Lateral	m	120,790
-5 Main Drainage Canal	m	73,300
-6 Drainage Lateral	m	103,240
-7 Main Road	m	51,700
-8 Farm Road	m	280,240
-9 Feeder Channel	m	100,050
-10 Miscellaneous Works	L.S.	—
3. On-Farm Development Works	ha	15,600
4. Rice Processing & Storage Facilities	Nos.	5
6. Pilot Farm	Nos.	1
7. Project Operation		
-1 Pilot Scheme	—	—
-2 Main Project	—	—

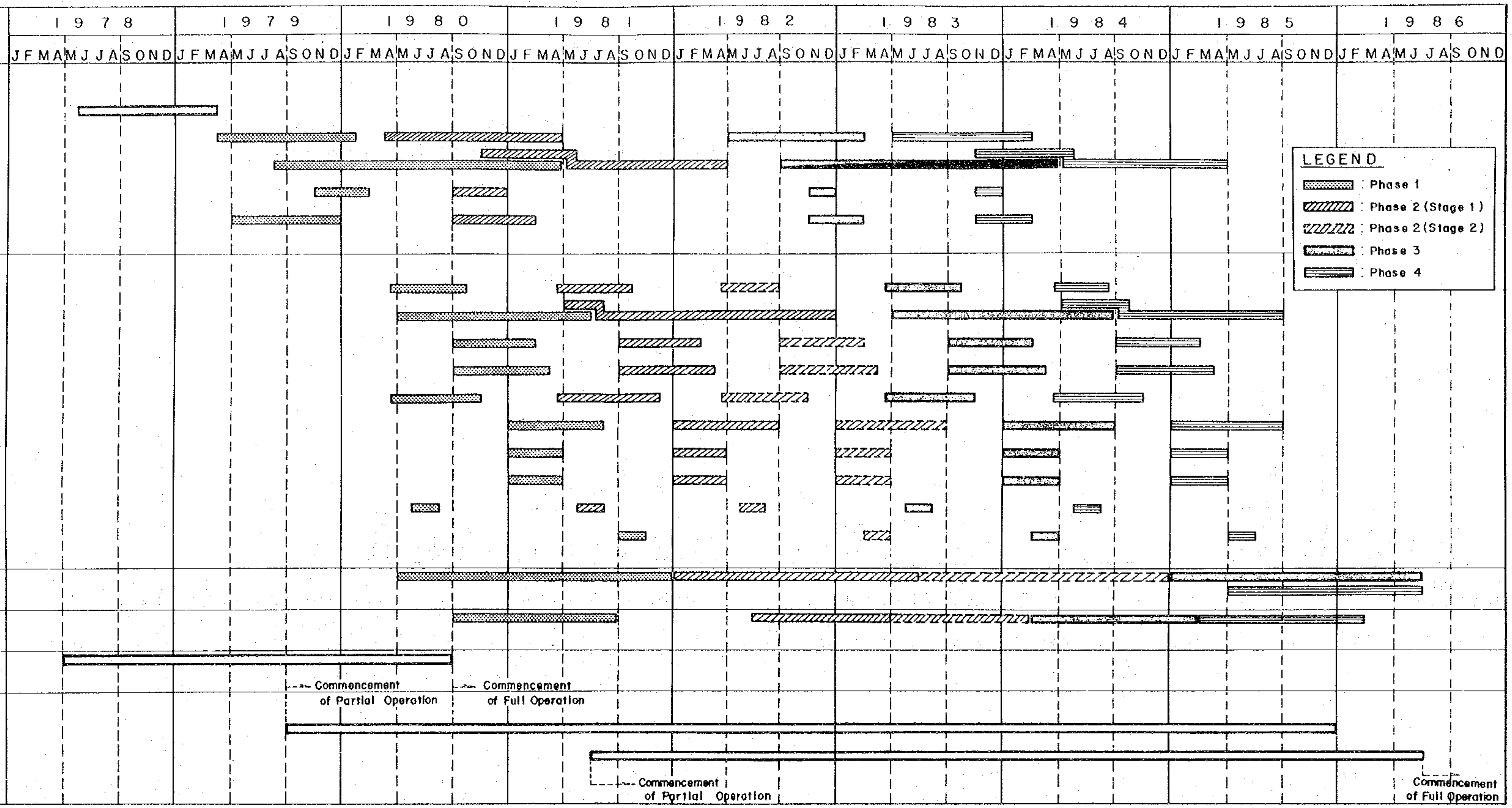


Fig.11.2 Construction Time Schedule for Phase 1 (Tract1)

Item	Unit	Quantity
1. Preparatory Works		
1.1 Engineering Services	LS	—
1.2 Procurement of Equipment	〃	—
1.3 Land Acquisition	ha	32.9
1.4 Administrative Facilities	LS	—
2. Dike		
2.1 Stripping	ha	85
2.2 Embankment	m^3	1,422,200
2.3 Pavement	〃	55,400
3. Pumping Station		
3.1 Inlet Channel	m^3	11,900
3.2 Foundation	〃	2,200
3.3 Building	m^2	375
3.4 Pump Installation	Set	3
4. Main Irrigation Canal		
4.1 Stripping	ha	25
4.2 Excavation	m^3	56,400
4.3 Embankment	〃	340,100
4.4 Related Structures	LS	—
5. Irrigation Lateral		
5.1 Stripping	ha	23
5.2 Excavation	m^3	9,400
5.3 Embankment	〃	150,000
5.4 Related Structures	LS	—
6. Main Drainage Canal		
6.1 Stripping	ha	6
6.2 Excavation	m^3	915,600
6.3 Embankment	〃	30,900
6.4 Related Structures	LS	—
7. Drainage Lateral		
7.1 Stripping	ha	8
7.2 Excavation	m^3	208,300
7.3 Embankment	〃	57,900
7.4 Related Structures	LS	—
8. Main Road		
8.1 Stripping	ha	3
8.2 Embankment	m^3	15,300
8.3 Pavement	〃	3,400
9. Farm Road		
9.1 Stripping	ha	51
9.2 Embankment	m^3	175,900
9.3 Pavement	〃	66,500
10. Feeder Channel (Excavation)	m^3	1,488,000
11. On-Farm Development Works		
11.1 Land Leveling	ha	3,000
11.2 On-Farm Ditch	km	150
11.3 On-Farm Drain	〃	75
11.4 On-Farm Road	〃	63

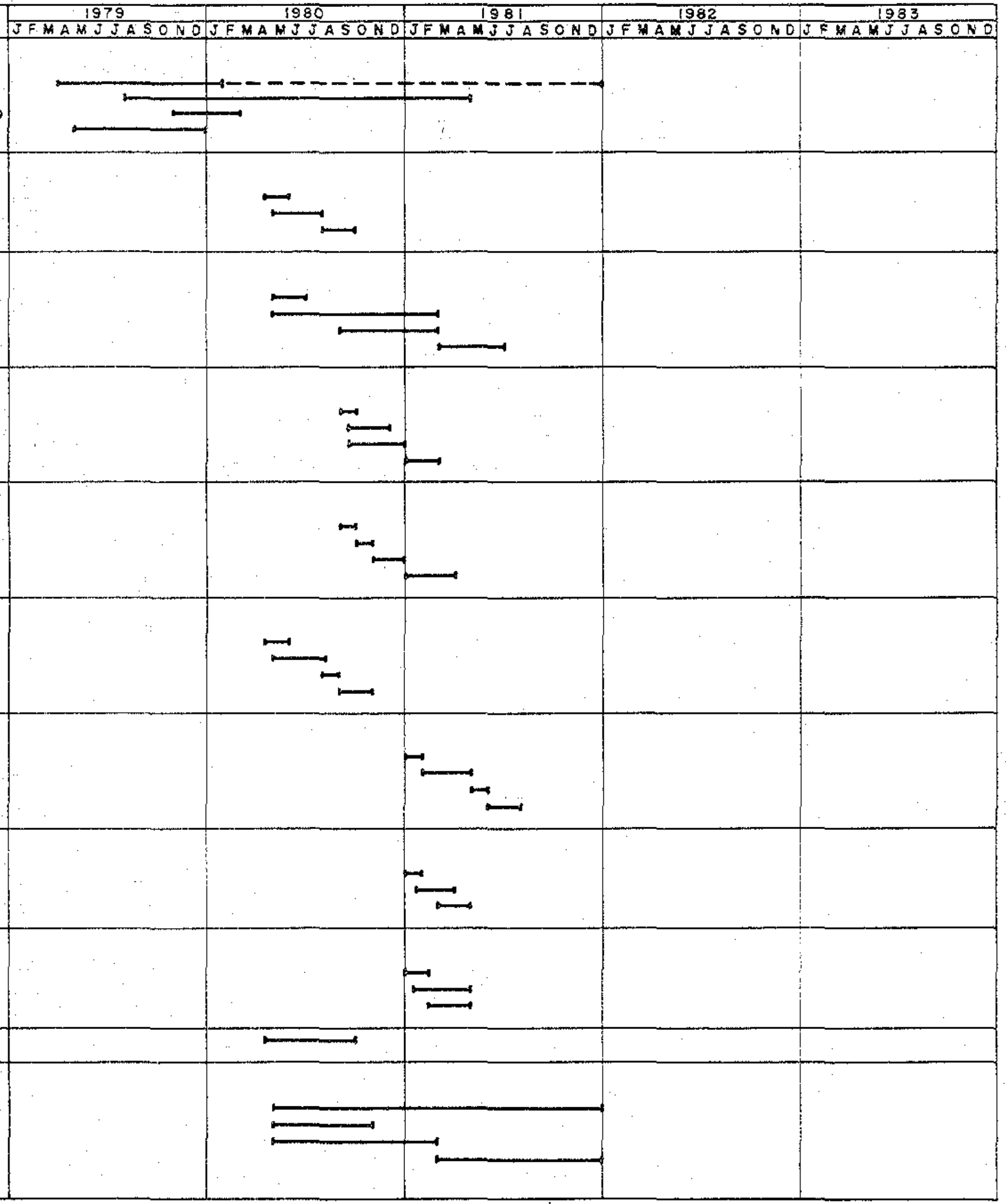


Fig. 11.3 Construction Time Schedule for Phase 2 (Tract 2)

Item	Unit	Quantity
1. Preparatory Works		
1.1 Engineering Services	LS	—
1.2 Procurement of Equipment	"	—
1.3 Land Acquisition	ha	45.5
1.4 Administrative Facilities	LS	—
2. Dike		
2.1 Stripping	ha	134
2.2 Embankment	m^3	2,267,600
2.3 Pavement	"	85,600
3. Pumping Station		
3.1 Inlet Channel	m^3	15,400
3.2 Foundation	"	4,300
3.3 Building	m^2	525
3.4 Pump Installation	Set	5
4. Main Irrigation Canal		
4.1 Stripping	ha	54
4.2 Excavation	m^3	192,700
4.3 Embankment	"	714,200
4.4 Related Structures	LS	—
5. Irrigation Lateral		
5.1 Stripping	ha	56
5.2 Excavation	m^3	16,500
5.3 Embankment	"	530,600
5.4 Related Structures	LS	—
6. Main Drainage Canal		
6.1 Stripping	ha	16
6.2 Excavation	m^3	1,690,300
6.3 Embankment	"	31,600
6.4 Related Structures	LS	—
7. Drainage Lateral		
7.1 Stripping	ha	19
7.2 Excavation	m^3	6,451,000
7.3 Embankment	"	144,700
7.4 Related Structures	LS	—
8. Main Road		
8.1 Stripping	ha	31
8.2 Embankment	m^3	165,500
8.3 Pavement	"	36,700
9. Farm Road		
9.1 Stripping	ha	61
9.2 Embankment	m^3	209,300
9.3 Pavement	"	79,000
10. Feeder Channel (Excavation)	m^3	2,496,400
11. On-Farm Development Works		
11.1 Land Leveling	ha	6,400
11.2 On-Farm Ditch	km	320
11.3 On-Farm Drain	"	160
11.4 On-Farm Road	"	135

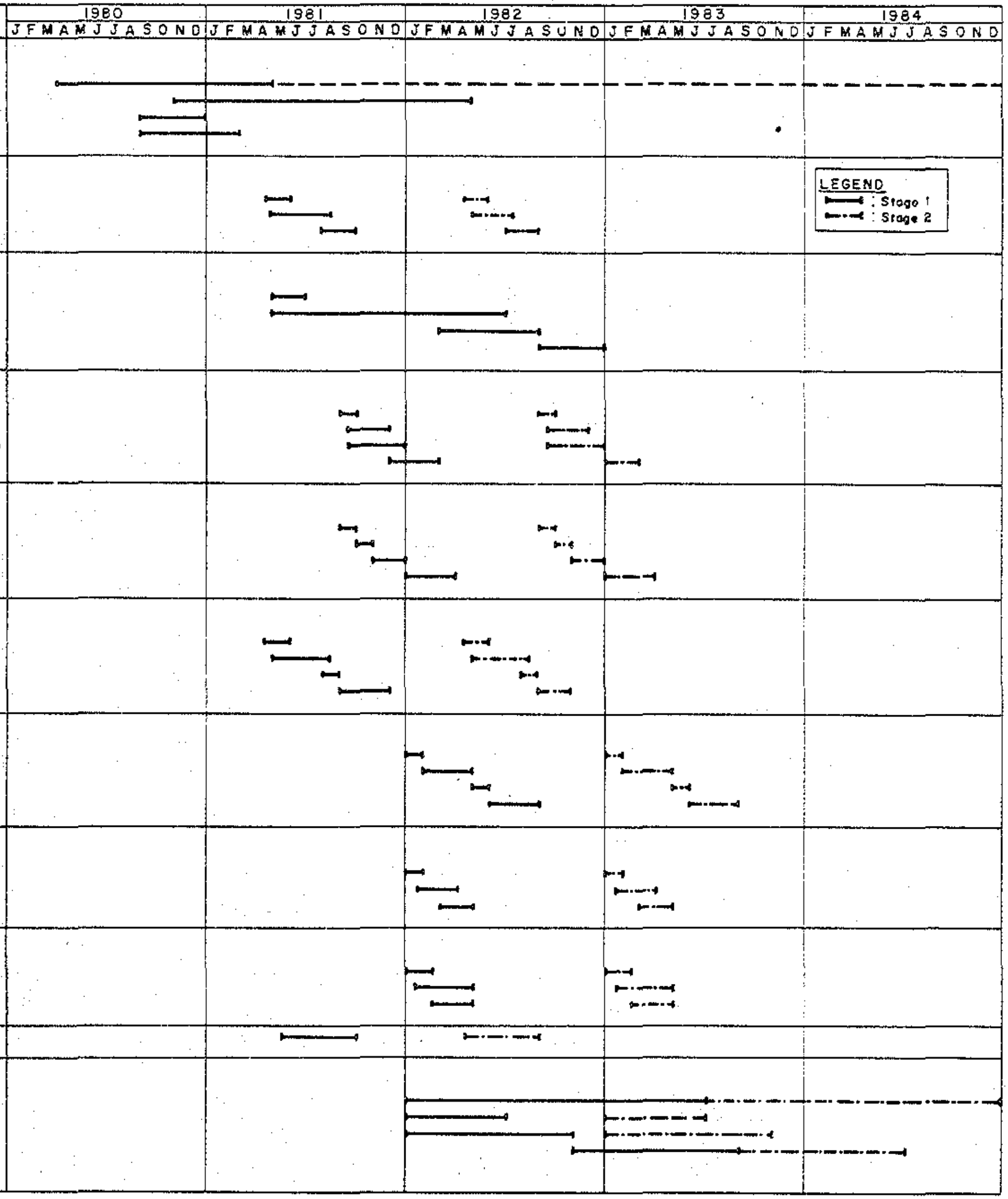


Fig. 11.4 Construction Time Schedule for Phase 3 (Tract 3)

Item	Unit	Quantity
1. Preparatory Works		
1.1 Engineering Services	LS	—
1.2 Procurement of Equipment	"	—
1.3 Land Acquisition	ha	84
1.4 Administrative Facilities	LS	—
2. Dike		
2.1 Stripping	ha	76
2.2 Embankment	m³	1,072,200
2.3 Pavement	"	40,800
3. Pumping Station		
3.1 Inlet Channel	m³	9,500
3.2 Foundation	"	2,200
3.3 Building	m²	375
3.4 Pump Installation	Set	3
4. Main Irrigation Canal		
4.1 Stripping	ha	8
4.2 Excavation	m³	7,900
4.3 Embankment	"	189,400
4.4 Related Structures	LS	—
5. Irrigation Lateral		
5.1 Stripping	ha	28
5.2 Excavation	m³	12,100
5.3 Embankment	"	184,400
5.4 Related Structures	LS	—
6. Main Drainage Canal		
6.1 Stripping	ha	5
6.2 Excavation	m³	798,800
6.3 Embankment	"	35,900
6.4 Related Structures	LS	—
7. Drainage Lateral		
7.1 Stripping	ha	6
7.2 Excavation	m³	226,600
7.3 Embankment	"	65,100
7.4 Related Structures	LS	—
8. Main Road		
8.1 Stripping	ha	11
8.2 Embankment	m³	58,300
8.3 Pavement	"	12,900
9. Farm Road		
9.1 Stripping	ha	44
9.2 Embankment	m³	150,500
9.3 Pavement	"	56,900
10. Feeder Channel (Excavation)	m³	1,131,500
11. On-Farm Development Works		
11.1 Land Leveling	ha	3,000
11.2 On-Farm Ditch	km	150
11.3 On-Farm Drain	"	75
11.4 On-Farm Road	"	63

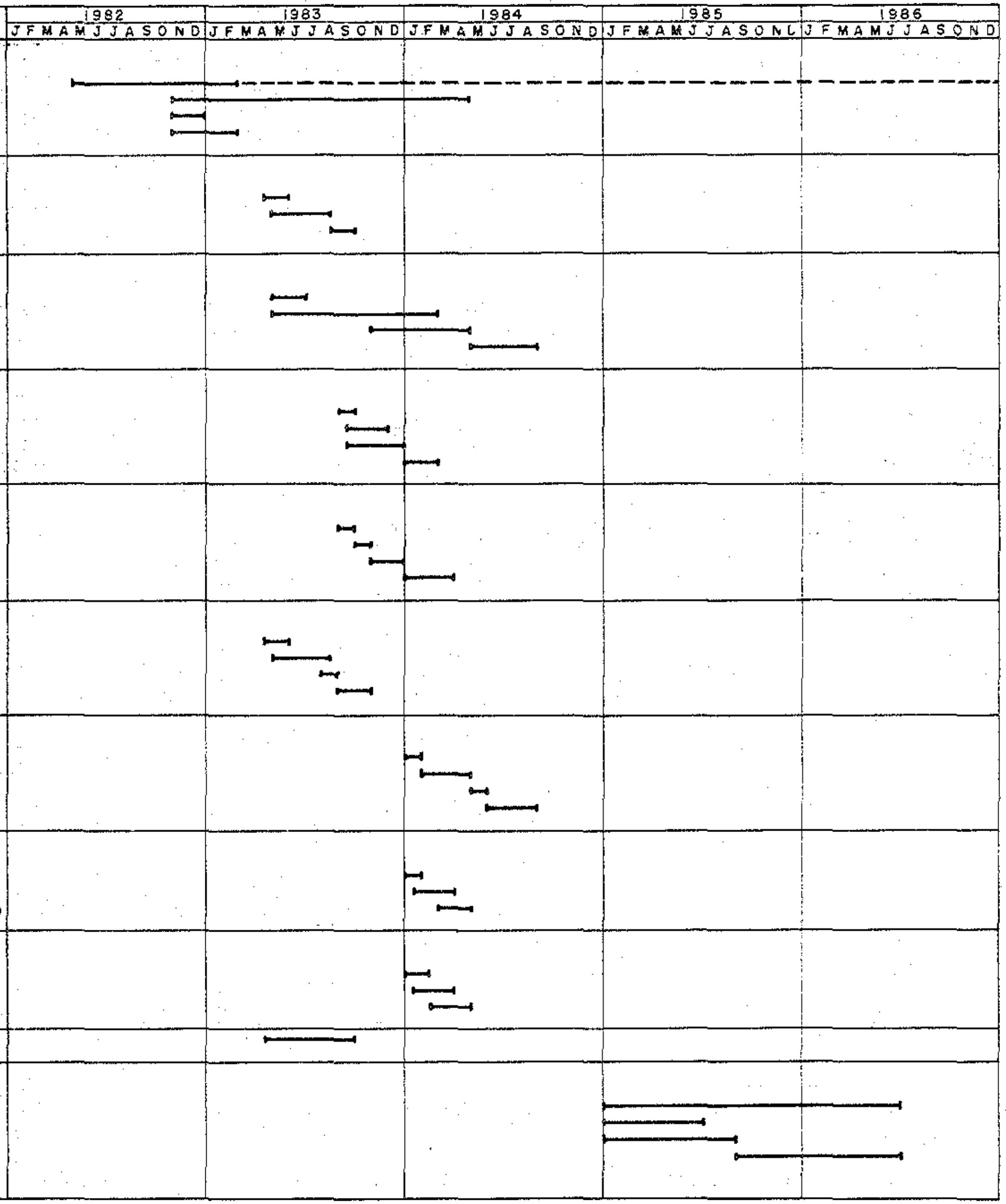
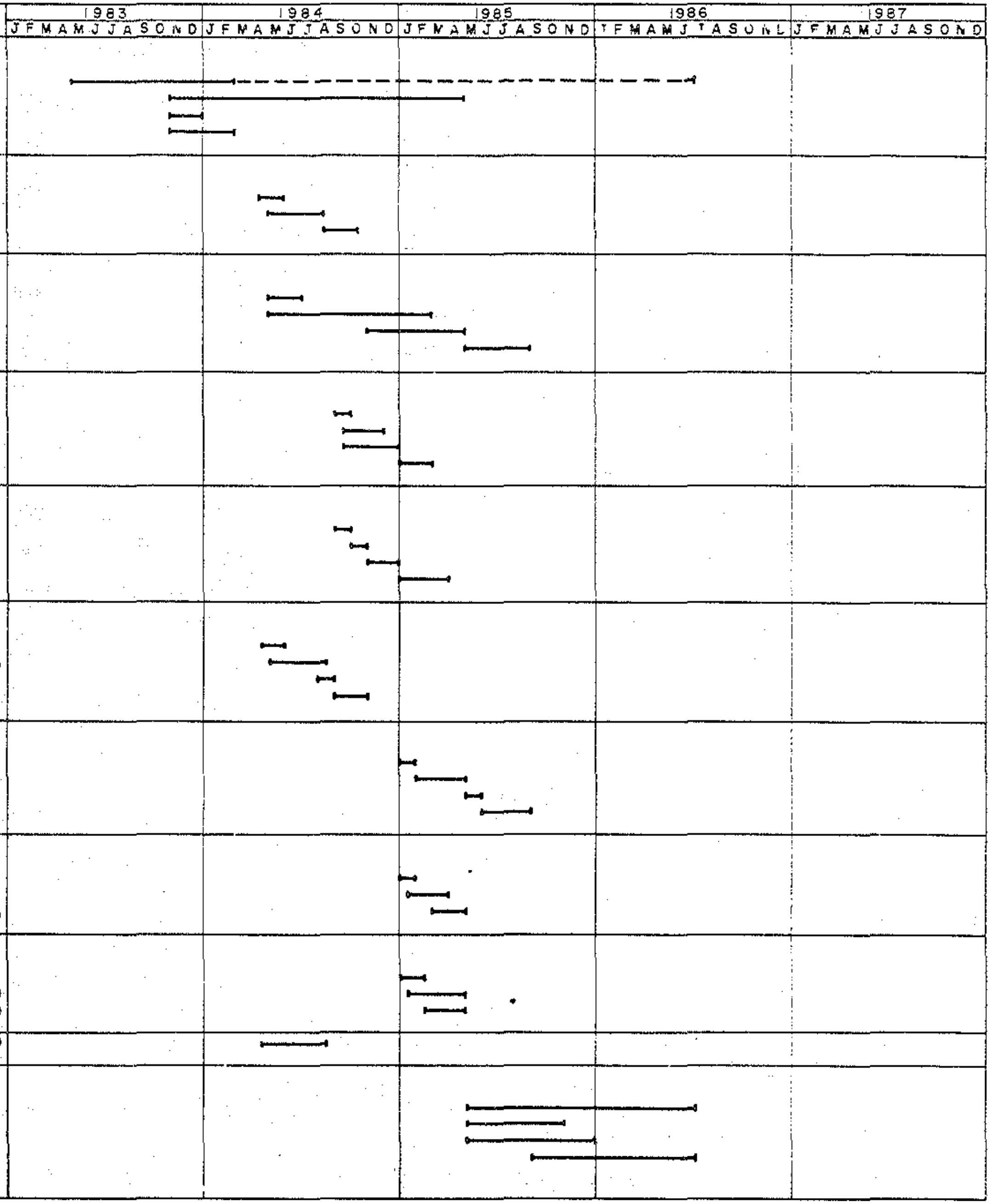


Fig. 11.5 Construction Time Schedule for Phase 4 (Tract 4)

Item	Unit	Quantity
1. Preparatory Works		
1.1 Engineering Services	LS	—
1.2 Procurement of Equipment	"	—
1.3 Land Acquisition	ha	8.2
1.4 Administrative Facilities	LS	—
2. Dike		
2.1 Stripping	ha	72
2.2 Embankment	m^3	1,146,800
2.3 Pavement	"	37,800
3. Pumping Station		
3.1 Inlet Channel	m^3	9,500
3.2 Foundation	"	2,200
3.3 Building	m^2	375
3.4 Pump Installation	Set	3
4. Main Irrigation Canal		
4.1 Stripping	ha	7
4.2 Excavation	m^3	4,900
4.3 Embankment	"	213,600
4.4 Related Structures	LS	—
5. Irrigation Lateral		
5.1 Stripping	ha	38
5.2 Excavation	m^3	21,800
5.3 Embankment	"	298,900
5.4 Related Structures	LS	—
6. Main Drainage Canal		
6.1 Stripping	ha	6
6.2 Excavation	m^3	1,064,700
6.3 Embankment	"	45,800
6.4 Related Structures	LS	—
7. Drainage Lateral		
7.1 Stripping	ha	9
7.2 Excavation	m^3	263,200
7.3 Embankment	"	70,000
7.4 Related Structures	LS	—
8. Main Road		
8.1 Stripping	ha	17
8.2 Embankment	m^3	88,700
8.3 Pavement	"	19,600
9. Farm Road		
9.1 Stripping	ha	43
9.2 Embankment	m^3	148,000
9.3 Pavement	"	56,000
10. Feeder Channel (Excavation)	m^3	1,149,000
11. On-Farm Development Works		
11.1 Land Leveling	ha	3,200
11.2 On-Farm Ditch	km	160
11.3 On-Farm Drain	"	80
11.4 On-Farm Road	"	67



ANNEX XII

AGRICULTURAL DEVELOPMENT PLAN

ANNEX XII

AGRICULTURAL DEVELOPMENT PLAN

Tables

Figures

Page

XII AGRICULTURAL DEVELOPMENT PLAN

12.1 Proposed Land Use Plan

Based upon the results of soil survey and land capability classification (Refer to Annex V), the project area is selected out of the total survey area.

Thus, the land graded at Class S2 (Moderately suitable land) with area of 13,180 ha (31,400 Feddans) and the land graded at Class S3 (Marginally suitable land) with area of 3,920 ha (9,300 Feddans) are demarcated as the net irrigable area whose total area amounts to 15,600 ha (37,100 Feddans). Besides, the partial lands of Class S2 and Class S3 with total area of 1,500 ha (3,600 Feddans) are allocated for the installation site of flood control, irrigation and drainage, road, wind-break and other facilities.

Then, the project area is totaled to 17,100 ha (40,700 Feddans), and the land graded at Class N1 (Currently unsuitable land) and the land graded at Sc (Conditionally suitable land) with totaled area of 2,900 ha (6,900 Feddans) are excluded from the project area.

The proposed land use plan is shown as follows.

Proposed Land Use Plan

Kind of Land Use	Area (ha)	Proportional Extent (%)
Project Area		
Net irrigable land	15,600	78.0
Site for major installation	400	2.0
Site for on-farm installation	1,100	5.5
(Sub-total)	(17,100)	(85.5)
Off-Project Area	2,900	14.5
Total Survey Area	20,000	100.0

12.2 Proposed Cropping Pattern

As for the present rice cultivation in the Sudan, only one cropping on a year is being conducted during the season from July to November.

In the objective area, it is generally accepted that the rice can grow throughout the year, although some of the climatic constraints, such as low relative humidity and low temperature in the winter season, etc., will disturb its favorable growth.

Taking into account the local climate, physiological characteristics of rice along with irrigation farming practices, three alternative cropping patterns are prepared as shown in Fig. 12.1. Among the alternatives, alternative I is single cropping in the flood season on a year. While, cropping pattern II and III are of double cropping of rice on a year.

12.2.1 Alternative Plan

1) Alternative I

Alternative I is the cropping pattern which is prepared mainly in due consideration of cost saving for irrigation practice. In order to successfully irrigate by gravity system, the cropping pattern is set up in the flood season from mid-September to mid-April. In this cropping pattern, it is unavoidable that rice is grown in the cool winter season especially in December and January. Consequently, the growing period of rice will become longer than usual.

As for the rice cultivation in the cool winter season, one trial was made in 1973/'74 at Ed Dueim, where the soil and eco-climatic conditions are very similar to those of the objective area, by the Agricultural Service Office, White Nile Province. In this trial, some 17 varieties or strains of rice, which introduced from the International Rice Research Institute (IRRI) in Philippines, were planted. In this trial cultivation, IR-8 and IR-5 varieties were able to ripen and to produce 4 tons and 3 tons of yield per ha, respectively. The other 15 varieties or strains, however, failed to ripen or barely ripened and then, the yields were lower than those of IR-8 and IR-5. The growing period of the said two varieties took for 180 days or so which is much longer than that of the varieties ordinarily grown.

According to the above results, it can be expected that the rice cultivation in the cool winter season will become practicable to some extent by introducing such varieties as IR-8 and IR-5 or further suitable varieties having low photo-sensitivity.

2) Alternative II

Alternative II is the cropping pattern in which two-time cultivation of rice on a year is programmed. The first cropping is conceptionally same to the pattern of the Alternative I. Following the first cropping, the second cropping will be done during the hot summer season from May to September.

As for the second cultivation of rice by the annual double cropping, there are rather deep experiences in Gezira area where agronomical conditions are similar to those of the objective area. In these experiences, it is recognized that the growing conditions and yield of rice are relatively normal, though there are some slight disturbances caused by high temperature and low humidity at the initial stage of rice growing.

According to the "Report on Rice Trial-Planting in Gezira Area in 1973" by the Chinese technical working team, 5 varieties were used for the trial cultivation conducted at the Agricultural Research Cooperation and the yield ranged from 7.6 tons to 4.0 tons per ha, or 5.8 ton/ha on an average.

These results would be acceptable in the present project area in general.

From irrigation engineering view point, gravity irrigation system can be adopted for the first cropping, while pumping irrigation is required for the second cropping. In this connection, some technical difficulties caused by different irrigation systems may limit the irrigation efficiency or it may be unavoidable to require expensive installation of pumping facilities.

3) Alternative III

The Alternative III is the cropping pattern revised from the Alternative II on the basis of the best results of the crop experiments in the Sudan. In this pattern, the coolest season of December and January is left fallow from the cropping programme, in due consideration of ill-effects on rice growing caused by low temperature.

The first cropping is programmed after the coolest season from February, and then, will be able to well ripen by early June. Following the first cropping, the second cropping will be operated during the season from July to November. In this cropping pattern, rice will be grown under the most favourable climatic conditions, particularly the critical growing period, such as reduction division stage, flowering stage and most active ripening stage may coincide with relatively high humidity, rather mild air temperature and sufficient sunshine energy.

According to the rice cultivation trials in the Gezira by the Chinese technical working team in 1973, yield by the regular cropping in season, which is similar to the second cropping prepared herein, ranges between 4.0 and 7.6 tons/ha and the highest yield in 1976 attains 8.4 tons/ha. Yield by the second cropping is also confirmed at the Surebaa agricultural station in 1973 as the level of 6.6 tons/ha to 5.3 tons/ha.

Many farmers are now planting rice in Gezira, during the rainy season and the yield is estimated at 7.1 to 2.4 tons/ha (3 tons to 1 ton per Feddan) in general, and skillful farmers are said to produce more than 6 tons per ha in a normal year.

Furthermore, as can be seen in Table 12. 1 , the results of rice cultivation trials at the project site conducted by Japanese Team prove that most varieties can produce more than 6 tons per ha, excepting Japanese and American varieties, and the productive varieties are possible to yield 9 tons per ha without difficulty.

There is no data available in the Sudan concerning to the yield by cropping to be similar to the first cropping programme. However, it can be definitely forseen at 4.0 to 5.0 tons per ha in yield on the basis of the trial cultivation made in Nigeria where eco-climatic conditions are quite similar to those in the growing period of the first cropping.

12.2.2 Recommendable Cropping Pattern

Three alternative cropping patterns and yield in each cropping are studied mainly from the agronomic point of view.

In general, high temperature and low relative humidity sometimes tend to exert unfavourable effect on the reproductive growth of rice, resulting in a decrease of the percentage of ripened grains and consequently in a remarkable reduction of yield, and an instance of which is shown in Fig. 12.2. It can generally be pointed out that the maximum temperature in May and June is rather high over the upper limit of temperature regime for favourable growth of rice and relative humidity is very low except for the period of July to October, as shown in Fig. 12.1 and Table 12.2. The present rice cultivation in the Sudan is, therefore, mostly practiced during the season from July to October when relative humidity and temperature are mild for rice growing.

Whereas, in the trial growing at Ed Dueim the said two varieties ripened during March and April when the temperature was quite high and the humidity was at the lowest, and still they produced 4 tons and 3 tons per ha, respectively. Unfortunately, the sterility percentage was not observed in the trial growing, so the exact effect of too low humidity and too high temperature on the ripening of rice grains could hardly be clarified, but the ill-effects of too low humidity and too high temperature did not appear to be exerted so seriously on the ripening of these two varieties as we estimated from the results of experiments in phytotrons using Japonica type varieties in Japan. There are, furthermore, big varietal differences among varieties in the tolerance against too high temperature and too low humidity, which has already been proved under natural conditions.

When suitable varieties are used in the first cropping of the Alternative II, rice plants will be able to ripen in April and May, even though it is rather low humidity and very high air-temperature in this season. However, the maturation period will become so long as 180 days or so due to the plant-stunt and cool injury caused by low temperature. In this case, more labour force for crop management and more irrigation water will be required as compared with that in the rice cultivation in other seasons.

In comparison with the cropping programme in each alternative, prospective maturation period and crop yield are foreseen in the followings:

Prospective Maturation Period and Yield

Cropping pattern	Maturation period (days)	Crop yield (ton/ha)
Alternative I	180	4.0
Alternative II		
1st cropping	180	4.0
2nd cropping	120	5.5
Alternative III		
1st cropping	110	4.0
2nd cropping	135	6.0

In due consideration of the agronomic constraints, crop yield as discussed in the above and the results of the economic examination stated in the Annex X , the cropping pattern of the alternative III is recommended on the future production programme in the objective area.

12.3 Selection of Variety

Scrutinizing the data obtained from the experiments in the Agricultural Research Corporation in Gezira and Rice Trial-Planting in Gezira by the Chinese technical working team, and further referring to the results of variety trial in the project site conducted by the Japanese team and those of variety tests conducted by the Nippon Koei team in the pilot farm in Nigeria, the following varieties are selected as recommendable varieties to the project area for the present. These varieties will be re-examined for further selection and be confirmed, and moreover, other improved varieties will be newly introduced in future through the experiments in the project site.

IR-28, Tos-103, C-11, C-15, IR-22, IR-5, IR-298, BG-34
BG-90, IR-8, C-6.

12.4 Proposed Farming Practices

In the rice cultivation recommended in the future crop production programme, full mechanized farming is proposed in due consideration of the very hard soil conditions, suitability of rice for mechanical farm operation, necessity of labour force saving, etc.

12.4.1 Land Preparation

At the beginning of January, land preparation will be started by the use of tractor with mounted disc plough having 4 bottoms in regular. The pre-irrigation will be practiced to advance the ploughing. In this work, some crawler type tractor will be also required in certain extent where the soils are very hardly consolidated.

Harrowing will be required at least twice after the ploughing in order to make the land levelling. Disc harrow attached to the tractor will be used for this practice. The crawler type tractor with dozer brande will be helpful for this work, particularly in the area where the soils are very hardly consolidated. In this work schedule, the rice straw will be incorporated into the soil for improving the soil conditions.

Following the harrowing works, temporary ridges will be prepared by the use of ridger and will divide the field plot into 2 or 3 small sub-plots, in order to achieve final land levelling for contributing to better water management and protection of young seedlings against wavelets.

Application of the basic fertilizers will be practiced by the use of broadcaster attached to the tractor. After the basic fertilization, rotar - harrowing by rotarvator and/or final land levelling by land leveller will be carried out for preparation of the good seed bed. This is very important practice particularly to ensure not only a good water spreading but also to promote the uniform germination of seeds as well as the growing of small seedlings.

As for the second cropping of rice, the land preparation will be carried out immediately after the harvesting of the first crop. All the practices except application of rice straw are same as the programme on the first crop mentioned above.

12.4.2 Seeding

At present, there are three types of rice cultivation methods broadly characterized by the seeding practice. One is the ordinary transplanting method in which seedlings are prepared at the nursery bed and thereafter are transplanted into the main field. This method is being widely practiced in the world and it is generally accepted that the yield can be expected higher as compared with that of the direct sowing method, particularly in poor field conditions, while a large labour force is required for the transplanting of seedlings. Recently, transplanting machinary (so-called transplanter) have been developed in Japan and being popular among farmers. However, those still have a narrow suitability with the field conditions.

The second is also the transplanting method which has been recently developed in Japan. Seedlings are prepared by the use of seedling boxes and thereafter those seedlings are broadcasted at randam spaces. In this method, labor requirement for transplanting is saved substantially and yield can be expected more than that by transplanting method. However, it will require rather big initial investment for preparation of seedling boxes.

The third is the direct seeding method. This method can be easily mechanized with shorter labor requirement than others. While, it is required to prepare the land leveling with more rigorous conditions as compared with that for others. The yield by this method is less than others in general, but it can be expected nearly as same as others only when germination of seeds is successfully achieved, weeds are well controlled and lodging of plants is nicely prevented.

Generally, the following seeding methods are practiced depending on the soil and field conditions.

1) Drill seeding on dry field conditions,
2) Broadcasting of seeds on dry field conditions, and
3) Broadcasting of seeds under submarged field conditions.

The method 3) is not recommendable in the objective area, in due consideration of the soil conditions. The seed germination will be largely restricted by clay coating in case of the method 3) due to very fine clayey soils in the objective area. Besides, under submarged conditions, trafficability and workability of farm machinery will be low in efficiency and in certain extent, it will be difficult to use the machinery, because the ground contact pressure decrease at less than 3 kg/cm^2, according to our field observation.

The following are the summary of comparison on the different conditions in each method.

Defferent Conditions in Each Method

Planting methods	Labor requirement /1 (manday/ha)	Field preparation cost /2 (US$/ha)	Yield
Ordinary transplanting method	60	13.00	6.0
Transplanting method with broadcastable seedlings	20	13.00	6.0
Direct seeding method	1	15.00	5.0

Taking into account the merits and demerits as seen in the above table, the direct seeding method in the dry field is mainly proposed in this production programme, but in some cases broadcast transplanting method is also recommendable.

Operation of seeding practice is that the seeds will be sown in shallow depth by the use of seeder (wide level disc harrow with seeder) attached to the tractor. The seeding rate will be at 80 kg/ha. Prior to the seeding, seeds will be selected by a salt-solution with 1.13 specific gravity and then treated by a chemical (Benrate) to control diseases.

The seeds used in this programme will be prepared through seed multiplication programme to be proceeded in the pilot farm which might be inplemented soon nearby the Project area.

/1 : Labor requirement is only for initial stage of rice cultivation i.e. land preparation, seed preparation and transplanting or seeding.

/2 : Cost excludes depreciation cost of farm machinery.

12.4.3 Water Control and Management

After the seeding, operation of irrigation will be started and it will be continued until 10 days before harvesting. Regarding the irrigation operation, the following water control and management will be properly practiced with the growth of rice plants.

1) Sprouting stage

As stated in the sub-chapter 12.4.2, germination of seeds will be largely restricted under submarged conditions. Thus, at this growing stage, the irrigation water will be applied only for sustaining the soil moisture at the field capacity or little over in level. In the second cropping, when rain-water is stagnant on the soil surface at this stage, it should be drained out completely from the nursery field.

2) Young seedling stage

In order to ensure the successful establishment of seedlings, it will be necessary to keep the nursery field with only saturated moisture in soil or little less and this conditions will be continued until the plant-age of 4 to 5 which is expressed by the leaf-number on the main stem. Even in this stage, if seedlings are completely submerged, they are seriously damaged. Therefore, an excessive irrigation water and/or rain-water should be elminated, as soon as possible, from the field.

3) Active tillering stage

At this stage, shallowly water-logged condition is required to effectively increase the number of tillers, and it also serves for controlling weeds. During the period from the stage of last emergence of bearing tillers to the stage of spikelet differentiation which roughly corresponds to 40 days to 27 days before heading, the water will drained out completely. This practise is called as "Mid-Season drying practice", and it is quite useful especially in ill-drained fields for controlling the non-bearing tillers and reductive soil conditions, but also increasing the resistance in lodging of plants and the percentage of ripened grains.

4) Spikelet initiation stage to full ripening stage.

After finishing "Mid-Season drying practice", the watering will start again and the field will consecutively be flooded until the full heading stage but upon occasion water is also drained out for 2 or 3 days, at intervals of 10 days for encouraging the root activity. When rice plants attain to maturity and 10th day before harvest, all the water will be drained out from the field for facilitating the operation of combine harvesters.

12.4.4 Fertilization

As recommended in the Annex V, proper application of fertilizers is essential for the realization of the agricultural potential in the objective area. According to the results of the detailed soil chemical analyses, the nutrients necessary for proper rice production are not always sufficiently contained in the soil. Accordingly some nitrogen and phosphorus and organic components are necessary to be supplemented.

On the basis of the chemical properties of soils, requirement of nitrogen and phosphate is estimated at about 70 kg/ha of N and 35 kg/ha of P_2O_5 for the first cropping and 90 to 95 kg/ha of N and 45 kg/ha of P_2O_5 for the second cropping. These are respectively corresponding to about 150 kg/ha of urea and 75 kg/ha of triple-supper phosphate (T.S.P.) for the first cropping and 200 kg/ha of urea and 100 kg/ha of T.S.P. for the second cropping. According to the results of the dosage test made in Gezira, good response on these fertilizers is clarified technically and economically.

In addition to the above, some 5 to 10 tons/ha of rice straw will be applied into the soil not only for improving the physical conditions of soils but also for supplying the nitrogen, humus and other minor elements in the soils.

As for the soil fertilization particularly by urea, split-application method is recommended, because its effective response will be largely ristricted by diammonification due to alkali-soils in the objective area.

Out of the total dosage of fertilizers, about one third of urea and all the T.S.P. will be applied as the basic fertilizer. Application of these is done by the use of broadcaster, and thereafter, these are effectively mixed with soils by the practice of rotar-harrowing as described in the above.

In the first cropping, the first top-dressing of urea will be applied with about 30 kg/ha just before the most active tillering stage (30 days after the seeding), and thereafter, the second with about 45 kg/ha just before the most active reduction division stage (20 days before heading, 70 days after the seeding) and the third with about 30 kg/ha at the full heading stage (90 days after the seeding).

Similarly, the second crop will grow under split-fertilization by urea, respectively, of 40 kg/ha just before the most active tillering stage, 60 kg/ha just before the reduction division stage and 40 kg/ha at the full heading stage.

The application of these urea will be done by the use of power dusters with 40 m long of pipe applicaters.

The yield of rice straw can be expected at about 5 tons/ha in the first cropping and at about 7.5 tons/ha in the second cropping. Out of the total production of rice straw, some 5 to 10 tons/ha will be returned into the soils and the remaining straw will be able to use for animal grazing as a kind of quority hay.

12.4.5 Plant Protection

According to the experience in the rice cultivation in Gezira, no remarkable damage is observed, at present. However, owing to the certain enlargement of rice production programme and continuous rice cultivation, insect, diseases and other pests will difinitly develop and increase damages in the future. Therefore, the plant protection schedule must be provided in this rice production programme. For this purpose, about 30 kg/ha each of insecticides and fungicides are estimated in the respective crop season.

12.4.6 Weeding

A production decrease caused by weeds is the most serious obstruction in the rice cultivation in general. Particularly the rice production by direct sowing methods is seriously affected due to far difficulty on the mechanical weed control. In this production programme, therefore, chemical weed control will be introduced, taking into account the availability of labour force and the effective farm operation. The harbicides will be applied at about 30 kg/ha just after the seeding and the second application with 30 kg/ha for about 30 days after the seeding. In the application of herbicides, chemical toxicity against fishes, animals and also human-being is carefully taking into consideration, and then, harmless varieties of chemicals such as MO, X-5-2, SWEP and SATURN will be selected and introduced. The harbicides will be applied by the power dusters with same practice of fertilizer application.

12.4.7 Harvesting

Harvesting of rice will be conducted by the rice combine harvesters with 4.0 - 4.5 m cutting width and half crawler type wheels. Prior to the harvesting, the field will be drained up completely.

The 1st crop will be harvested in June and the 2nd crop in the middle of November to middle of December. The optimum time of harvesting in each crop will carefully be decided in order to avoid grain losses by lodging, shattering and spoil of the grains due to the clack (sun check) etc.

In the harvesting, rice straw will also cut down by the straw chopper attached to the combine harvester.

Details of the farm input requirement is summarized in Table 12.3 and detailed application schedule is presented in Table 12.4 and Table 12.5. The selection of the type of farm machinery to be used for this production programme will be made upon due consideration of the local climate, soil conditions in the objective area and the proposed works and those practices. Detailed study on the farm machinery will be stated in the Annex XIII.

12.5 Anticipated Rice Production

As discussed in 12.2, Alternative Cropping Pattern target yield of rice will be estimated at 4 tons/ha by the first cropping and 6 tons/ha by the second cropping. With the implementation of the project, the anticipated rice production will increase year after year through improved field conditions and farming techniques.

The first crop will grow in the hot dry season. The rice cultivation in this season has never been commonly conducted in the Sudan mainly due to the availability of irrigation water. So far as we are aware, only one cultivation trials on the hot dry-season cropping have been conducted so far in this district. In this trials, some of the varieties showed rather high potential on the productivity ranging pretty good yield of 3 tons/ha and 4 tons/ha. From the results, it can be safely estimated that if more suitable varieties are selected and grow with proper irrigation, the yield of 4 tons/ha will successfully be obtained even in the initial stage of the development. Besides, this anticipated yield would be able to confirm by the yields of the first cropping which had been operated in our pilot farm in Nigeria, whose season and duration of crop growing were quite same as in this case. For instance, some 4.5 tons to 5.5 tons/ha were constantly obtained by using the varieties of IR-28 and TOS-103, whose maturation period are for 100 to 110 days.

The second crop will grow mainly in the rainy season. It is very mild climate for the critical growing stage of rice, i.e. reduction division, flowering and active ripening. The most of experiences on rice cultivation in Sudan is, therefore, being concentrated in this season and the yields ranged between 4 tons and 7.6 tons/ha are harvested in either trial cultivation or commercial basis. In case of the trial cultivation with C-6 in Gezira, estimated yield of 8.3 tons/ha has been reported. It is sujested that if more advanced farming techniques and selected varieties will be introduced, more than 6 tons/ha of yield can be expected on this crop season. Some 6 tons/ha as the prospective yield herein estimated will be conservative.

On the basis of the estimation of the anticipated rice yield, and also estimation of the construction schedule, total rice production at the full development stage is foreseen as below:

Rice Production at Full Development Stage

Tract	Phase	Planted Area (ha)	Harvested Paddy 1st Crop (ton)	Harvested Paddy 2nd Crop (ton)	Harvested Paddy Total (ton)
I	1	3,000	12,000	18,000	30,000
II	2	3,200	12,800	19,200	32,000
II	3	3,200	12,800	19,200	32,000
III	4	3,000	12,000	18,000	30,000
IV	5	3,200	12,800	19,200	32,000
Total		15,600	62,400	93,600	156,000

Table 12.1 Results of Rice Cultivation Trials in the Project Site (1977)

Trials	Sowing date	Heading date	Maturity date	Panicle length (cm)	Culm length (cm)	No. of panicles per hill	No. of grains per panicle	No. of grains per m² (x1000)	Percent of ripened grains (%)	Wt. of 1,000 grains (g)	Yield	
											Ton/ha	Ton/fed
1. Cultivation Method Trial (Variety used: IR-298-12-1.1.1.)												
Direct sowing (Drilling)	Jun. 23	Sep. 21	Oct. 19	23.2	75	10.2	122	43.0	83	19.6	7.0	2.9
Direct sowing (Broad casting)	Jun. 23	Sep. 21	Oct. 19	21.6	69	-	99	34.9	84	19.8	5.8	2.4
Transplanting (regular)	Jun. 15	Sep. 21	Oct. 20	22.2	69	12.6	150	41.9	90	19.9	7.5	3.2
Transplanting (Broad cast)	Jun. 15	Sep. 15	Oct. 17	22.4	74	14.1	120	44.9	88	20.0	7.9	3.3
2. Variety Trial												
Fujiminori (Japan)	Jun. 7	Aug. 15	Sep. 9	21.3	73	14.5	78	25.1	78	24.5	4.8	2.0
Reimei (Japan)	Jun. 7	Aug. 22	Sep. 9	20.5	60	15.1	75	25.1	82	25.7	5.3	2.2
Toyonishiki (Japan)	Jun. 7	Aug. 22	Sep. 9	18.6	65	16.1	66	23.3	92	26.1	5.6	2.3
Koganenishiki (Japan)	Jun. 7	Aug. 3	Sep. 1	16.5	53	12.2	30	8.0	73	20.6	1.2	0.5
Aseminori (Japan)	Jun. 7	Aug. 1	Sep. 1	16.3	52	12.6	46	12.8	73	23.6	2.2	0.9
Toitsu (Korea)	Jun. 7	Sep. 4	Oct. 8	21.8	55	14.5	114	37.0	83	24.4	7.5	3.2
Taichung-65 (Taiwan)	Jun. 7	Aug. 28	Oct. 3	21.7	85	10.7	98	23.2	86	25.6	5.1	2.1
Taichuikukyu (Taiwan)	Jun. 7	Aug. 27	Oct. 15	20.5	71	12.5	159	44.1	69	23.0	7.0	2.9
Down (U.S.A.)	Jun. 7	Aug. 28	Oct. 11	27.0	69	5.2	298	34.3	63	20.8	4.5	1.9
Blue Bonnet (U.S.A.)	Jun. 7	Sep. 12	Oct. 17	26.8	87	4.6	199	20.3	79	22.4	3.6	1.5
Dasmati (U.S.A.)	Jun. 20	Sep. 15	Oct. 11	27.2	109	12.2	103	28.0	75	20.0	4.2	1.8
Covad Mali (U.S.A.)	Jun. 20	Oct. 14		27.6	114							
IR-127 (Philippines)	Jun. 7	Sep. 4	Oct. 15	24.1	68	6.6	355	52.0	70	18.6	6.8	2.9
IR-298-12-1.1.1. (Philippines) (Broadcast transplanting)	Jun. 15	Sep. 15	Oct. 17	22.4	74	14.1	120	44.9	88	20.0	7.9	3.3
IR-5 (Philippines) (Broadcast transplanting)	Jun. 15	Sep. 4	Oct. 12	23.0	60	18.1	99	35.6	87	23.6	7.3	3.1
IR-2053 (Philippines)	Jun. 15	Sep. 21	Oct. 20	24.7	66	14.8	117	38.4	77	23.0	6.8	2.9
IR-22 (Philippines)	Jun. 15	Sep. 21	Oct. 18	21.8	59	17.3	90	34.7	88	22.3	6.8	2.9
IR-2153 (Philippines)	Jun. 15	Sep. 17	Oct. 18	21.9	62	20.0	75	33.3	86	22.0	6.3	2.7
IR-1514 (Philippines)	Jun. 15	Sep. 24	Oct. 22	24.1	62	20.0	126	56.0	74	18.1	7.5	3.2
IR-1561 (Philippines)	Jun. 15	Sep. 9	Oct. 12	22.0	53	22.0	91	44.4	90	19.3	7.7	3.2
IR-298-12-1.1.1. (Philippines)	Jun. 15	Sep. 21	Oct. 20	22.2	69	12.6	150	41.9	90	19.9	7.5	3.2
IR-20 (Philippines)	Jun. 20	Sep. 27	Oct. 22	26.0	61	14.9	144	45.0	78	19.1	6.7	2.8
IR-8 (Philippines)	Jun. 20	Sep. 28	Nov. 1	23.0	58	14.5			86	26.8	8.7	3.7
C-11 (China)	Jun. 15	Aug. 27	Oct. 2	22.9	56	15.7	88	30.1	91	24.8	6.8	2.9
C-15 (China) (Broadcast transplanting)	Jun. 15	Sep. 13	Oct. 15	23.7	68	16.0	128	44.6	90	22.4	9.0	3.8
BG-34-8 (Sri Lanka)	Jun. 20	Sep. 9	Oct. 8	23.6	66	10.2	189	43.1	77	19.9	6.6	2.8
BG-34-8 (Sri Lanka)	Jul. 7	Sep. 25	Oct. 30		79	12.0			81	21.7	8.0	3.4
SLM-18 (Surinum)	Jun. 7	Sep. 4	Oct. 11	25.6	77	11.6	55	18.8	83	35.2	5.5	2.3
Native Variety (Nigeria)	Jul. 7	Oct. 8			118							
IR-298-12-1.1.1.	Jul. 7	Oct. 4			68	16.0			80	18.7	8.1	3.4

Table 12.2 Temperature and Humidity Conditions

I. Temperature (°C)

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	Mean
Khartoum	22.5	23.8	27.2	30.7	33.1	33.3	30.8	29.4	30.9	31.4	27.5	23.7	28.7
Enugu	26.8	28.0	28.9	28.7	27.1	27.1	26.2	25.8	25.7	26.3	27.1	26.3	26.8
Kumagaya	2.8	3.5	6.6	12.3	17.0	20.7	24.6	25.8	21.7	15.7	10.3	5.2	13.9

II. Relative Humidity (%)

Khartoum	31	26	20	19	24	28	34	56	47	31	31	34	32
Enugu	63	62	71	75	78	80	80	81	84	77	66	73	74
Kumagaya	59	58	61	68	74	79	83	82	82	79	72	64	72

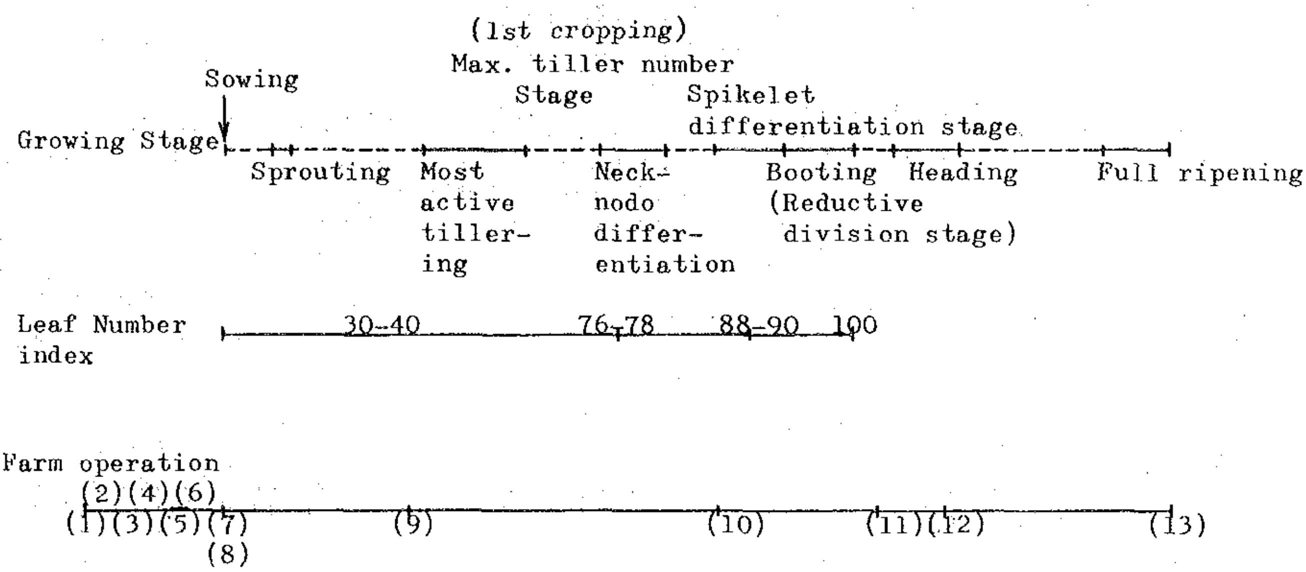
Note: Enugu is in Nigeria, in the neighborhood of Enugu Nippon Koei Co. is now establishing a pilot farm having an area of 1,000 ha, and Kumagaya is located near Tokyo.

Table 12.3 Proposed Farm Input

Crop	Inputs	Quantity (Kg/ha)	Amount (tons/400 ha)	Amount (tons/15,600 ha)
1st crop (Feb. - Jan.)				
	- Seeds	80	32	1,248
	- Urea	150	60	2,340
	- Triple-super phosphate	75	30	1,170
	- Fungicide /1	0.1	0.04	1.56
	- Insecticides	30	12	468
	- Rice strow	2,500	1,000	39,000
2nd crop (Jul. - Nov.)				
	- Seeds	80	32	1,248
	- Urea	200	80	3,120
	- Triple-super phosphate	100	40	1,560
	- Fungicides /1	0.1	0.04	1.56
	- Fungicides	30	12	468
	- Insecticides	30	12	468
	- Herbicides	30	12	468
	- Rice strow	5,000	2,000	78,000

/1: to be used for seed treatment.

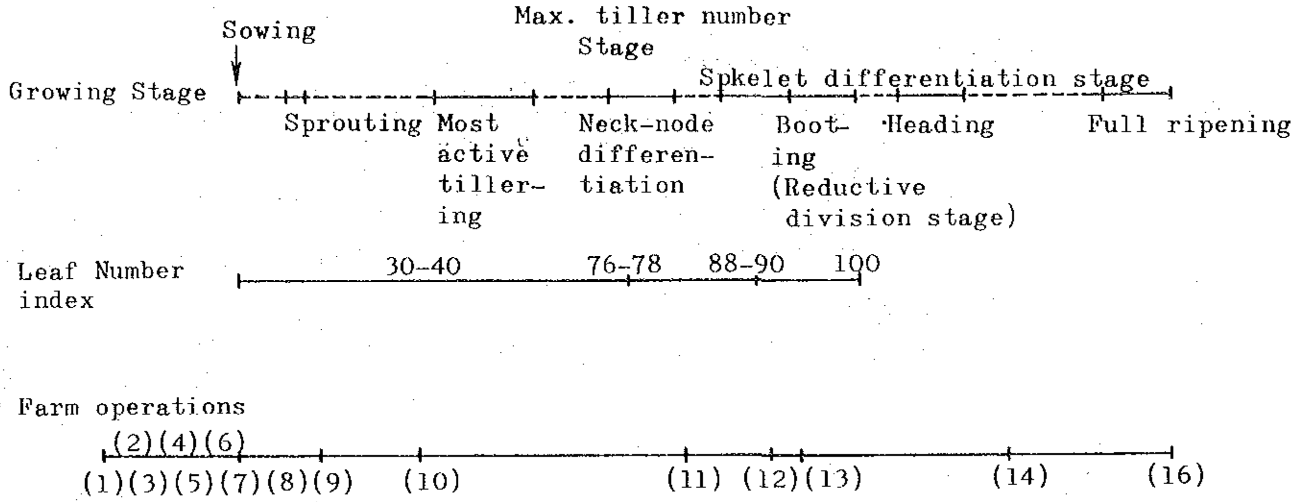
Table 12.4 Rice Growing Stages, Farming Practices and Timing of Works Required by the Stages



Farm Operation		Major Equipment	Farm Inputs	Timing (days before or after seeding)
(1)	plowing	Dsic plough	–	-45
(2)	1st harrowing	Offset disc harrow	–	-45
(3)	2nd harrowing	– do –	–	-15
(4)	Basic fertilizing		Urea: 50 kg/ha T.S.P.: 75 kg/ha	-12
(5)	Rotorvating	Rotorvater	–	-10
(6)	Ridging	Ridzer	–	- 7
(7)	Final levelling	Grader	–	- 5
(8)	Seeding	Drill seeder	Seeds: 80 kg/ha	0
(9)	2nd fertilizing	Power duster	Urea: 30 kg/ha	+30
(10)	3rd fertilizing	– do –	Urea: 45 kg/ha	+55
(11)	Plant protection	– do –	Insecticides: 30 kg/ha	+65
(12)	4th fertilizing	– do –	Urea: 30 kg/ha	+80
(13)	Harvesting	Combine harvester	–	+110

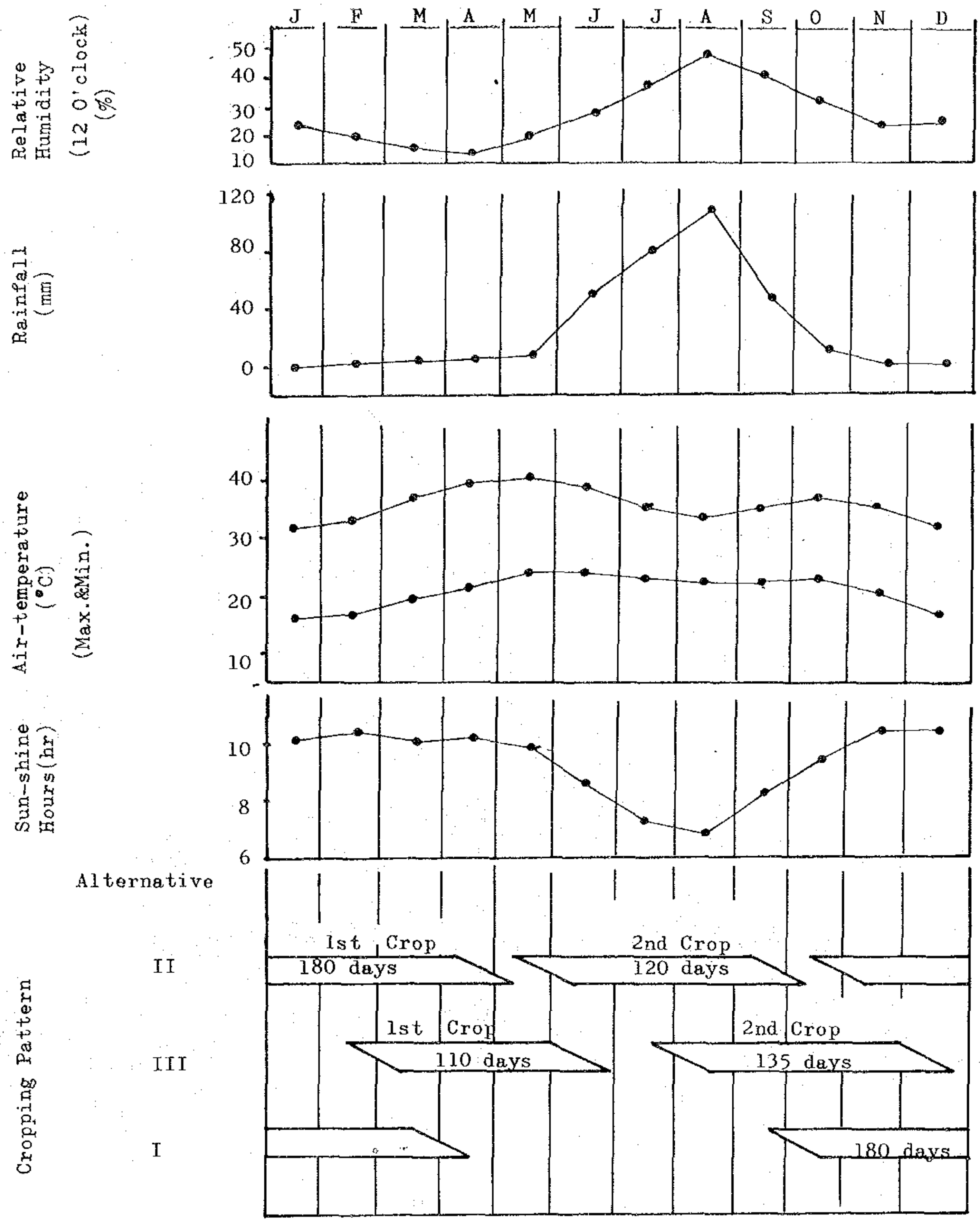
Table 12.5 Rice Growing Stages, Farming Practices and Timing of Works Required by the Stages

(2nd cropping)



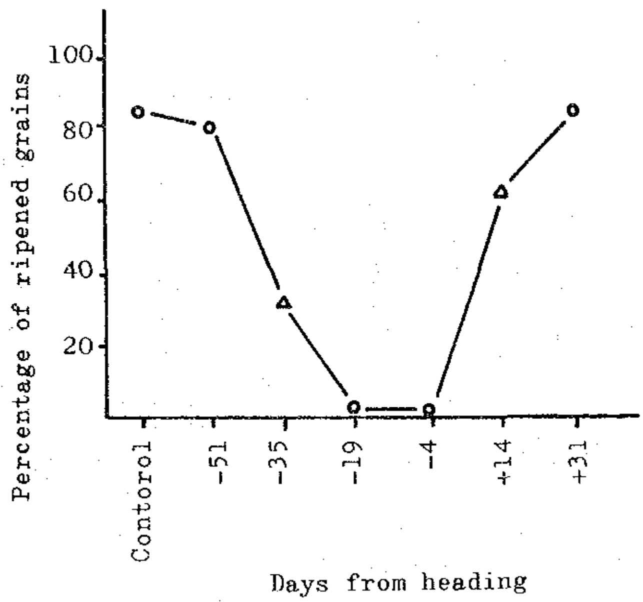
	Farm Operation	Major Equipment	Farm Inputs	Timing (days before or after seeding)
(1)	Plowing	Disc. plough	-	-45
(2)	1st harrowing	Offset disc harrow	-	-45
(3)	2nd harrowing	- do -	-	-45
(4)	Basic fertilizing	Broadcaster	Urea: 60 kg/ha T.S.P.: 75 kg/ha	-42
(5)	Rotarvating	Rotarvater	-	-40
(6)	Ridging	Ridger	-	-15
(7)	Final levelling	Grader	-	-10
(8)	Seeding	Drill seeder	Fungicides: 1 kg/ha Seeds: 80 kg/ha	0
(9)	Weeding	Power duster	Herbicides: 30 kg/ha	+10
(10)	2nd fertilizing	- do -	Urea: 40 kg/ha	+40
(11)	1st protection	- do -	Fugicides: 30 kg/ha	+60
(12)	3rd fertilizing	- do -	Urea: 60 kg/ha	+70
(13)	2nd protection	- do -	Insecticides: 30 kg/ha	+80
(14)	4th fertilizing	- do -	Urea: 40 kg/ha	+100
(15)	Harvesting	Combine harvester	-	+135

Fig 12.1 Meteorological Conditions and Cropping Pattern



Note: Relative humidity, Rainfall and Mean Air-temperature are the average values obtained at Ed Dueim over a period of 29 years, while Sun-shine hours are those observed at Kosti over a period of 14 years.

Fig 12.2 Damages in the Reproductive Growth Period Caused by a High Temperature Treatment



Note:

1. The experiment was conducted in a phytotron in Japan, using a Japonica type variety.
2. Different symbols in the figure indicate significant differences between them, while identical symbols show no significant difference with each other.
3. Source: S . Matsushima's "Crop Science in Rice" pp.180.

ANNEX XIII

AGRICULTURAL MECHANIZATION

ANNEX XIII

AGRICULTURAL MECHANIZATION

Tables

XIII AGRICULTURAL MECHANIZATION

13.1 Soil and Farming Conditions

13.1.1 Soil Condition

The soils in the project area are very deep, cracking, self-multing with high-water holding capacities but low permeabilities. Under dry conditions, the soils are hard and deep cracks permit very rapid initial intake of water. When wet, however, the soils swell and seal the cracks, become very sticky and almost impermeable.

They can be effectively cultivated only when their moisture content is within a narrow range and cultivation under irrigation required special skills and careful water management.

Very fine clayey soil is another constraint on the seed germination. As shown in Table 13.1, the germination of seeds will be seriously restricted by clay coating under submerged conditions due to the soils having high swelling characteristics.

13.1.2 Ground Contact Pressure

According to the test results on the ground contact pressure in the existing soil conditions in the project area, cone resistance values at five testing points are at more than 5 kg/cm^2 in depth of 50 cm of soil profile. This conditions indicate that even the heavy machinery can introduce into the proposed mechanization programme, successfully. Under submerged conditions, however, the ground contact pressure decrease at less than 3 kg/cm^2. In this condition, traficability and workability will become low in efficiency, and sometimes, it will be difficult to use machinery.

Through the experiences in Malaysia, where is distributed by alluvial soil group with same characteristics as in the project area, the submerged soils will be get more than 5 kg/cm^2 after 7 or 10 days of draining up the paddy field.