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DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT

FEASIBILITY REPORT ON THE WONOGIRI IRRIGATION AND UPPER SALA RIVER IMPROVEMENT PROJECT

APPENDIX I IRRIGATION

JAPAN INTERNATIONAL COOPERATION AGENCY

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1. ENGINEERING SURVEYS AND INVESTIGATIONS

1.1 EXISTING IRRIGATION SYSTEMS

The right-bank irrigation area which consists of approximately 84 % of the entire irrigation area under the project is currently supplied with irrigation water from the following seven tributaries:

Kali Jlantah

" Samin

" Grompol (Kumpul)

" Mungkung (Jlanprang)

" Sragen

" Kenatan

" Sawur

The existing irrigation systems in direct relationship with the Project-area, their respective water sources, and the total size of farmland and that coming under the project by category-wise classification of their irrigation facilities will be known from Table 1.1.1 which has been prepared on the basis of "Daftar Adanya Lapuran Pasten Air" and through assimilation of various related information. The farmland coming under the project has been divided into 3 Regions as per Table 1.1.2 below and Fig.1.1.1 (see Drawing 001). The existing irrigation facilities inside the Project-area are given as per Data-3.

Table 1.1.2 Existing Land Classification in the Project-area

Region	Technical Area (ha)	Semi-Technical Area (ha)	Other (+) Areas (ha)	Total Area (ha)
Karanganyar Region	7,290	450	2,360	10,100
Sragen "	6,740	260	2,500	9,500
Dengkeng "	410*	990	2,200	3,600
Total	14,440*	1,700	7,060	23,200

Notes: (*) including 300 ha. which is habitually inundated during rainy season and treated as "Non-rainfed Area;"

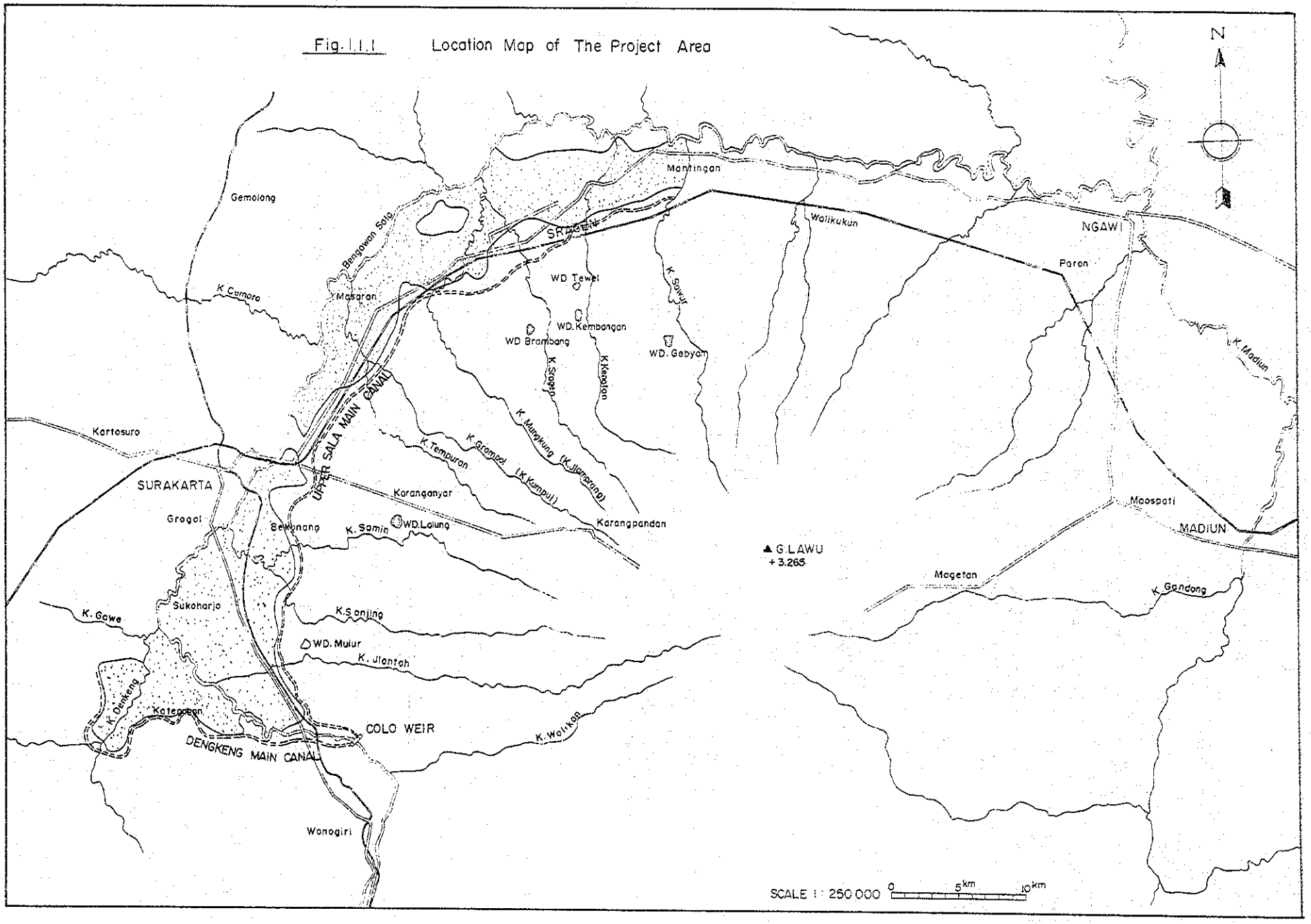
(+) Other Areas are made up of non-technical area and rainfed area.

Table 1.1.1 Farmland coming under the Project which is irrigated by Different Water Sources

Seksi	Ranting	Water Source		Irrigation Area: Whole Area ha	Irrigation Area: Inside Project Area ha	Ratio %
Karanganyar	Sukoharjo**	B.Papen, B.Geneng, B.Garotan/K.Jlantah (Wd. Mulur)	(T)	5,107	3,990	78
		B.Ambil[2]/K.Jlantah, B.Jatimatang	(1/2 T)	2,733	440	16
		(N,R)			3,860	-
	Bekonang	B.Kaliduren/K.Buret	(T)	631	70	11
		B.Dari/K.Umet	(T)	500	150	30
		B.Gemb.Truni/K.Samin	(T)	2,137	830	39
		(N,R)			350	-
	Karanganyar	B.Gemb.Truni/K.Samin	(T)	2,183	490	22
		(N,R)			100	-
	Tasikmadu	B.Kalongan/K.Siwaluh	(T)	2,022	510	25
		B.Jungkang/K.Siwaluh	(T)	624	400	64
		B.Lencong/K.Jirak, Cobor	(T)	450	60	13
		B.Pengin/K.Jirak, Color	(T)	900	900	100
		B.Ledok/K.Kumpul	(1/2 T)	633	230	36
		(N,R)			250	-
	Sub-total		(T)	14,554	7,400	51
			(1/2 T)	3,366	670	20
			(N,R)		4,560	-
Sragen		K.Jlampraug	(T)	4,336	2,080	43
		K.Sragen	(T)	3,755	510	14
		K.Sawur	(T)	3,137	1,630	52
		K.Kenatan	(T)	4,360	2,520	58
		K.Kenatan	(1/2 T)	1,848	260	14
		(N.R)			2,500	-
	Sub-total		(T)	15,592	6,740	43
			(1/2 T)	1,848	260	14
			(N,R)		2,500	
Klaten	Dalanggu	B.Kaligowe,B.Jetis,B.Tempel	(T)	1,268	300*	24
		B.Pogung,B.Grojagan, etc.	(1/2 T)		770	-
Total		Technical irrigation area	(T)	31,414	14,440*	46
		Semi-technical irrigation area	(1/2 T)		1,700	
		Non-interrened and Rainfed area	(N,R)		7,060	
					23,200	

Notes: 1) *: include inundation area of 300ha 2) B: weir, K: River, Wd.: Reservoir
3) **: include Dengkeng Region (T... 110 ha, 1/2T... 220 ha, N,R ... 2,200 ha)

Fig. I.1.1 Location Map of The Project Area



1.2 ASSESSMENT OF EXISTING WATER USE AND RESOURCES

The existing water use and resources inside the Project-area have been assessed for the irrigation planning through the undermentioned four (4) investigations and surveys:

a) Investigation of the existing water distribution by the conventional method;

b) Assessment of the existing water use based on the data obtained from the Seksi offices;

c) Water balance survey in the Project-area, and

e) Water balance study in the Madiun Project.

1.2.1 Existing Water Distribution

Distribution of irrigation water has long been managed in the Sala River Basin, as it has generally been done in Java Island, on the basis of Pasten Method, a local estimation method of irrigation water requirement, which seems rather reasonable under the present irrigation conditions. Pasten is an average unit irrigation water requirement for different crops in comparison with that for polowijo during its growing stage. According to this method, the irrigation water requirement for each crop can be calculated as shown in the following equation:

Irrigation water requirement:

$$\frac{R \times \text{Pasten} \times \text{Terrain Coefficients}}{1 - \text{water losses}} (\text{litre/sec/ha})$$

R: the ratio of water-use for crops in comparison with the water-use for polowijo during its growing stage;

Terrain Coefficients: the values relating to topographical and hydro-geological conditions ruling in the area, taking into account the elevation of groundwater surface, the porosity of the soil, and the gradient of the land concerned.

Table 1.2.1 gives three kinds of ratio applicable in the Project-area.

Table 1.2.1 Pasten and Ratio of Irrigation Water-Use for Crops compared with Polowijo and Terrain Coefficients.

Seedling & Preparation Stage	R	Pasten (l/sec/ha)	Water Requirement (l/sec/ha)	Terrain Co-efficient
Paddy - seedling	2.0	0.15	0.30	C = 1
- preparation	5.0		0.75	
Sugarcane				
-seedling	4.0		0.60	
- preparation	4.0		0.60	
Polowijo	2.0		0.30	
Growing Stage				
Rainy season paddy rice	3.0		0.45	
Dry season paddy rice	3.0		0.45	
Sugarcane	2.0		0.30	
Polowijo	1.0		0.15	

(Data source: Wilayah Surakarta Office)

The basic Pasten for polowijo is determined by the availability of irrigation water, as follows:

More than 0.25	lit/sec/ha	= Fairly good
0.25 - 0.20	"	= Good
0.19 - 0.07	"	= Sufficient
0.07 - 0.04	"	= Insufficient
Less than 0.04	"	= Quite insufficient

1.2.2 Existing Water Use

Data on the intake water from each water source for the past 10 years were made available for our study by D.P.U. office (see Data-2.1/ "Daftar Adanya Lapuran Pasten Air"). From these data, the total amount of intake water to the technical area under the jurisdiction of each Seksi has been tabulated as per Table 1.2.2. The monthly amount of intake water (per ha) to the total irrigable area are shown on Table 1.2.3 and Fig.1.2.1. They tell us that unit intake water during dry season is 0.17 lit/sec/ha in Karanganyar Area and 0.21 lit/sec/ha in Sragen Area. This means that only 60-70 % of the entire irrigable area (technical area) could have been irrigated in "good" conditions (0.6 litre/sec/ha. is being required) during rainy season, and its percentage during dry season would drop to the level of 30-35 % only.

On-the-farm water-use for paddy rice cultivation during the growing stage in the technical area has been estimated from the same data as per Tables 1.2.4 and 1.2.5 as well as Fig.1.2.2. Its average reads at 0.3-0.4 lit/sec/ha, or 67-90 % of the water requirement obtained by the Pasten Method (0.45 litre/sec/ha).

Table 1.2.2 Existing Monthly Average Intaken Water in Technical Area

Unit: l/sec

Seksi Karanganyar Area (Irrigable area 14,552 ha)

Year	J	F	M	A	M	J	J	A	S	O	N	D
1966	*	/1 4,230	/1 4,215	/1 4,233	/1 3,620	/1 2,689	/1 1,935	/1 873	/1 360	/1 1,704	/1 4,123	/1 3,947
1967	*	/1 3,878	/1 3,594	/1 4,695	/1 3,636	/1 1,496	/2 851	/1 611	/1 329	/1 226	1,891	/3 4,458
1968	4,500	4,510	5,449	/4 3,878	/5 2,306	/4 3,334	/4 3,650	/5 1,590	/4 1,772	2,393	4,488	4,301
1969	4,265	5,360	/6 2,701	5,217	3,436	2,917	1,966	797	/7 1,263	/7 561	/4 2,071	/4 4,725
1970	/4 4,774	/4 4,912	/4 4,772	/4 4,028	4,312	4,300	2,597	837	967	1,358	4,353	5,183
1971	5,684	5,899	4,887	4,508	4,758	4,428	3,460	1,221	809	2,693	3,729	4,911
1972	6,004	4,996	5,272	4,797	4,178	2,371	1,132	699	264	280	1,473	4,783
1973	5,106	6,190	5,863	5,857	/6 2,234	5,593	4,102	1,426	1,201	1,677	/8 3,194	6,032
1974	/9 4,109	5,687	/9 4,746	6,388	/6 1,691	3,950	2,647	1,735	2,369	/11 2,942	6,191	5,390
1975	/10 4,516	/10 4,394	/10 3,723	/4 5,775	4,806	4,871	2,433	942	1,747	/11 1,622	/12 2,422	/13 1,713

Note: /1: 12,580 ha /2: 12,080 ha /3: 13,421 ha /4: 13,654 ha
/5: 9,333 ha /6: 5,286 ha /7: 14,102 ha /8: 12,369 ha
/9: 12,415 ha /10: 9,445 ha /11: 7,308 ha /12: 5,125 ha
/13: 6,677 ha

Seksi Sragen Area (Irrigable area 15,592 ha)

Year	J	F	M	A	M	J	J	A	S	O	N	D
1966	*	7,116	6,839	4,119	6,046	4,278	2,030	1,074	686	2,034	3,548	4,956
1967	*	4,768	5,088	4,389	3,036	1,524	1,020	588	443	655	2,186	5,015
1968	5,490	5,284	5,526	4,503	3,721	5,233	4,840	2,651	1,981	4,500	6,574	7,444
1969	7,730	7,424	7,666	6,994	4,810	4,741	2,442	1,418	946	1,602	3,571	5,706
1970	6,758	7,219	6,199	6,906	6,000	4,550	3,277	1,711	2,191	1,631	3,791	5,984
1971	7,505	6,787	6,521	5,602	6,104	4,140	2,070	2,223	1,580	3,734	6,339	5,963
1972	5,662	7,801	7,197	7,705	6,184	3,066	1,754	1,349	1,321	1,448	3,548	4,396
1973	6,973	8,172	6,386	6,790	5,076	5,163	3,945	2,829	3,591	3,717	8,261	9,714
1974	8,338	*	8,233	7,325	7,034	4,191	2,856	3,690	5,563	5,720	8,050	8,380
1975	9,610	8,325	8,378	8,342	8,293	5,300	3,314	2,318	3,354	*	8,238	6,431

Note: (1) Compiled from Table to
Data Source: D.P.U. office in each Seksi

Table 1.2.3 Existing Monthly Average Intaken Water per Hectare in Technical Area

Unit: l/sec/ha

Seksi Karanganyar Area

Year	J	F	M	A	M	J	J	A	S	O	N	D	Average
1966	*	0.34	0.34	0.34	0.29	0.21	0.15	0.07	0.03	0.14	0.33	0.31	0.23
1967	*	0.31	0.29	0.37	0.29	0.12	0.07	0.05	0.03	0.02	0.13	0.33	0.18
1968	0.31	0.31	0.37	0.28	0.25	0.24	0.27	0.17	0.13	0.16	0.31	0.30	0.26
1969	0.29	0.37	0.51	0.36	0.24	0.20	0.14	0.05	0.09	0.04	0.15	0.35	0.23
1970	0.35	0.36	0.35	0.30	0.30	0.30	0.18	0.06	0.07	0.09	0.30	0.36	0.25
1971	0.39	0.41	0.34	0.31	0.33	0.30	0.24	0.08	0.06	0.19	0.26	0.34	0.26
1972	0.41	0.34	0.36	0.33	0.29	0.16	0.08	0.05	0.02	0.02	0.10	0.33	0.21
1973	0.35	0.43	0.40	0.40	0.42	0.38	0.28	0.10	0.08	0.12	0.26	0.41	0.30
1974	0.33	0.39	0.38	0.44	0.32	0.27	0.18	0.12	0.16	0.40	0.43	0.37	0.32
1975	0.48	0.47	0.39	0.42	0.33	0.33	0.17	0.06	0.12	0.22	0.47	0.26	0.31
Average	0.36	0.37	0.37	0.36	0.31	0.25	0.18	0.08	0.08	0.14	0.27	0.34	

Dry season (M - O) 0.17
Rainy season (N - A) 0.35

Seksi Sragen Area

Year	J	F	M	A	M	J	J	A	S	O	N	D	Average
1966	*	0.46	0.44	0.26	0.39	0.27	0.13	0.07	0.04	0.13	0.23	0.32	0.25
1967	*	0.31	0.33	0.28	0.19	0.10	0.07	0.04	0.03	0.04	0.14	0.32	0.17
1968	0.35	0.34	0.35	0.29	0.24	0.34	0.31	0.17	0.13	0.29	0.42	0.48	0.31
1969	0.50	0.48	0.49	0.45	0.31	0.30	0.16	0.09	0.06	0.10	0.23	0.37	0.30
1970	0.43	0.46	0.40	0.44	0.38	0.29	0.21	0.11	0.14	0.10	0.24	0.38	0.30
1971	0.48	0.44	0.42	0.36	0.39	0.27	0.13	0.14	0.10	0.24	0.41	0.38	0.31
1972	0.36	0.50	0.46	0.49	0.40	0.20	0.11	0.09	0.08	0.09	0.23	0.28	0.27
1973	0.45	0.52	0.41	0.44	0.33	0.33	0.25	0.18	0.23	0.24	0.53	0.62	0.38
1974	0.53	*	0.53	0.47	0.45	0.27	0.18	0.24	0.36	0.37	0.52	0.54	0.41
1975	0.62	0.53	0.54	0.54	0.53	0.34	0.21	0.14	0.22	*	0.53	0.41	0.42
Average	0.47	0.45	0.44	0.40	0.36	0.27	0.18	0.13	0.14	0.18	0.35	0.41	

Dry season (M - O) 0.21
Rainy season (N - A) 0.42

Note: Above figures are calculated by dividing the average discharge of the intaken water, which is given in Table 1.2.2, by the irrigable areas of each resource.

Fig. I.2.1 Existing Monthly Average Intaken Water per Hectare in Technical Area

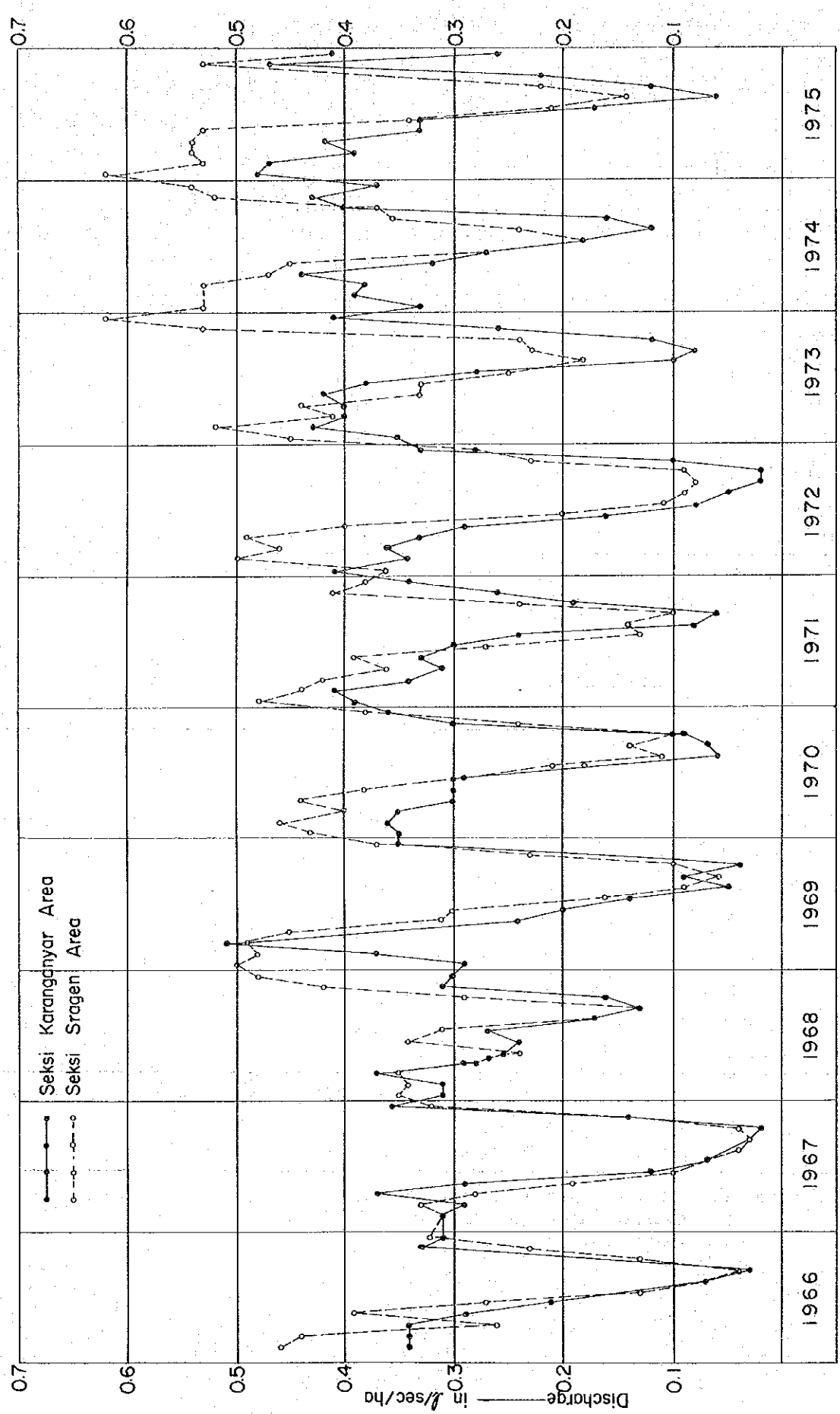


Table 1.2.4 Existing Monthly Irrigation Water Use for Growing Paddy
(in Technical Area)

Unit : l/sec/ha

Sukoharjo (Seksi Karanganyar)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1965	0.21	0.18	0.15	-	0.15	0.15	0.30	0.12	0.06	0.15	0.18	0.15	0.16
1966	-	0.30	0.09	0.21	0.15	0.21	0.30	-	-	-	0.27	0.21	0.22
1967	-	0.21	0.18	0.60	0.27	0.18	-	0.21	-	-	0.39	0.30	0.29
1968	0.18	0.18	0.30	0.18	0.60	0.45	0.48	-	-	-	0.27	0.21	0.32
1969	0.09	0.09	-	0.33	0.21	0.18	0.24	0.21	-	0.15	0.18	0.39	0.20
1970	0.18	0.12	0.09	0.27	0.54	0.27	0.33	0.15	-	-	0.18	0.30	0.24
1971	0.39	0.30	0.21	0.33	0.36	0.42	0.42	0.69	0.60	0.18	0.15	0.24	0.35
1972	0.36	0.27	0.15	0.24	0.18	0.21	0.27	0.24	0.12	-	0.45	0.21	0.25
1973	0.30	0.27	0.36	0.42	-	0.39	0.36	0.30	0.30	0.36	0.36	0.30	0.34
1974	0.36	0.36	0.36	0.36	-	0.30	0.30	0.30	0.36	0.60	0.60	0.60	0.45
1975	0.60	0.60	0.60	0.45	0.45	0.42	0.36	0.36	0.45	0.45	-	0.60	0.49
Mean	0.30	0.26	0.25	0.34	0.32	0.29	0.34	0.28	0.32	0.32	0.30	0.35	0.30

Note: 1) Above figures are based on the data named "Daftar Adanya Lapuran Pasten Air" from the D.P.U. Wilayah Surakarta office.

2) Ratio of Irrigation Water Use for "Growing stage paddy" compared with polowijo (Pasten) is 3.0.

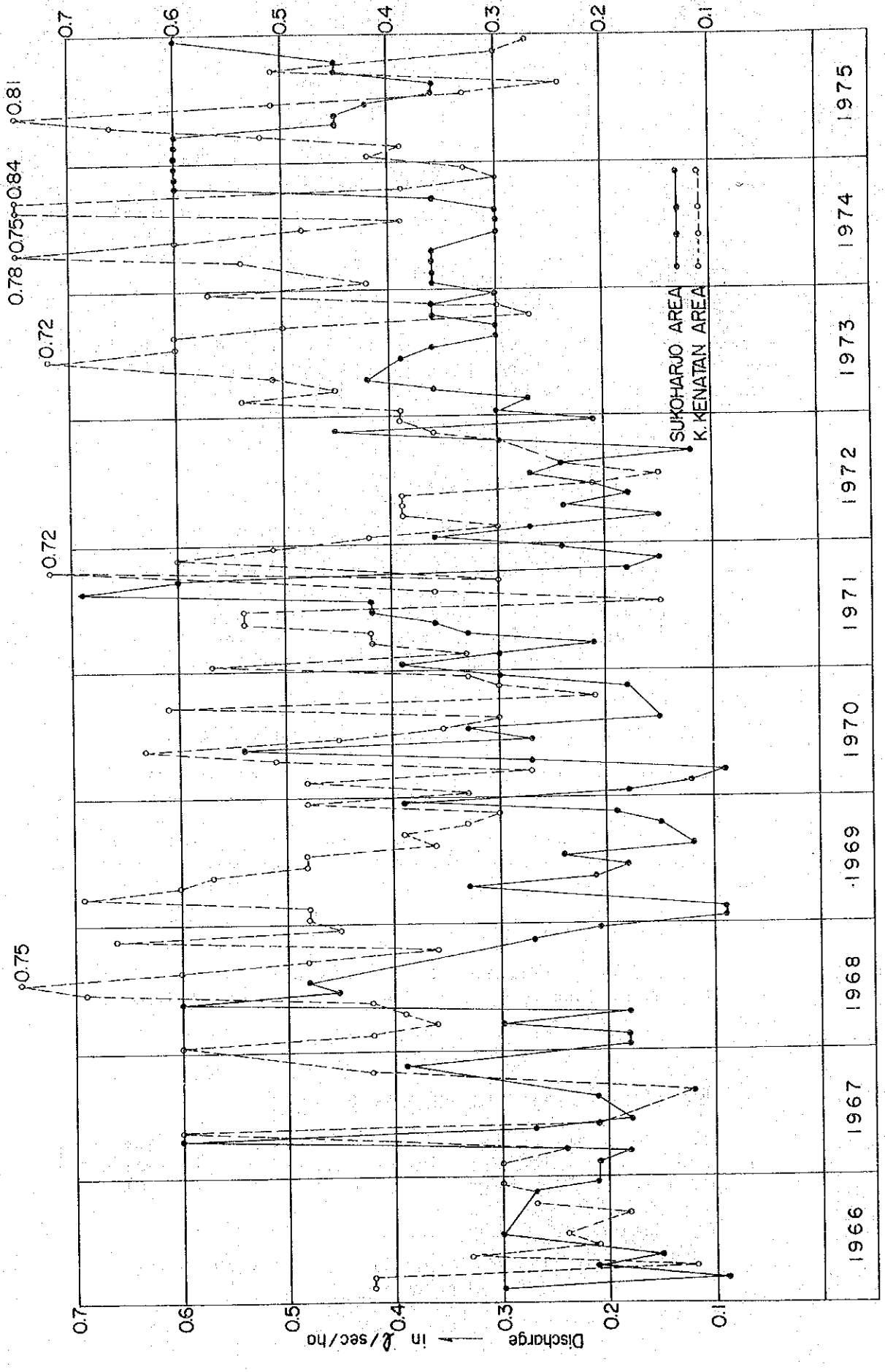
3) Ratio for Sugar Cane is 2.0.

Table 1.2.5 K. Kenatan (Seksi Sragen)

Unit : l/sec/ha.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1965	0.45	0.30	0.30	0.30	0.24	0.12	0.12	0.09	0.21	0.18	0.22	-	0.23
1966	-	0.42	0.42	0.12	0.33	0.21	0.24	0.21	0.18	0.27	0.27	0.30	0.27
1967	-	0.30	0.24	0.60	0.21	0.18	0.15	0.15	0.12	0.06	0.42	0.54	0.27
1968	0.60	0.42	0.36	0.39	0.42	0.69	0.75	0.60	0.48	0.36	0.66	0.45	0.52
1969	0.48	0.48	0.69	0.60	0.57	0.48	0.48	0.36	0.39	0.33	0.30	0.48	0.47
1970	0.33	0.48	0.27	0.51	0.63	0.45	0.36	0.30	0.61	0.21	0.30	0.33	0.40
1971	0.57	0.33	0.42	0.42	0.54	0.54	0.15	0.36	0.30	0.72	0.60	0.51	0.46
1972	0.42	0.30	0.39	0.39	0.39	0.21	0.15	0.24	0.18	0.30	0.36	0.39	0.31
1973	0.39	0.54	0.45	0.51	0.60	0.72	0.60	0.60	0.50	0.27	0.30	0.57	0.59
1974	0.42	-	0.54	0.78	0.60	0.48	0.39	0.75	0.84	0.39	0.30	0.33	0.53
1975	0.42	0.39	0.54	0.66	0.81	0.51	0.33	0.24	0.51	-	0.30	0.27	0.45
Mean	0.45	0.40	0.42	0.48	0.49	0.42	0.39	0.34	0.48	0.31	0.37	0.42	0.41

Fig. I.2.2 Existing Monthly Irrigation Water Use at Field Level for Growing Paddy
(in technical area)



1.2.3. Water Balance Survey

1.2.3.1 Field survey

An area with an extent of 3,400 ha, which is surrounded by the Bengawan Sala, Kali Jlantah and Sala-Wonogiri Highway, was selected for the measurement related with water balance. The location map of the selected area is shown in Fig. 1.2.3. All the inflows from the irrigation canals and the pumping units in operation were measured, side by side, with all the out-flows into riverlets and drainage channels on the boundary of the selected area, for six days by using currentmeters and other devices. Fortunately, no rainfall occurred in the area during this water measurement survey and the data as shown on Table 1.2.6 have been obtained. The unit requirement estimated on the measurement data has been assessed at 0.37 to 0.63 litre/sec/ha, similar to that based on Pasten Method.

1.2.3.2 Reference from the Madiun water balance study

Drought flow in dry season in the Upper Sala Basin has been estimated from the results of water balance study undertaken in connection with the Groundwater Development Project in Madiun and Upper Sala Watersheds. This study had been carried out in the area which is extending from Sragen to Madiun where much similarity is supposed to exist between the Upper Sala area including the Project-area, so far as the geological formation, vegetation and groundwater movements are concerned.

a) Flow measurement in Sub-Area I of Madiun Project

This measurement was carried out along all the river canals crossing the road running from Ngrambo to Mageran, on the day which was supposed to be the driest time of a year. This road is running parallel to the counter-line +300 m which is supposed to be the upper-limit line for paddy cultivation. The measurement data and the related figures are given as Data-5.1 and Data-5.2.

b) Estimation of watershed

The watershed extending from the road to the summit of the Gunung Lawu has been measured by use of a planimeter on 1/50,000 scale map. The result was:

$$A = 160.75 \text{ km}^2$$

c) Specific discharge in Sub-Area I

From the water balance study data in Sub-Area I, the specific discharge of run-off from the watershed above the upper-limit line for paddy cultivation (counter-line + 300 m) has been estimated:

$$\text{Total amount of Run-off: } Q = 4.954 \text{ m}^3/\text{sec}$$

$$q = 4.954/160.75 = 0.031 \text{ m}^3/\text{sec/km}^2 \doteq 30 \text{ litre/sec/km}^2$$

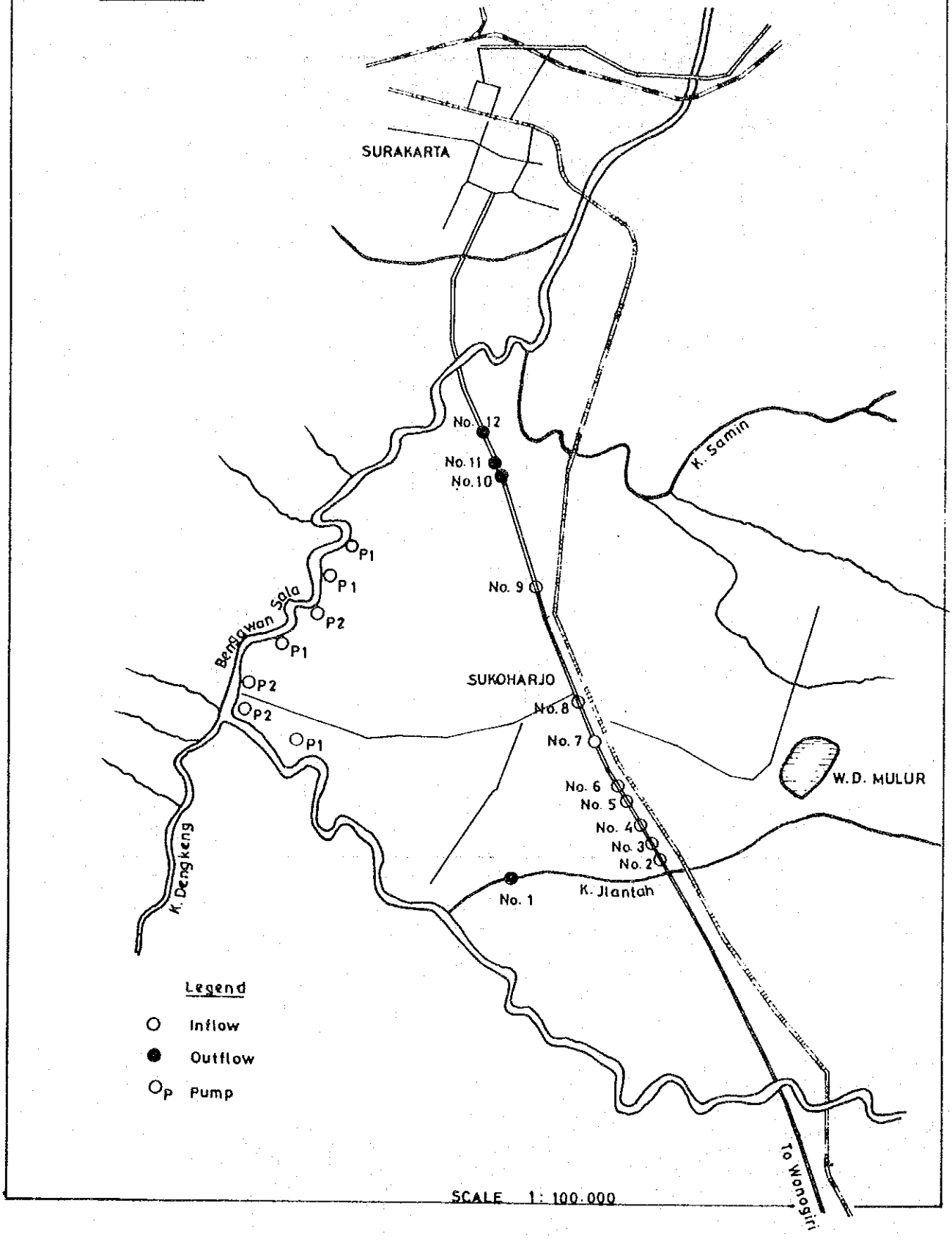
Table 1.2.6 Measurement of the Existing Water Balance

Unit : m^3/sec

	22 Apr	23 Apr	24 Apr	26 Apr	27 Apr	30 Apr
No. 1*	-0.019	-0.012	-0.013	-0.012	-0.004	0
No. 2	0.007	0	0	0	0	0
No. 3	0.573	0.326	0.486	0.095	0.094	0.345
No. 4*	- 0	- 0	- 0	- 0	-0.001	- 0
No. 5	0.029	0.014	0	0	0.001	0
No. 6	0.382	0.412	0.331	0.357	0.266	0.483
No. 7	0.158	0.047	0.075	0.165	0.064	0
No. 8	0.251	0.198	0.203	0.294	0.241	0.117
No. 9	0.294	0.287	0.247	0.180	0.160	0.210
No. 10*	-0.019	-0.012	- 0	- 0	- 0	- 0
No. 11*	- 0	- 0	-0.007	-0.117	-0.040	- 0
No. 12*	-0.296	-0.173	-0.181	-0.065	-0.080	- 0
Pump	0.646	0.646	0.646	0.483	0.474	0.458
Total	2.006	1.733	1.787	1.380	1.174	1.613
Unit Water Use	0.63 ℓ/s/ha	0.54 ℓ/s/ha	0.56 ℓ/s/ha	0.43 ℓ/s/ha	0.37 ℓ/sec/ha	0.51 ℓ/sec/ha

Note: Location ..... Sukoharjo
Instrument ..... Current meter
Area ..... 3,400 Ha
Water Source .... Wd. Mulur
Irrigation Area.. 3,180 Ha (Cropping ratio 93%)
* ; outflow

Fig.I.2.3 Location Map of Water Balance Measurement



d) Drought discharge in the Upper Sala Area

The watershed above the upper-limit line for paddy cultivation towards the summit of the Gunung Lawu has been measured from 1/50,000 scale map:

$$A = 307 \text{ km}^2$$

Drought discharge from the seven tributaries in the watershed above the upper-limit line for paddy cultivation has been estimated as follows:

$$Q = 0.03 \times 307 = 9.2 \text{ m}^3/\text{sec}$$

e) Conclusions

The paddy field spreading between the Main Canal and the upper-limit line for paddy cultivation is about 37,000 ha. On the assumption that 70 % of the drought discharge calculated in the above will consist of the available water resources for irrigation, the unit available water resources in this area during dry season is estimated at:

$$9.2 \times 1{,}000 \times 0.7/37{,}000 = 0.17 \text{ litre/sec/ha}$$

2. PLANS AND STUDIES

2.1 IDENTIFICATION OF IRRIGABLE AREA AND CANAL ALIGNMENT

Upon identifying the irrigable area which was to be stemmed within such boundaries as rivers, roads, and natural ridges and justifiable in its extent by the results of water balance studies between the available water resources and the diversion requirements for irrigation, the two main canals have been aligned by taking into consideration the patterns of land-use and topography there.

'Tegal' or Upland of 300 ha, which is scattering in small patches over the entire project area has been excluded from irrigation area, since it is not technically feasible to irrigate these elevated lands systematically without introduction of pumping irrigation system.

Therefore, only 'Sawah' or paddyfield having the total extent of 23,200 ha will be made irrigable, out of the gross project area of 24,600 ha; the irrigable area is commanded by two main canals, namely, the Upper Sala Main Canal and the Dengkeng Main Canal. (See Tables 2.1.1 and 2.1.2).

Table 2.1.1 Summary of Land Use (Sawah & Tegal)

(Unit: Ha)

Region	Paddy			Upland			Total		
	Gross Area	Public Use	Net Area	Gross Area	Public Use	Net Area	Gross Area	Public Use	Net Area
Karanganyar & Sragen Region	20,420	820	19,600	242	10	232	20,662	830	19,832
Dengkeng Region	3,850	250	3,600	73	5	68	3,923	255	3,668
Total	24,270	1,070	23,200	315	15	300	24,585	1,085	23,500

Note: Public Uses such as farm roads, farm ditches, etc., are estimated at about 4% of the gross area.

Table 2.1.2 Land Use Pattern

Unit: ha

No. of Map	Land Use		Total	No. of Map	Land Use		Total
	Paddy	Upland			Paddy	Upland	
1.	-	-	-	33.	128	-	128
2.	-	-	-	34.	633	-	633
3.	-	-	-	35.	25	-	25
4.	-	-	-	36.	-	-	-
5.	34	-	34	37.	-	-	-
5A.	22	-	22	38.	130	-	130
6.	22	3	25	39.	702	-	702
7.	60	-	60	40.	26	-	26
8.	106	2	108	41.	-	-	-
9.	483	2	485	42.	264	-	264
9A.	398	9	407	43.	582	-	582
10.	98	-	98	44.	-	-	-
11.	119	11	130	45.	-	-	-
12.	791	-	791	46.	-	-	-
13.	677	19	696	47.	417	-	417
14.	564	14	578	48.	77	-	77
14A.	260	-	260	49.	-	-	-
15.	-	-	-	50.	-	-	-
16.	474	-	474	51.	-	-	-
17.	582	4	586	52.	250	-	250
18.	589	6	595	53.	-	-	-
19.	466	-	466	54.	-	-	-
20.	121	1	122	55.	271	-	271
21.	129	-	129	56.	290	-	290
22.	664	-	664	57.	-	-	-
23.	600	8	608	58.	423	-	423
24.	40	-	40	59.	128	-	128
25.	-	-	-	60.	119	-	119
26.	-	-	-	61.	597	-	597
27.	7	-	7	62.	-	-	-
28.	723	1	724	63.	-	-	-
29.	508	-	508	64.	-	-	-
30.	239	-	239	*65.	510	-	510
31.	-	-	-	66.	505	10	515
32.	-	-	-	67.	26	-	26

Unit: ha

No. of Map	Land Use		Total	No. of Map	Land Use		Total
	Paddy	Upland			Paddy	Upland	
68.	-	-	-				
69.	2	-	2				
*70.	759	-	759				
71.	742	3	745				
72.	103	4	107				
73.	-	-	-				
74.	220	-	220				
*75.	763	-	763				
76.	531	2	533				
77.	-	-	-				
78.	144	-	144				
79.	339	-	339				
80.	596	7	603				
81.	494	-	494				
82.	-	-	-				
83.	441	-	441				
84.	677	6	683				
85.	418	35	453				
86.	500	46	546				
87.	14	-	14				
88.	426	-	426				
89.	634	46	680				
90.	501	-	501				
91.	390	73	463				
92.	146	-	146				
93.	-	-	-				
94.	180	-	180				
95.	35	-	35				
96.	254	-	254				
97.	40	-	40				
98.	29	3	32				
99.	-	-	-				
100.	-	-	-				
101.	-	-	-				
102.	-	-	-				
Total	24.270	315	24.585				

2.2 ESTIMATION OF IRRIGATION WATER REQUIREMENTS

2.2.1 General

a) Definition

Several terms used in this section are defined and denoted as follow;

Evapotranspiration (ET) = Evaporation (EV) + Transpiration (Consumptive use)

Water requirement (WR) = (ET) + Percolation

Irrigation requirement (IR) = (WR) + Farm waste - Effective rainfall

Diversion requirement (DR) = (IR) + Conveyance loss

Puddling requirement (PR) = Water to be required for field preparation

Note: Farm waste is the quantity of water losses on farm due to seepage, leakage through, over application of water and spillage.

b) Basic year for irrigation planning

According to the supporting report of Master-plan of Sala River Basin Development, the year 1967/1968 was chosen as the basic year, on the ground that the rainfall (1,623 mm, from May 1967 to April 1968) is equivalent to seven year probability rainfall. This seems to be the reasonable approach to identify the design rainfall.

While, in the Wonogiri Dam Feasibility Report Annex II, the yearly deficit of irrigation water or the yearly required storage capacity for Wonogiri reservoir was estimated on the basis of the water balance study between the diversion requirement and the inflow of the reservoir at the Wonogiri Dam Site for a period of 20 years. Based on these data, the excess probability analysis on the required storage was examined by Iwai Method.

Consequently, the year with 7 return period from the yearly required storage capacity point-of-view coincides with 1967/1968 which was chosen as the basic year in the Master Plan of Sala River Basin Development, as the result of the rainfall probability analysis. The year 1967/1968 was, thus, selected as the basic year for irrigation planning under the Project.

c) Water resources for the Project

The total irrigation water requirement in the project area is dependably supplied by Wonogiri reservoir, which is the stable water resources facility with an active storage capacity of 440 million m^3, as has been justified by the Feasibility Study 1975. Wonogiri reservoir is now in the stage of detailed design.

The feasibility report specified that the reservoir's total storage capacity consists the following three: the storage for net diversion requirement amounting to 400 million m^3, the pondage losses in Colo reservoir estimated at 10 million m^3, and the storage for release to downstream in the volume of 30 million m^3. The irrigation plan, therefore, has to be proposed on the basis of 400 million m^3.

d) Regional cultivation pattern

Paddy-rice and sugarcane are the two main crops prevailing in the entire project area. The cultivation ratio seems to vary from region to region, judging from the data available on the existing land use.

Accordingly, the entire project area has been divided into three regions for the convenience of irrigation planning:

Dengkeng region

This region extending over the down reach of Kali Dengkeng is managed under Seksi Karanganyar and is commanded by Dengkeng main canal.

Proposed irrigable area ---------- 3,600 ha
Proposed hectareage of sugarcane cultivation -- non cultivation

Karanganyar region

This region sprawling over Sukohardjo is managed under Seksi Karanganyar and is commanded by the upper reach of the Upper Sala Main Canal.

Proposed irrigable area ---------- 10,100 ha
Proposed hectarage of sugarcane cultivation -- 600 ha

Sragen region

This region spreading in and around Sragen, is managed under Seksi Sragen and is commanded by the lower reach of the Upper Sala Main Canal.

Proposed irrigable area ---------- 9,500 ha
Proposed hectareage of sugarcane cultivation -- 1,500 ha

e) Alternative cropping patterns

Three alternative cropping patterns have been studied for irrigation planning by taking into account the current cultivation practices and agro-economic factors in the area, namely:

Alternative - 1: Less intensive cultivation, paddy-paddy per year.
Alternative - 2: Medium intensive cultivation, paddy-paddy-polowijo per year.
Alternative - 3: More intensive cultivation, five (5) paddys per two (2) years or paddy-paddy-half paddy per year.

Each Alternative is illustrated in Fig. 2.2.1 to Fig. 2.2.3. The details of the above-mentioned cropping patterns are given in the relevant sections.

f) Calculation procedure

A series of water requirements for irrigation planning was calculated according to the chart of calculation procedure as shown in Fig. 2.2.4.

First of all, the irrigation area was tentatively assumed, consideration of topographical condition and the main canal alignment being undertaken simultaneously. Then, a series of calculation of water consumption in the field was carried out to get diversion requirement, which was balanced with the storage capacity of Wonogiri reservoir of 400 million m^3.

In case they are not balanced, the calculation must be repeated until the water consumption of the assumed irrigation area keeps balance with the storage capacity of the Wonogiri reservoir of 400 million m^3.

g) Summary of estimation

Several kinds of water requirements and water balance estimated for each alternative cropping pattern are summarized in Table 2.2.61 to Table 2.2.63.

The principal figures such as the maximum diversion discharge, total amount of diversion capacity and storage capacity required for the Wonogiri reservoir vary from alternative to alternative as shown in the following Table.

Fig 2.2.1 Future Cropping Pattern (Alternative I)

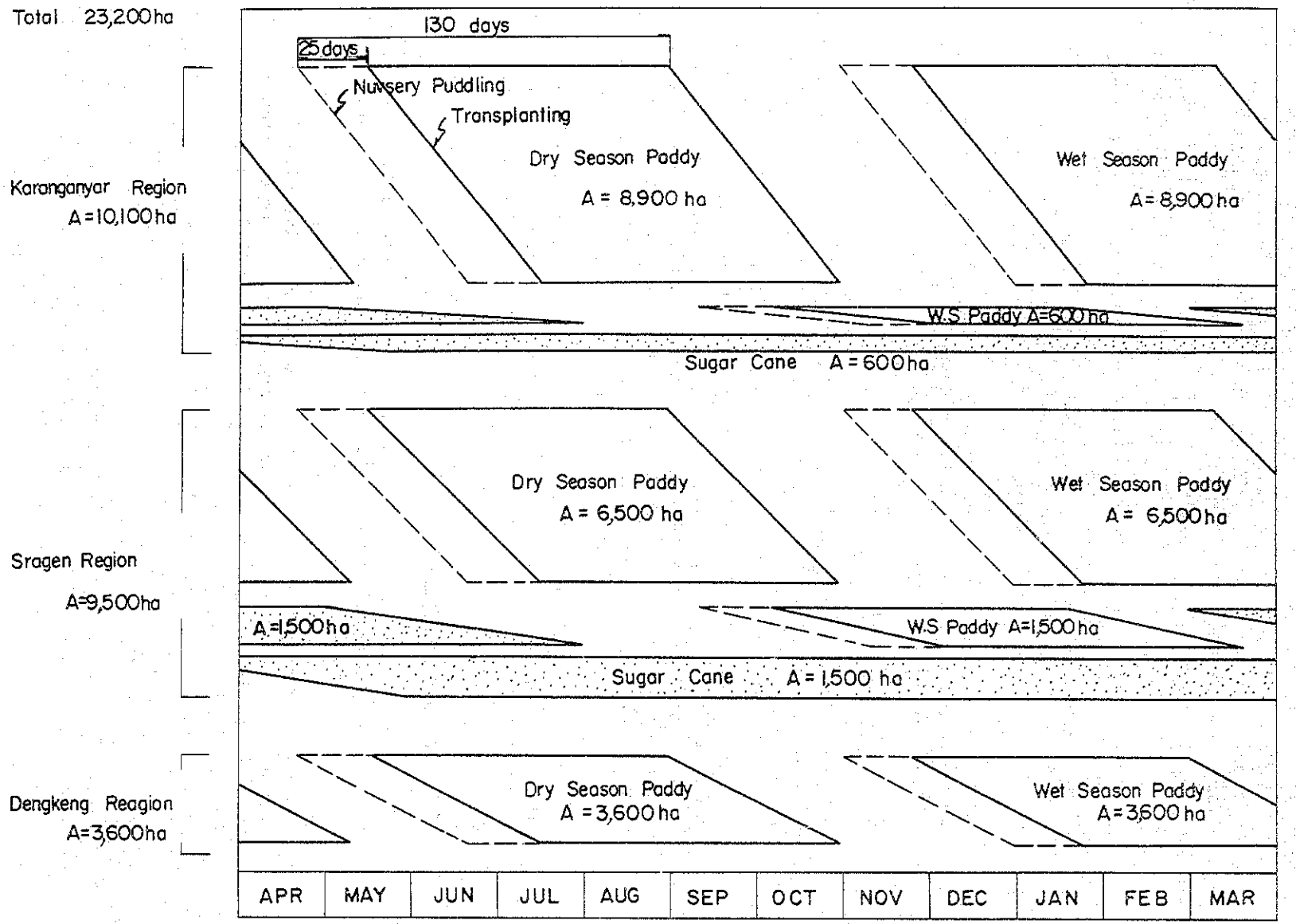


Fig. 2.2.2

Future Cropping Pattern (Alternatire 2)

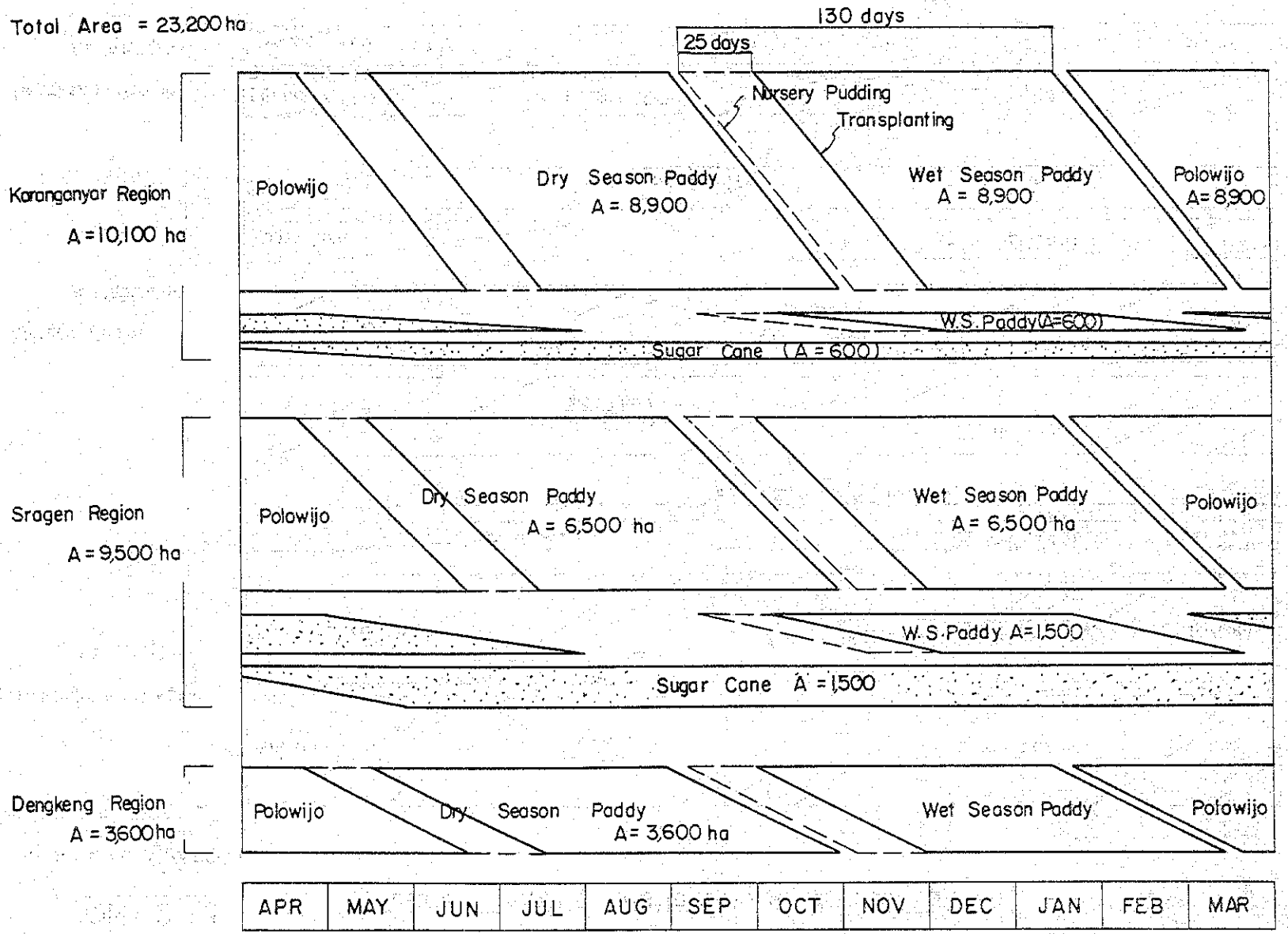


Table 2.2.3

Future Cropping Pattern (Alternative 3)

Total Area = 23,200 ha

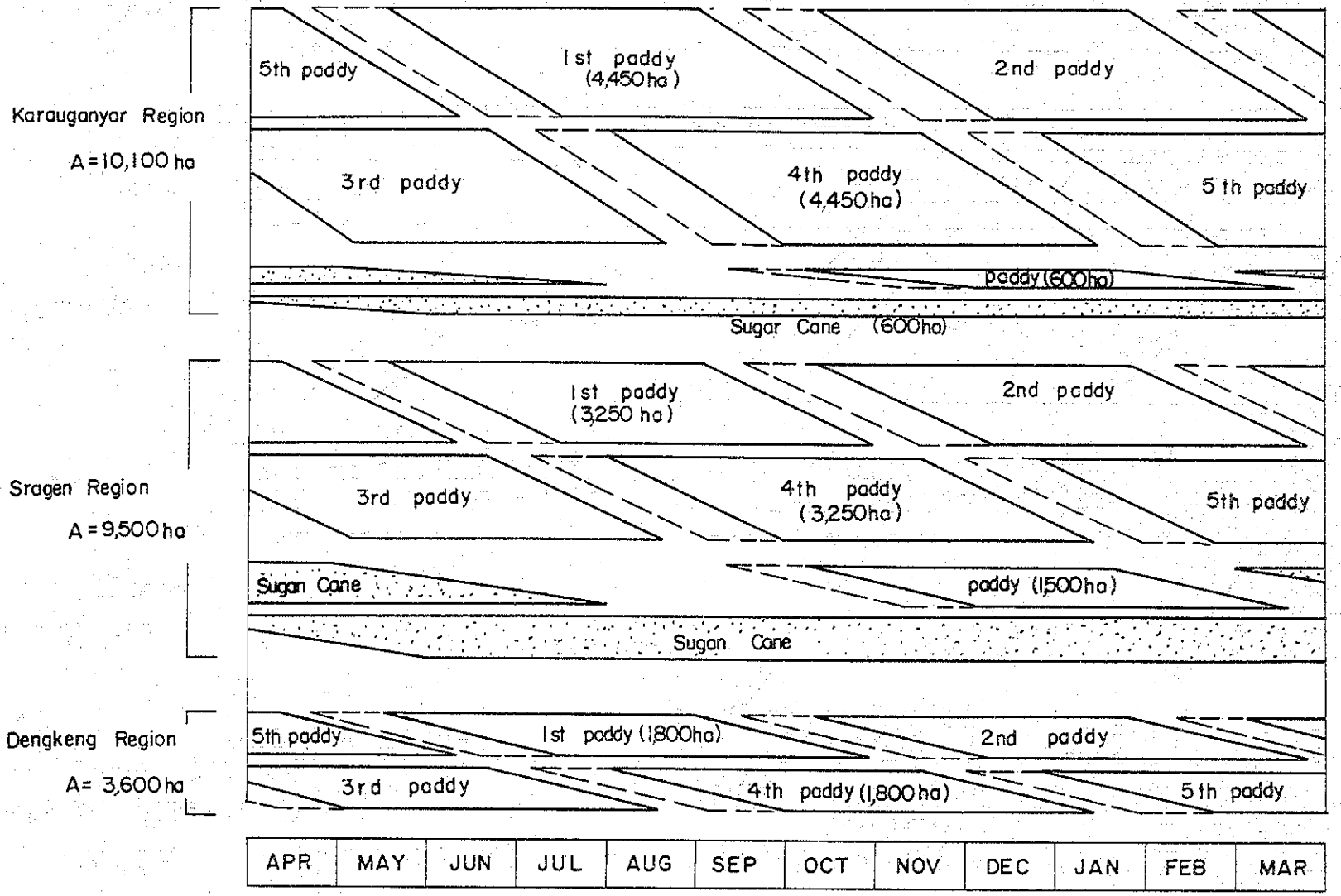


Fig.2.2.4 Calculation Flow Chart

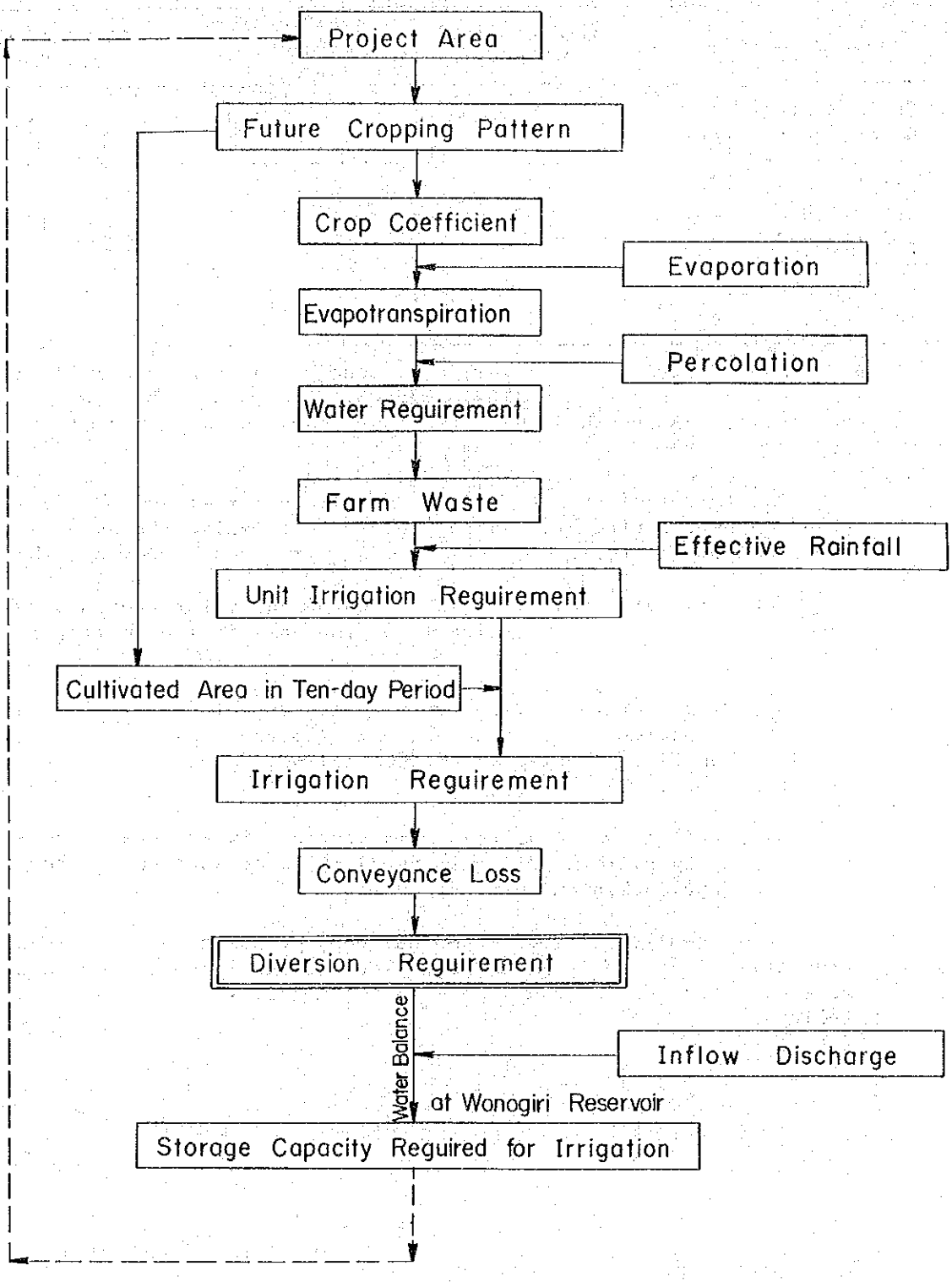


Table 2.2.1 Maximum Diversion Requirement and Storage Capacity Required by Each Alternative

Cropping Pattern	Alternative-1 2-Paddy	Alternative-2 2-Paddy & Polowijo	Alternative-3 2.5-Paddy
Maximum Diversion Discharge (m^3/sec)	34.0	33.3	29.4
Total Amount of Diversion Capacity (Million m^3)	389	452	483
Storage Capacity Required (Million m^3)	323	415	397

As for the maximum diversion discharge, Alternative-1 and Alternative-2 are larger than Alternative-3, even though the former two are less intensive than the latter, as shown in Table 2.2.64 and Fig. 2.2.15.

The larger discharge figures for Alternative-1 and -2 are supposed to be affected by puddling requirement, while the water consumption for Alternative-3 seems to be quite even throughout the year.

However, total amount of diversion capacity for each Alternative seems to increase in proportion to an increase of the cultivation intensity.

Speaking from the irrigation planning aspect, Alternative-3 is the optimal pattern and, moreover, only Alternative-3 can be accommodated to the storage capacity of 400 million m^3, guaranteed by Wonogiri reservoir.

As detailed in the agro-economy section, two-and-half crops a year paddy cropping pattern (Alternative-3) is being adopted on about 20,000 ha in Kabupaten Klaten even at present.

Consequently, Alternative-3 has been proposed as a future cropping pattern in the project area. The design discharge for each region, based on the requirement of Alternative-3, has been decided as follows:

Table 2.2.2 Diversion Discharge for Each Region

Region	Command area (ha)	Design Discharge (m^3/sec)	Unit Design Discharge (l/sec/ha)
Entire Irrigation area	23,200	29.5	1.27
Upper Sala Region			
Karanganyar	10,100	12.9	1.28
Sragen	9,500	11.4	1.20
Dengkeng Region	3,600	5.2	1.44

2.2.2 Cropping Area Needs for Irrigation Water

Based on the three alternative cropping calendars adopted for this study, the cropping area by every ten-day period needs for irrigation water by crop are calculated as shown in Table 2.2.3 for an area of 1,000 ha of each crop.

The unit irrigation area and the total irrigation area by crops are calculated as shown in Tables 2.2.4 to 2.2.9.

The nursery area in the paddy field is presumed to be 5 % of the total cropping area of paddy.

Table 2.2.3 Irrigation Area by Cropping Patterns in Case of Cultivation Area of 1,000 ha

Unit: ha

Ten-Day Period	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Case 1			Nursery Puddling			Transplanting														
			50x25/60																	
Nursery Puddling	/1 0.83	0.83	0.83	0.83	0.83	0.83	130 days													
Puddling			/2 8.3	/3 16.7	16.7	16.7	16.7	16.7	8.3											
Growing (Nursery bed)	/4 3.34	/5 11.7	/6 19.0	/7 20.0	20.0	20.0	/8 16.7	/9 8.33	/10 1.04											
(Field)			/11 12.5	/12 150.0	/13 316.6	/14 483.3	/15 650.0	/16 816.6	/17 970.9	1,000	1,000	1,000	1,000	/18 916.7	/19 750.0	/20 583.3	/21 416.7	/22 250.0	/23 83.3	
(Total)	3	12	32	170	337	503	667	825	972	1,000	1,000	1,000	1,000	917	750	583	417	250	83	
Case 2			25 days																	
			60 days											60 days						
Nursery Puddling	/24 0.42	/1 0.83	0.83	0.83	0.83	0.83	0.42													
Puddling				/3 16.7	16.7	16.7	16.7	16.7	16.7											
Growing (Nursery bed)	/25 0.62	7.50	/26 15.8	/7 20.0	20.0	20.0	/27 19.4	/28 12.5	/29 4.2											
(Field)				/30 66.6	/31 233.3	/32 400.0	/33 566.6	/34 733.3	/35 900.0	1,000	1,000	1,000	1,000	/36 979.2	/37 833.3	/38 666.7	/39 500.0	/40 333.3	/41 166.7	/42 20.8
(Total)	1	8	16	87	253	420	586	746	904	1,000	1,000	1,000	1,000	979	833	667	500	333	167	21

Note: Nursery area is equivalent to 5 % of cultivation area. (1,000 ha x 0.05 = 50 ha)

/1 = $50 \times \frac{1}{60}$

/2 = $1{,}000 \times \frac{1}{60} \times \frac{1}{2}$

/3 = $1{,}000 \times \frac{1}{60}$

/4 = $50 \times \frac{25}{60} \times \frac{5}{25} - 0.83$

/5 = $50 \times \frac{25}{60} \times \frac{5}{25} - 0.83$

/6 = $50 \times \frac{25}{60} \times (\frac{22.5}{25} + 1) \times 0.5 - 0.83$

/7 = $50 \times \frac{25}{60} \times 1$

/8 = $50 \times \frac{25}{60} \times \frac{20}{25}$

/9 = $50 \times \frac{25}{60} \times \frac{10}{25}$

/10 = $50 \times \frac{25}{60} \times \frac{2.5}{25} \times \frac{1}{2}$

/11 = $(1{,}000 \times \frac{5}{60} \times \frac{1}{2} - 16.7) \times \frac{1}{2}$

/12 = $1{,}000 \times \frac{10}{60} - 16.7$

/13 = $1{,}000 \times \frac{20}{60} - 16.7$

/14 = $1{,}000 \times \frac{30}{60} - 16.7$

/15 = $1{,}000 \times \frac{40}{60} - 16.7$

/16 = $1{,}000 \times \frac{50}{60} - 16.7$

/17 = $1{,}000 \times (\frac{57.5}{60} + 1) \times 0.5 - 8.3$

/18 = $1{,}000 \times \frac{55}{60}$

/19 = $1{,}000 \times \frac{45}{60}$

/20 = $1{,}000 \times \frac{35}{60}$

/21 = $1{,}000 \times \frac{25}{60}$

/22 = $1{,}000 \times \frac{15}{60}$

/23 = $1{,}000 \times \frac{5}{60}$

/24 = $50 \times \frac{1}{60} \times \frac{1}{2}$

/25 = $50 \times \frac{25}{60} \times \frac{2.5}{25} \times \frac{1}{2} - 0.42$

/26 = $50 \times \frac{25}{60} \times \frac{20}{25} - 0.83$

/27 = $50 \times \frac{25}{60} \times (\frac{22.5}{25} + 1) \times 0.5 - 0.42$

/28 = $50 \times \frac{25}{60} \times \frac{15}{60}$

/29 = $50 \times \frac{25}{60} \times \frac{5}{25}$

/30 = $1{,}000 \times \frac{5}{60} - 16.7$

/31 = $1{,}000 \times \frac{15}{60} - 16.7$

/32 = $1{,}000 \times \frac{25}{60} - 16.7$

/33 = $1{,}000 \times \frac{35}{60} - 16.7$

/34 = $1{,}000 \times \frac{45}{60} - 16.7$

/35 = $1{,}000 \times \frac{55}{60} - 16.7$

/36 = $1{,}000 \times (\frac{57.5}{60} + 1) \times 0.5$

/37 = $1{,}000 \times \frac{50}{60}$

/38 = $1{,}000 \times \frac{40}{60}$

/39 = $1{,}000 \times \frac{30}{60}$

/40 = $1{,}000 \times \frac{20}{60}$

/41 = $1{,}000 \times \frac{10}{60}$

/42 = $1{,}000 \times \frac{2.5}{60} \times \frac{1}{2}$

Table 2.2.4 Unit Irrigation Area by Crops per 1,000 ha (ALT-1)

Unit: ha

Month	10Day Period	Paddy					Second cropping paddy			Sugar Cane /1		
		Nursery puddling	Puddling	Growing			Nursery puddling	Puddling	Growing	1st year	2nd year	Total
				1st	2nd	3rd						
A	1	-	-	-	583	583	-	-	-	1,000	389	1,389
	2	-	-	-	417	417	-	-	-	1,000	500	1,500
	3	0.83	-	3	250	253	-	-	-	1,000	611	1,611
M	1	0.83	-	12	83	95	-	-	-	/2 944	722	1,666
	2	0.83	8	32	-	32	-	-	-	833	833	1,666
	3	0.83	17	170	-	170	-	-	-	722	944	1,666
J	1	0.83	17	337	-	337	-	-	-	611	1,000	1,611
	2	0.83	17	503	-	503	-	-	-	500	1,000	1,500
	3	-	17	667	-	667	-	-	-	389	1,000	1,389
J	1	-	17	825	-	825	-	-	-	278	1,000	1,278
	2	-	8	972	-	972	-	-	-	167	1,000	1,167
	3	-	-	1,000	-	1,000	-	-	-	/3 56	1,000	1,056
A	1	-	-	1,000	-	1,000	-	-	-	-	1,000	1,000
	2	-	-	1,000	-	1,000	-	-	-	-	1,000	1,000
	3	-	-	1,000	-	1,000	-	-	-	-	1,000	1,000
S	1	-	-	917	-	917	-	-	-	-	1,000	1,000
	2	-	-	750	-	750	0.83	-	3	-	1,000	1,000
	3	-	-	583	-	583	0.83	-	12	-	1,000	1,000
O	1	-	-	417	-	417	0.83	8	32	-	1,000	1,000
	2	-	-	250	-	250	0.83	17	170	-	1,000	1,000
	3	-	-	83	-	83	0.83	17	337	-	1,000	1,000
N	1	0.83	-	-	3	3	0.83	17	503	-	1,000	1,000
	2	0.83	-	-	12	12	-	17	667	-	1,000	1,000
	3	0.83	8	-	32	32	-	17	825	-	1,000	1,000
D	1	0.83	17	-	170	170	-	8	972	-	1,000	1,000
	2	0.83	17	-	337	337	-	-	1,000	-	1,000	1,000
	3	0.83	17	-	503	503	-	-	1,000	-	1,000	1,000
J	1	-	17	-	667	667	-	-	1,000	-	1,000	1,000
	2	-	17	-	825	825	-	-	1,000	-	1,000	1,000
	3	-	8	-	972	972	-	-	917	-	1,000	1,000
F	1	-	-	-	1,000	1,000	-	-	750	-	1,000	1,000
	2	-	-	-	1,000	1,000	-	-	583	-	1,000	1,000
	3	-	-	-	1,000	1,000	-	-	417	-	1,000	1,000
M	1	-	-	-	1,000	1,000	-	-	250	56	1,000	1,056
	2	-	-	-	917	917	-	-	83	167	1,000	1,167
	3	-	-	-	750	750	-	-	-	278	1,000	1,278

/1 : in case of cultivation are of 1,000 ha x 2

/2 : $1{,}000 \times \frac{85}{90}$

/3 : $1{,}000 \times \frac{5}{90}$

Table 2.2.5 Unit Irrigation Area by Crop per 1,000 ha (ALT-2)

Unit: ha

Month	10-Day Period	Paddy					Polowijo	Second cropping paddy	Sugar cane
		Nursery puddling	Puddling	Growing					
				1st	2nd	Total			
A	1	-	-	-	-	-	1,000		
	2	-	-	-	-	-	1,000		
	3	0.83	-	3	-	3	917 /1		
M	1	0.83	8	12	-	12	750	ALT-1	ALT-1
	2	0.83	8	32	-	32	583		
	3	0.83	17	170	-	170	417		
J	1	0.83	17	337	-	337	250		
	2	0.83	17	503	-	503	83 /2	as	as
	3	-	17	667	-	667	-		
J	1	-	17	825	-	825	-		
	2	-	8	972	-	972	-	Same	Same
	3	-	-	1,000	-	1,000	-		
A	1	-	-	1,000	-	1,000	-		
	2	-	-	1,000	-	1,000	-		
	3	-	-	1,000	-	1,000	-		
S	1	0.42	-	917	1	918	-		
	2	0.83	-	750	8	758	-		
	3	0.83	-	583	16	599	-		
O	1	0.83	17	417	87	504	-		
	2	0.83	17	250	253	503	-		
	3	0.83	17	83	420	503	-		
N	1	0.42	17	-	586	586	-		
	2	-	17	-	746	746	-		
	3	-	17	-	904	904	-		
D	1	-	-	-	1,000	1,000	-		
	2	-	-	-	1,000	1,000	-		
	3	-	-	-	1,000	1,000	-		
J	1	-	-	-	1,000	1,000	-		
	2	-	-	-	979	979	-		
	3	-	-	-	833	833	83		
F	1	-	-	-	667	667	250		
	2	-	-	-	500	500	417		
	3	-	-	-	333	333	583		
M	1	-	-	-	167	167	750		
	2	-	-	-	21	21	917		
	3	-	-	-	-	-	1,000		

/1: $1{,}000 \times \frac{55}{60}$

/2: $1{,}000 \times \frac{5}{60}$

Table 2.2.6 Unit Irrigation Area by Crops Per 1,000 ha x 2 (ALT-3)

Unit: ha

Month	10Day Period	Paddy											
		Nursery puddling			Puddling			Growing					
		1st 2nd 3rd	3rd 4th 5th	Total	1st 2nd 3rd	3rd 4th 5th	Total	1st	2nd	3rd	4th	5th	Total
A	1	-	0.83	0.83	-	16.7	17	-	-	503	-	1,000	1,503
	2	-	-	-	-	16.7	17	-	-	667	-	917	1,584
	3	0.83	-	0.83	-	16.7	17	3	-	825	-	750	1,578
M	1	0.83	-	0.83	-	8.3	8	12	-	972	-	583	1,567
	2	0.83	-	0.83	8.3	-	8	32	-	1,000	-	417	1,449
	3	0.83	-	0.83	16.7	-	17	170	-	1,000	-	250	1,420
J	1	0.83	-	0.83	16.7	-	17	337	-	1,000	-	83	1,420
	2	0.83	-	0.83	16.7	-	17	503	-	1,000	-	-	1,503
	3	-	-	-	16.7	-	17	667	-	917	-	-	1,584
J	1	-	0.42	0.42	16.7	-	17	825	-	750	1	-	1,576
	2	-	0.83	0.83	8.3	-	8	972	-	583	8	-	1,563
	3	-	0.83	0.83	-	-	-	1,000	-	417	16	-	1,433
A	1	-	0.83	0.83	-	16.7	17	1,000	-	250	87	-	1,337
	2	-	0.83	0.83	-	16.7	17	1,000	-	83	253	-	1,336
	3	-	0.83	0.83	-	16.7	17	1,000	-	-	420	-	1,420
S	1	-	0.42	0.42	-	16.7	17	917	-	-	586	-	1,503
	2	0.42	-	0.42	-	16.7	17	750	1	-	746	-	1,497
	3	0.83	-	0.83	-	16.7	17	583	8	-	904	-	1,495
O	1	0.83	-	0.83	-	-	-	417	16	-	1,000	-	1,433
	2	0.83	-	0.83	16.7	-	17	250	87	-	1,000	-	1,337
	3	0.83	-	0.83	16.7	-	17	83	253	-	1,000	-	1,336
N	1	0.83	-	0.83	16.7	-	17	-	420	-	1,000	-	1,420
	2	0.42	-	0.42	16.7	-	17	-	586	-	979	-	1,565
	3	-	-	-	16.7	-	17	-	746	-	833	-	1,579
D	1	-	0.83	0.83	16.7	-	17	-	904	-	667	3	1,574
	2	-	0.83	0.83	-	-	-	-	1,000	-	500	12	1,512
	3	-	0.83	0.83	-	8.3	8	-	1,000	-	333	32	1,365
J	1	-	0.83	0.83	-	16.7	17	-	1,000	-	167	170	1,337
	2	-	0.83	0.83	-	16.7	17	-	1,000	-	21	337	1,358
	3	-	0.83	0.83	-	16.7	17	-	979	-	-	503	1,482
F	1	-	-	-	-	16.7	17	-	833	-	-	667	1,500
	2	0.83	-	0.83	-	16.7	17	-	667	3	-	825	1,495
	3	0.83	-	0.83	-	8.3	8	-	500	12	-	972	1,484
M	1	0.83	-	0.83	8.3	-	8	-	333	32	-	1,000	1,365
	2	0.83	-	0.83	16.7	-	17	-	167	170	-	1,000	1,337
	3	0.83	-	0.83	16.7	-	17	-	21	337	-	1,000	1,358

Note: Second cropping paddy and sugar cane are same as ALT-1.

Table 2.2.7 Total Irrigation Area by Crops (ALT-1)

Unit : ha

		Karanganyar Region							Sragen Region							Dengkeng Region		
		Paddy (8,900 ha)			Second paddy (600 ha)			Sugar Cane (600 ha x2)	Paddy (6,500 ha)			Second paddy (1,500 ha)			Sugar Cane (1,500 ha x2)	Paddy (3,600 ha)		
		Nursery Puddling	Puddling	Growing	Nursery Puddling	Puddling	Growing		Nursery Puddling	Puddling	Growing	Nursery Puddling	Puddling	Growing		Nursery Puddling	Puddling	Growing
	1	-	-	5,189	-	-	-	833	-	-	3,790	-	-	-	2,084	-	-	2,099
A	2	-	-	3,711	-	-	-	900	-	-	2,711	-	-	-	2,250	-	-	1,501
	3	7.4	-	2,252	-	-	-	967	5.4	-	1,645	-	-	-	2,417	3.0	-	911
	1	7.4	-	846	-	-	-	1,000	5.4	-	618	-	-	-	2,499	3.0	-	342
M	2	7.4	71	285	-	-	-	1,000	5.4	52	208	-	-	-	2,499	3.0	29	115
	3	7.4	151	1,513	-	-	-	1,000	5.4	111	1,105	-	-	-	2,499	3.0	61	612
	1	7.4	151	2,999	-	-	-	967	5.4	111	2,191	-	-	-	2,417	3.0	61	1,213
J	2	7.4	151	4,477	-	-	-	900	5.4	111	3,270	-	-	-	2,250	3.0	61	1,811
	3	-	151	5,936	-	-	-	833	-	111	4,336	-	-	-	2,084	-	61	2,401
	1	-	151	7,343	-	-	-	767	-	111	5,363	-	-	-	1,917	-	61	2,970
J	2	-	71	8,651	-	-	-	700	-	52	6,318	-	-	-	1,751	-	29	3,499
	3	-	-	8,900	-	-	-	634	-	-	6,500	-	-	-	1,584	-	-	3,600
	1	-	-	8,900	-	-	-	600	-	-	6,500	-	-	-	1,500	-	-	3,600
A	2	-	-	8,900	-	-	-	600	-	-	6,500	-	-	-	1,500	-	-	3,600
	3	-	-	8,900	-	-	-	600	-	-	6,500	-	-	-	1,500	-	-	3,600
	1	-	-	8,161	-	-	-	600	-	-	5,961	-	-	-	1,500	-	-	3,301
S	2	-	-	6,675	0.5	-	2	600	-	-	4,875	1.2	-	5	1,500	-	-	2,700
	3	-	-	5,189	0.5	-	7	600	-	-	3,790	1.2	-	13	1,500	-	-	2,099
	1	-	-	3,711	0.5	5	19	600	-	-	2,711	1.2	12	48	1,500	-	-	1,501
O	2	-	-	2,225	0.5	10	102	600	-	-	1,625	1.2	26	255	1,500	-	-	900
	3	-	-	739	0.5	10	202	600	-	-	540	1.2	26	506	1,500	-	-	299
	1	7.4	-	27	0.5	10	302	600	5.4	-	20	1.2	26	755	1,500	3.0	-	11
N	2	7.4	-	107	-	10	400	600	5.4	-	78	-	26	1,001	1,500	3.0	-	43
	3	7.4	71	285	-	10	495	600	5.4	52	208	-	26	1,238	1,500	3.0	29	115
	1	7.4	151	1,513	-	5	583	600	5.4	111	1,105	-	12	1,458	1,500	3.0	61	612
D	2	7.4	151	2,999	-	-	600	600	5.5	111	2,191	-	-	1,500	1,500	3.0	61	1,213
	3	7.4	151	4,477	-	-	600	600	5.4	111	3,270	-	-	1,500	1,500	3.0	61	1,811
	1	-	151	5,936	-	-	600	600	-	111	4,336	-	-	1,500	1,500	-	61	2,401
J	2	-	151	7,343	-	-	600	600	-	111	5,363	-	-	1,500	1,500	-	61	2,970
	3	-	71	8,651	-	-	550	600	-	52	6,318	-	-	1,376	1,500	-	29	3,499
	1	-	-	8,900	-	-	450	600	-	-	6,500	-	-	1,125	1,500	-	-	3,600
F	2	-	-	8,900	-	-	350	600	-	-	6,500	-	-	875	1,500	-	-	3,600
	3	-	-	8,900	-	-	250	600	-	-	6,500	-	-	626	1,500	-	-	3,600
	1	-	-	8,900	-	-	150	634	-	-	6,500	-	-	375	1,584	-	-	3,600
M	2	-	-	8,161	-	-	50	700	-	-	5,961	-	-	125	1,751	-	-	3,301
	3	-	-	6,675	-	-	-	767	-	-	4,875	-	-	-	1,917	-	-	2,700

Table 2.2.8 Total Irrigation Area by Crops (ALT-2)

Unit : ha

Month	Ten Day Period	Karanganyar Region				Sragen Region				Dengkeng Region			
		Paddy (8,900 ha)			Polowijo (8,900 ha)	Paddy (6,500 ha)			Polowijo (6,500 ha)	Paddy (3,600 ha)			Polowijo (3,600 ha)
		Nursery Puddling	Puddling	Growing		Nursery Puddling	Puddling	Growing		Nursery Puddling	Puddling	Growing	
A	1	-	-	-	8,900	-	-	-	6,500	-	-	-	3,600
	2	-	-	-	8,900	-	-	-	6,500	-	-	-	3,600
	3	7.4	-	27	8,161	5.4	-	20	5,961	3.0	-	11	3,301
M	1	7.4	-	107	6,675	5.4	-	78	4,875	3.0	-	43	2,700
	2	7.4	71	285	5,189	5.4	52	208	3,790	3.0	29	115	2,099
	3	7.4	151	1,513	3,711	5.4	111	1,105	2,711	3.0	61	612	1,501
J	1	7.4	151	2,999	2,225	5.4	111	2,191	1,625	3.0	61	1,213	900
	2	7.4	151	4,477	739	5.4	111	3,270	540	3.0	61	1,811	299
	3	-	151	5,936	-	-	111	4,336	-	-	61	2,401	-
J	1	-	151	7,343	-	-	111	5,363	-	-	61	2,970	-
	2	-	71	8,651	-	-	52	6,318	-	-	29	3,499	-
	3	-	-	8,900	-	-	-	6,500	-	-	-	3,600	-
A	1	-	-	8,900	-	-	-	6,500	-	-	-	3,600	-
	2	-	-	8,900	-	-	-	6,500	-	-	-	3,600	-
	3	-	-	8,900	-	-	-	6,500	-	-	-	3,600	-
S	1	3.7	-	8,170	-	2.7	-	5,967	-	1.5	-	3,305	-
	2	7.4	-	6,746	-	5.4	-	4,927	-	3.0	-	2,729	-
	3	7.4	-	5,331	-	5.4	-	3,894	-	3.0	-	2,156	-
O	1	7.4	151	4,486	-	5.4	111	3,276	-	3.0	61	1,814	-
	2	7.4	151	4,477	-	5.4	111	3,270	-	3.0	61	1,811	-
	3	7.4	151	4,477	-	5.4	111	3,270	-	3.0	61	1,811	-
N	1	3.7	151	5,215	-	2.7	111	3,809	-	1.5	61	2,110	-
	2	-	151	6,639	-	-	111	4,849	-	-	61	2,686	-
	3	-	151	8,046	-	-	111	5,876	-	-	61	3,254	-
D	1	-	-	8,900	-	-	-	6,500	-	-	-	3,600	-
	2	-	-	8,900	-	-	-	6,500	-	-	-	3,600	-
	3	-	-	8,900	-	-	-	6,500	-	-	-	3,600	-
J	1	-	-	8,900	-	-	-	6,500	-	-	-	3,600	-
	2	-	-	8,713	-	-	-	6,364	-	-	-	3,524	-
	3	-	-	7,413	739	-	-	5,415	540	-	-	2,999	299
F	1	-	-	5,936	2,225	-	-	4,336	1,625	-	-	2,401	900
	2	-	-	4,450	3,711	-	-	3,250	2,711	-	-	1,800	1,500
	3	-	-	2,964	5,189	-	-	2,165	3,790	-	-	1,199	2,099
M	1	-	-	1,486	6,675	-	-	1,086	4,875	-	-	601	2,700
	2	-	-	187	8,161	-	-	137	5,961	-	-	76	3,301
	3	-	-	-	8,900	-	-	-	6,500	-	-	-	3,600

Note : Second cropping paddy and sugar cane are same as ALT-1.

Table 2.2.9 Total Irrigation Area by Crops (ALT-3)

Unit : Ha

Month	Ten Day Period	Karanganyar Region			Sragen Region			Dengkeng Region		
		Paddy (4,450 ha x 2)			Paddy (3,250 ha x 2)			Paddy (1,800 ha x 2)		
		Nursery Puddling	Puddling	Growing	Nursery Puddling	Puddling	Growing	Nursery Puddling	Puddling	Growing
A	1	3.7	76	6,688	2.7	55	4,885	1.5	31	2,705
	2	-	76	7,049	-	55	5,148	-	31	2,851
	3	3.7	76	7,022	2.7	55	5,129	1.5	31	2,840
M	1	3.7	36	6,973	2.7	26	5,093	1.5	14	2,821
	2	3.7	36	6,448	2.7	26	4,709	1.5	14	2,608
	3	3.7	76	7,022	2.7	55	4,615	1.5	31	2,556
J	1	3.7	76	6,319	2.7	55	4,615	1.5	31	2,556
	2	3.7	76	6,688	2.7	55	4,885	1.5	31	2,705
	3	-	76	7,049	-	55	5,148	-	31	2,851
J	1	1.9	76	7,013	1.4	55	5,122	0.8	31	2,837
	2	3.7	36	6,955	2.7	26	5,080	1.5	14	2,813
	3	3.7	-	6,377	2.7	-	4,657	1.5	-	2,579
A	1	3.7	76	5,950	2.7	55	4,345	1.5	31	2,407
	2	3.7	76	5,945	2.7	55	4,342	1.5	31	2,405
	3	3.7	76	6,319	2.7	55	4,615	1.5	31	2,556
S	1	1.9	76	6,688	1.4	55	4,885	0.8	31	2,705
	2	1.9	76	6,662	1.4	55	4,865	0.8	31	2,695
	3	3.7	76	6,653	2.7	55	4,859	1.5	31	2,691
O	1	3.7	-	6,377	2.7	-	4,657	1.5	-	2,579
	2	3.7	76	5,950	2.7	55	4,345	1.5	31	2,407
	3	3.7	76	5,945	2.7	55	4,342	1.5	31	2,405
N	1	3.7	76	6,319	2.7	55	4,615	1.5	31	2,556
	2	1.9	76	6,964	1.4	55	5,086	0.8	31	2,817
	3	-	76	7,027	-	55	5,132	-	31	2,842
D	1	3.7	76	7,004	2.7	55	5,116	1.5	31	2,833
	2	3.7	-	6,728	2.7	-	4,914	1.5	-	2,722
	3	3.7	36	6,074	2.7	26	4,436	1.5	14	2,457
J	1	3.7	76	5,950	2.7	55	4,345	1.5	31	2,407
	2	3.7	76	6,043	2.7	55	4,414	1.5	31	2,444
	3	3.7	76	6,595	2.7	55	4,817	1.5	31	2,668
F	1	3.7	76	6,675	-	55	4,875	-	31	2,700
	2	3.7	76	6,653	2.7	55	4,859	1.5	31	1,691
	3	3.7	36	6,604	2.7	26	4,823	1.5	14	2,671
M	1	3.7	36	6,074	2.7	26	4,436	1.5	14	2,457
	2	3.7	76	5,950	2.7	55	4,345	1.5	31	2,407
	3	3.7	76	6,043	2.7	55	4,414	1.5	31	2,444

Note: Second cropping paddy and Sugar Cane are same as ALT-1.

2.2.3 Evapotranspiration (Consumptive Use)

The most desirable way to determine the consumptive use is that based on the actual measurement of water requirement in the field over a long period.

Since no data are available in this area at present, several methods of estimating the evapotranspiration have been compared to select the most suitable.

a) Comparison of consumptive use estimation method

Three popular methods in Indonesia, namely, Penman, Modified Blaney-Criddle, and Hargreaves, have been compared under the same climatic condition for one cropping season (April to August: dry season paddy-rice). The results are in Table 2.2.10.

Penman method would bring excessively lower values, while Modified Blaney-Criddle method tends to bring too high values, judging from actual evaporation data obtained at Madiun (unfortunately, the data on evaporation during dry season at Panasan Airport were not available).

Consequently, the Hargreaves method is supposed to be most adequate for estimating the evapotranspiration in the project area.

The calculations made by using the three methods are presented in Tables 2.2.11, 2.2.13 and 2.2.14.

Penman method

Penman method has made the most complete theoretical approach, showing that the consumptive use is inseparably connected with the incoming solar energy. The formula representing the potential evapotranspiration (consumptive use) is as follows:

$$E_T = \frac{\Delta H + 0.27 Ea}{\Delta + 0.27}$$

with values of H and Ea given by

$$H = R_A(1 - r)(0.18 + 0.55\ n/N) - \delta Ta^4(0.56 - 0.092\sqrt{ed})(0.10 + 0.90\ n/N)$$

$$Ea = 0.35\ (e_a - e_d)(1 + 0.0098\ U_2)$$

where H = daily heat budget at surface in mm H_2O/day
R_A = mean monthly extra terrestrial radiation in mm H_2O/day
r = reflection coefficient of sunshine
N = maximum possible duration of bright sunshine
δ = Boltzmann constant
δTa^4 = mm H_2O/day (see Table 2.2.12)

Table 2.2.10 Comparison of Consumptive Use

Month		Penman	Blaney-Criddle	Hargreaves
Apr.	(mm/day)	3.9	6.7	4.9
	(mm/month)	116.1	202.1	145.4
May	(mm/day)	4.4	7.7	6.1
	(mm/month)	135.2	238.1	188.5
Jun.	(mm/day)	5.0	8.0	7.8
	(mm/month)	151.2	239.6	234.7
Jul.	(mm/day)	4.5	6.7	7.0
	(mm/month)	140.4	206.4	216.7
Aug.	(mm/day)	2.4	3.1	3.6
	(mm/month)	75.0	97.5	112.1
Total	(mm)	617.9	983.7	897.4

Reference: Mean Monthly Evaporation at Madiun

Apr.	120.0 mm/month	4.0 mm/day
May	136.4	4.4
June.	150.0	5.0
Jul.	148.8	4.8
Aug.	176.7	5.7
Total	731.9 mm/month	

e_d = saturation vapor pressure at mean dew point (i.e., actual vapor pressure in the air) mmHg
Ea = evaporation in (mm) H_2O/day
e_a = saturation vapor pressure at mean air temperature in mmHg
U_2 = mean wind velocity at 2 meters above the ground (miles/day)
E_T = potential evapotranspiration in mm H_2O/day
U_1 = measured wind velocity in miles per day at height h in feet
Δ = slope of saturated vapor pressure curve of air at absolute temperature Ta in °F (mmHg/°F) (see Fig 2.2.5)

Blaney-Criddle method

Blaney and Criddle developed a simplified formula using temperature and day-time hours for the arid western portion of the United States.

Modification of basic formula in the metrik unity is as follows:

$$U = K \times P \times \left(\frac{45.7\ t + 813}{100}\right)$$

where: U = monthly consumptive use of crops in mm
K = empirical coefficient
= Kc x Kt

Kc = coefficient reflecting the growing stage of the crops
Kt = climatic coefficient related to the mean temperature
= 0.0311 t + 0.240
t = mean monthly temperature in °C
P = percentage of day-time hours of the year
f = monthly consumptive use factor
$= \frac{P(45.7\ t + 813)}{100}$

Hargreaves method

Hargreaves proposed the use of Class A pan evaporation data as the climatic index. Because pan evaporation data are not always available, and due to the variation in measured evaporation with pan exposure, an attempt was made to find an equation for computing a climatic factor equal to Class A pan evaporation from a pan located in standardized exposure or in a large irrigated area.

The equation is expressed as follow:

$$Ev = 17.4 \cdot D \cdot Tc \cdot (1 - Hn) \quad \ldots\ldots\ldots \quad (1)$$

Table 2.2.11 Computation Sheet for Penman Method of Consumptive Use

Latitude: 7°-30' southern hemisphere
Crop : Paddy Rice

Data	Apr	May	Jun	Jul	Aug
1. Air Temp. (°C)	28.3	28.5	28.0	27.5	28.0
2. Relative humidity (%)	72.0	69.4	66.6	62.7	59.4
3. Sunshine n/N (%)	45.6	51.1	63.3	70.0	72.5
4. Wind speed, U_2 (Mi/day)	74.6	85.0	101.4	98.4	125.3
5. Radiation rate, R_A (mmH_2O/day)	14.0	12.8	12.1	12.3	13.3
6. Reflection coefficient, r (%)	25				
R_A (1-r)(0.18+0.55 n/N)					
7. (1-r)	0.75				
8. (0.18+0.55 n/N)	0.43	0.46	0.53	0.57	0.58
9. Item 5 x item 7 x item 8	4.52	4.42	4.81	5.26	5.79
σTa^4 (0.56-0.092$\sqrt{ed}$)(0.10+0.90 n/N)					
10. Vapor pressure					
(a) Saturated, ea (see Fig. 2.2.6)	29.3	29.5	29.0	28.0	29.0
(b) Actual ed = (R.H. x ea)	21.1	20.5	19.3	17.6	17.2
(c) $\sqrt{ed}$	4.6	4.5	4.4	4.2	4.1
11. σTa^4 (see Table 2.2.12)	16.6	16.7	16.6	16.5	16.6
12. (0.56-0.092$\sqrt{ed}$)	0.14	0.15	0.16	0.17	0.18
13. (0.10+0.90 n/N)	0.51	0.56	0.67	0.73	0.75
14. Item 11 x item 12 x item 13	1.19	1.40	1.78	2.05	2.24
H					
15. Item 9 - item 14	3.33	3.02	3.03	3.21	3.55
$Ea = 0.35(ea - ed)(1 + 0.0098U_2)$					
16. 0.35 (ea - ed)	2.87	3.15	3.40	3.64	4.13
17. (1 + $0.0098U_2$)	1.73	1.83	1.99	1.96	2.23
18. Item 16 x item 17	4.97	5.76	6.77	7.13	9.21
$ET = \frac{\Delta H + 0.27Ea}{\Delta + 0.27}$					
19. Δ (see Fig. 2.2.5)	0.94	0.95	0.92	0.90	0.92
20. Δ H	3.13	2.87	2.79	2.89	3.27
21. 0.27Ea	1.34	1.56	1.83	1.93	2.49
22. Δ H + 0.27Ea	4.47	4.43	4.62	4.82	5.76
23. Δ + 0.27	1.21	1.22	1.19	1.17	1.19
24. Item 22/item 23	3.69	3.63	3.88	4.12	4.84
Consumptive use					
25. Crop coefficient	1.05	1.20	1.30	1.10	0.50
26. Item 24 x item 25 (mm/day)	3.87	4.36	5.04	4.53	2.42
(mm/month)	116.1	135.2	151.2	140.4	75.0

Note: Data of item 1, 2, 3 and 4 .... at Panasan

TABLE 2.2.12

VALUES OF σT_a^4 FOR VARIOUS TEMPERATURES WHEN COMPUTING EVAPO-TRANSPIRATION BY THE PENMAN METHOD (AFTER CRIDDLE)

Temperature	σT_a^4	Temperature	σT_a^4
°Abs	mm H_2O/day	°F	mm H_2O/day
270	10.73	35	11.48
275	11.51	40	11.96
280	12.40	45	12.45
285	13.20	50	12.94
290	14.26	55	13.45
295	15.30	60	13.96
300	16.34	65	14.52
305	17.46	70	15.10
310	18.60	75	15.65
315	19.85	80	16.25
320	21.15	85	16.85
325	22.50	90	17.46
		95	18.10
		100	18.80

Note: Heat of vaporization was assumed to be constant at 590 gal/gm of H_2O.

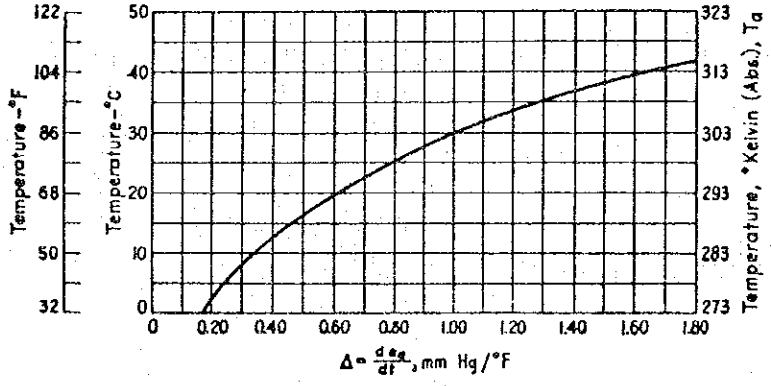


Fig. 2.2.5 Temperature vs. Δ $\left(\frac{d \text{ Saturation Vapor Pressure, mm Hg.}}{d \text{ Temperature, °F}}\right)$ (After Criddle.)

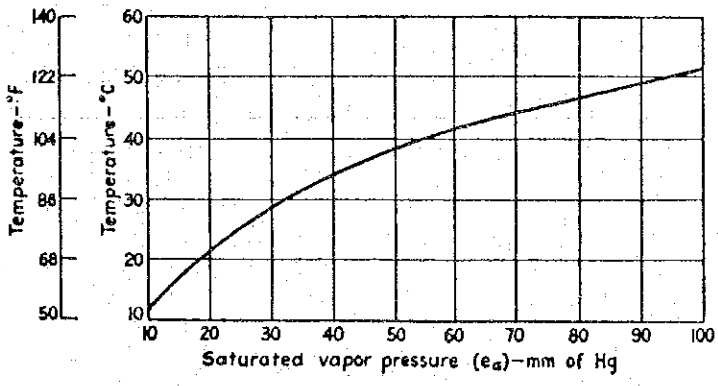


Fig. 2.2.6 Temperature vs. saturated vapor pressure. (After Criddle.)

where: Ev = class A pan evaporation in mm
D = monthly day time coefficient (see Table 2.2.15)
Tc = mean monthly temperature in °C
Hn = mean monthly relative humidity at noon

Above equation can be modified factor (1.0-Hn) in the wind factor, sunshine and elevation as follow:

$$Ev = 17.4 \cdot D \cdot Tc \cdot (Fh \cdot Fw \cdot Fs \cdot Fe)$$

$$Fh = 0.59 - 0.55\ Hn^2$$
$$Fw = 0.75 + 0.0255\sqrt{W\ kd}$$
$$Fs = 0.478 + 0.58\ S$$
$$Fe = 0.950 + 0.0001\ E$$

where: Hn = mean noon humidity in decimally (%)
$0.40\ Hm + 0.60\ Hm^2$
Wkd = mean wind velocity (km/day) in the level 2 m
S = mean monthly sunshine hour (%)
Hm = mean daily relative humidity (%)
E = Elevation above the sea level

Above equation is for calculation of evapotranspiration

$$Et = k \cdot Ev$$

where: Et = evapotranspiration in mm
K = Crop coefficient

b) Evaporation

The Hargreaves method is applied in the project area. In this study, climatic data, (Tc), (Hm), (Wkd) and (S) are taken from the average monthly records at the Panasan gauges as shown in Table 2.2.16.

The calculation process and the results are presented in Table 2.2.17.

Evapotranspiration or consumptive use of water by crops is computed as follow:

$$Et = K \cdot Ev$$

where: Et = evapotranspiration in mm
K = crop coefficient

c) Crop coefficient

Various kinds of crop coefficient curves are being utilized for calculating water requirement in connection with the irrigation projects in Indonesia, but none of them seems quite suitable for the intended purposes as they fail to give any decisive clue. An evapotranspiration - pan evaporation ratio on paddy field measured in Japan

Table 2.2.13 Computation Sheet for Blaney-Criddle Method of Consumptive Use of Crop

Latitude : 7°-30' South hemisphere
Crop : Paddy Rice

Data	Apr.	May	Jun.	Jul.	Aug.
1. Mean monthly temp. (°C)	28.3	28.5	28.0	27.5	28.0
2. Day-time hours at 7°-30'S.1. (%)	8.12	8.26	7.96	8.24	8.33
3. Crop coefficient, Kc	1.05	1.20	1.30	1.10	0.50
$K = K_c \times K_t$					
4. $K_t = 0.0311t + 0.24$	1.12	1.13	1.11	1.10	1.11
5. Item 3 x item 4	1.18	1.36	1.44	1.21	0.56
$f = \frac{P(45.7t + 813)}{100}$					
6. (45.7t + 813)/100	21.1	21.2	20.9	20.7	20.9
7. Item 2 x item 6	171.3	175.1	166.4	170.6	174.1
$U = K.f$					
8. Item 5 x item 7 (mm/month)	202.1	238.1	239.6	206.4	97.5
(mm/day)	6.7	7.7	8.0	6.7	3.1

Table 2.2.14 Computation Sheet for Hargreaves Method of Consumptive Use
Latitude : 7°-30' Southern hemisphere

Data	Apr.	May	Jun.	Jul.	Aug.
1. monthly day-time coefficient, D (see Table 2.2.15)	0.97	0.99	0.95	0.98	1.00
2. mean monthly temperature, Tc (°C)	28.3	28.5	28.0	27.5	28.0
3. mean daily relative humidity, Hm(%)	72.0	69.4	66.6	62.7	59.4
4. mean wind velocity, Wkd (km/day)	120	137	163	158	202
5. mean monthly sunshine hour, S (%)	45.6	51.1	63.3	70.0	72.5
6. crop coefficient	1.05	1.20	1.30	1.10	0.50
7. elevation above the sea level (m)	90				
$(F_h . F_w . F_s . F_e)$					
8. mean noon humidity, H_n (%) $= 0.40\ H_m + 0.6\ H_m^2$	0.59	0.57	0.53	0.49	0.45
9. $F_h = 0.59 - 0.55\ H_n^2$	0.40	0.41	0.44	0.46	0.48
10. $F_w = 0.75 + 0.0255\sqrt{W_{kd}}$	1.03	1.05	1.08	1.07	1.11
11. $F_s = 0.478 + 0.58S$	0.74	0.77	0.85	0.88	0.90
12. $F_e = 0.950 + 0.0001E$	0.96	0.96	0.96	0.96	0.96
13. Item 9 x item 10 x item 11 x item 12	0.29	0.32	0.39	0.42	0.46
$E_v = 17.4.D.T_c(F_h.F_w.F_s.F_e)$					
14. 17.4 x item 1 x item 2 x item 13	138.5	157.1	180.5	197.0	224.1
$E_t = K.\ E_v$					
15. Item 6 x item 14 (mm/month)	145.4	188.5	234.7	216.7	112.1
(mm/day)	4.85	6.08	7.82	6.99	3.61

Table 2.2.15 Monthly Day-time Coefficient, D
(for use with Hargreaves equations)

Latitude degree	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
North												
10	0.97	0.89	1.01	1.01	1.06	1.03	1.06	1.05	0.99	0.99	0.95	0.97
8	0.98	0.89	1.01	1.01	1.05	1.02	1.05	1.04	0.99	0.99	0.95	0.97
6	0.98	0.90	1.01	1.01	1.05	1.02	1.05	1.04	0.99	1.01	0.95	0.98
4	0.98	0.91	1.02	1.00	1.04	1.01	1.04	1.04	0.99	1.01	0.95	0.98
2	1.01	0.91	1.02	0.99	1.02	0.99	1.02	1.02	0.98	1.02	0.98	1.01
0	1.02	0.92	1.02	1.00	1.02	0.99	1.02	1.02	0.98	1.02	0.99	1.02
South												
2	1.02	0.93	1.02	0.98	1.01	0.98	1.01	1.01	0.98	1.02	0.99	1.03
4	1.04	0.93	1.02	0.98	1.01	0.97	0.98	1.01	0.98	1.03	1.00	1.04
6	1.05	0.94	1.02	0.97	1.00	0.96	0.98	1.00	0.98	1.03	1.01	1.05
8	1.05	0.94	1.02	0.97	0.99	0.95	0.98	1.00	0.98	1.02	1.02	1.06
10	1.06	0.94	1.02	0.97	0.98	0.94	0.97	0.99	0.98	1.04	1.02	1.07

Table 2.2.16 Meteorological Data for Computing Evaporation by Hargreaves Method

Station: Panasan Airport

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean monthly temperature Tc(°C)	27.3	27.4	27.8	28.3	28.5	28.0	27.5	28.0	29.1	29.6	28.8	28.1
Mean monthly relative humidity, Hm(%)	75.8	76.9	76.4	72.0	69.4	66.6	62.7	59.4	59.5	60.8	70.5	74.0
Mean monthly wind velocity (km/hour)	5.2	4.7	5.8	5.0	5.7	6.8	6.6	8.4	10.3	8.5	8.1	6.4
Wkd (km/day)	125	113	139	120	137	163	158	202	247	204	194	154
Mean monthly sunshinehour, s(%)	30.4	31.1	36.6	45.6	51.1	63.3	70.0	72.5	75.0	52.5	48.8	33.8

Table 2.2.17 Calculation of Evaporation by Hargreaves Method

7° - 30' south latitude

Month	Hm Relative humid %	Hn Humid at noon %	Wkd Wind speed km/day	S Sunshine hour %	E Elevation	Constant	D Day time coef	Tc Mean Temp °C°	Fh	Fw	Fs	Fe	Ev mm/month	Ev mm/day
Apr	72.0	59.9	120	45.6	90 m	17.4	0.97	28.3	0.393	1.03	0.742	0.959	137.6	4.6
May	69.4	56.7	137	51.1	"	"	0.99	28.5	0.413	1.05	0.774	"	158.0	5.1
Jun	66.6	53.3	163	63.3	"	"	0.95	28.0	0.434	1.08	0.845	"	175.8	5.9
Jul	62.7	48.7	158	70.0	"	"	0.98	27.5	0.460	1.07	0.884	"	197.7	6.4
Aug	59.4	44.9	202	72.5	"	"	1.00	28.0	0.479	1.11	0.899	"	223.3	7.2
Sep	59.5	45.0	247	75.0	"	"	0.98	29.1	0.479	1.15	0.913	"	239.3	8.0
Oct	60.8	46.5	204	52.5	"	"	1.03	29.6	0.471	1.12	0.783	"	210.1	6.8
Nov	70.5	58.0	194	48.8	"	"	1.02	28.8	0.405	1.10	0.761	"	166.2	5.5
Dec	74.0	62.5	154	33.8	"	"	1.06	28.1	0.375	1.07	0.674	"	134.4	4.3
Jan	75.8	64.8	125	30.4	"	"	1.05	27.3	0.359	1.03	0.654	"	115.7	3.7
Feb	76.9	66.2	113	31.1	"	"	0.94	27.4	0.349	1.02	0.658	"	101.7	3.6
Mar	76.4	65.6	139	36.6	"	"	1.02	27.8	0.353	1.05	0.690	"	121.0	3.9

$Hn = 0.4\ Hm + 0.60\ Hm^2$ $Fh = 0.59 - 0.55\ Hn^2$ $Fw = 0.75 + 0.0255\ \sqrt{Wkd}$ $Fs = 0.478 + 0.58\ S$

$Fe = 0.950 + 0.0001E$ $Ev = 17.4\ D\ Tc\ (Fh \cdot Fw \cdot Fs \cdot Fe)$

shows the values between 1.2 and 1.3 in maximum. Accordingly, the maximum crop coefficient in the project area might as well be identified at around 1.3 or so.

In this respect, the crop coefficient proposed by NEDECO for whole Indonesia in its "Computation of Irrigation Water Requirement for Wet Sawah Paddy" seems applicable to the Project and the specific monthly crop coefficient prescribed by Hargreaves for the estimation of evapotranspiration nearly meets the curve recommened by NEDECO.

Accordingly, the crop coefficient curve shown in Fig. 2.2.7 was adopted to figure out the evapotranspiration for three crops grown in the project area, namely, paddy rice, sugarcane, and polowijo.

The seasonal values of the crops coefficient which have been assumed on the above are calculated according to the cropping patterns, as shown in Table 2.2.19 to Table 2.2.24.

The results of calculation are summarized in Table 2.2.18.

d) Evapotranspiration (Consumptive Use)

On the basis of the above, evaporations and crop coefficients have been calculated, and estimation of the monthly evapotranspiration by each crop by each alternative has been made in the process of calculating unit irrigation requirement, as shown in Tables 2.2.29 to 2.2.35, Tables 2.2.43 to 2.2.48 and Tables 2.2.55 to 2.2.57, respectively.

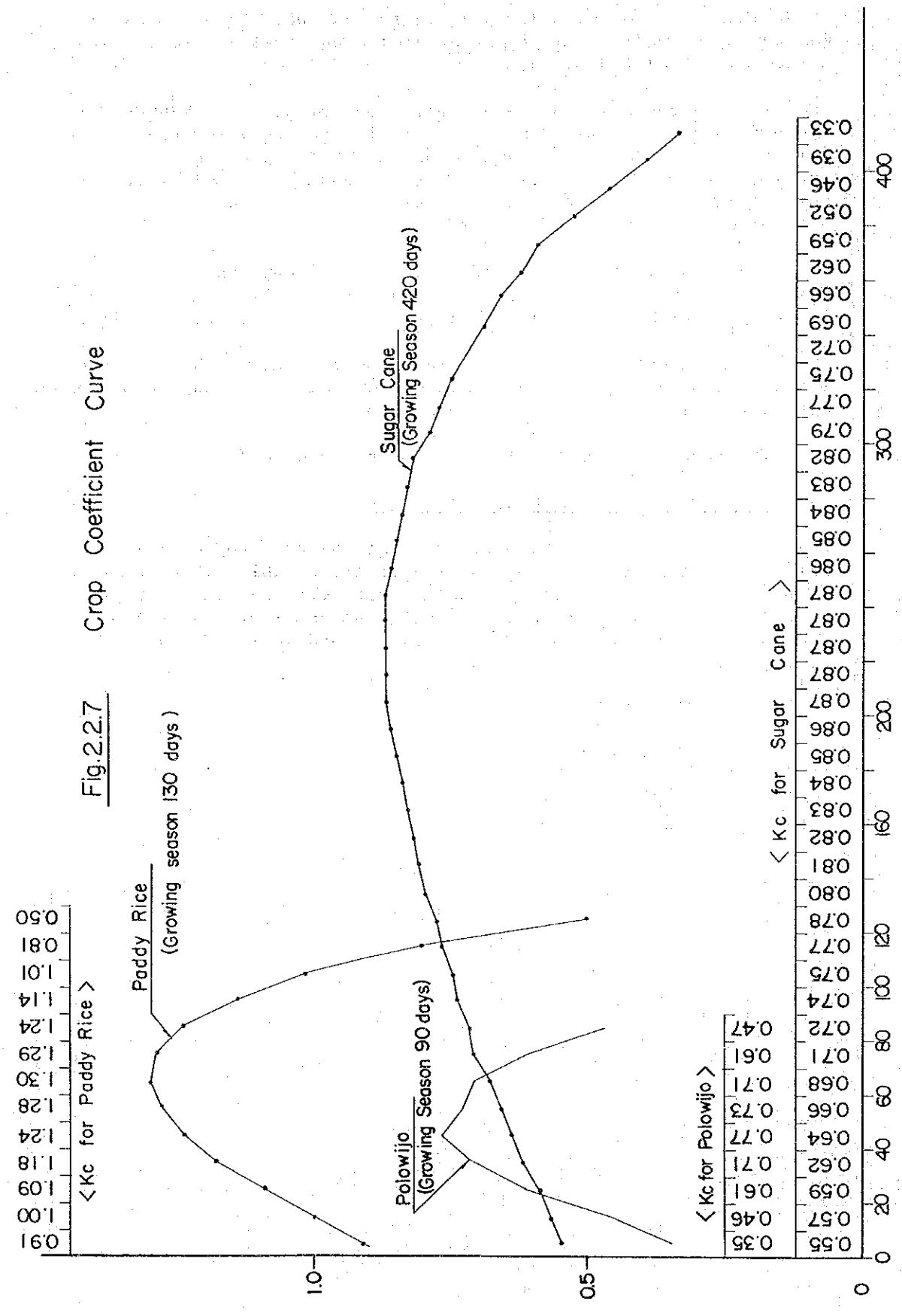


Fig.2.2.7 Crop Coefficient Curve
Paddy Rice
(Growing season 130 days)
Polowijo
(Growing Season 90 days)
Sugar Cane
(Growing Season 420 days)
< Kc for Paddy Rice >
< Kc for Polowijo >
< Kc for Sugar Cane >
0.50 0.81 1.01 1.14 1.24 1.29 1.30 1.28 1.24 1.18 1.09 1.00 0.91
0.47 0.61 0.71 0.77 0.73 0.71 0.61 0.46 0.35
0.33 0.39 0.46 0.52 0.59 0.62 0.66 0.69 0.72 0.75 0.77 0.79 0.82 0.83 0.84 0.85 0.86 0.87 0.87 0.87 0.87 0.86 0.85 0.84 0.83 0.82 0.81 0.80 0.78 0.77 0.75 0.74 0.72 0.71 0.68 0.66 0.64 0.62 0.57 0.55
1.0
0.5
0
0 20 40 60 80 100 120 160 200 300 400

Table 2.2.18 Summary of Crop Coefficients Calculated by Crops

Month	Ten-day Period	Paddy Rice ALT-1	Paddy Rice ALT-2	Paddy Rice ALT-3	Second Cropping Paddy	Sugar Cane	Polowijo
Apr	1	0.87	-	1.08	-	0.64	0.66
	2	0.77	-	1.08	-	0.60	0.66
	3	0.74	0.91	1.08	-	0.58	0.67
May	1	0.80	0.96	1.08	-	0.58	0.66
	2	1.00	1.00	1.08	-	0.58	0.63
	3	1.05	1.05	1.08	-	0.58	0.60
Jun	1	1.08	1.08	1.08	-	0.59	0.54
	2	1.12	1.12	1.08	-	0.60	0.47
	3	1.14	1.14	1.08	-	0.61	-
Jul	1	1.20	1.20	1.08	-	0.63	-
	2	1.23	1.23	1.07	-	0.66	-
	3	1.24	1.24	1.06	-	0.70	-
Aug	1	1.21	1.21	1.06	-	0.76	-
	2	1.15	1.15	1.05	-	0.77	-
	3	1.04	1.04	1.05	-	0.79	-
Sep	1	1.00	0.99	1.05	-	0.80	-
	2	0.94	0.93	1.05	0.91	0.81	-
	3	0.87	0.90	1.05	0.96	0.82	-
Oct	1	0.77	0.89	1.06	1.00	0.83	-
	2	0.66	0.91	1.07	1.05	0.84	-
	3	0.50	0.98	1.08	1.08	0.85	-
Nov	1	0.91	1.09	1.11	1.12	0.86	-
	2	0.96	1.14	1.06	1.14	0.86	-
	3	1.00	1.20	1.08	1.20	0.86	-
Dec	1	1.05	1.23	1.08	1.23	0.86	-
	2	1.08	1.24	1.08	1.24	0.86	-
	3	1.12	1.21	1.08	1.21	0.86	-
Jan	1	1.14	1.15	1.08	1.15	0.85	-
	2	1.20	1.04	1.08	1.04	0.84	-
	3	1.23	1.00	1.08	1.00	0.83	0.35
Feb	1	1.24	0.94	1.08	0.94	0.81	0.41
	2	1.21	0.87	1.08	0.87	0.79	0.47
	3	1.15	0.77	1.08	0.77	0.77	0.53
Mar	1	1.04	0.66	1.08	0.66	0.73	0.53
	2	1.00	0.50	1.08	0.50	0.70	0.61
	3	0.94	-	1.08	-	0.66	0.62

Table 2.2.19 Crop Coefficient of Paddy (ATL-1)

Month	Ten day period	1	2	3	4	5	6	7		Average
A	1	-	-	-	0.50	0.81	1.01	1.14		0.87
	2	-	-	-	-	0.50	0.81	1.01		0.77
	3	0.91	-	-	-	-	0.50	0.81		0.74
M	1	1.00	0.91	-	-	-	-	0.50		0.80
	2	1.09	1.00	0.91	-	-	-	-		1.00
	3	1.18	1.09	1.00	0.91	-	-	-		1.05
J	1	1.24	1.18	1.09	1.00	0.91	-	-		1.08
	2	1.28	1.24	1.18	1.09	1.00	0.91	-		1.12
	3	1.30	1.28	1.24	1.18	1.09	1.00	0.91		1.14
J	1	1.29	1.30	1.28	1.24	1.18	1.09	1.00		1.20
	2	1.24	1.29	1.30	1.28	1.24	1.18	1.09		1.23
	3	1.14	1.24	1.29	1.30	1.28	1.24	1.18		1.24
A	1	1.01	1.14	1.24	1.29	1.30	1.28	1.24		1.21
	2	0.81	1.01	1.14	1.24	1.29	1.30	1.28		1.15
	3	0.50	0.81	1.01	1.14	1.24	1.29	1.30		1.04
S	1	-	0.50	0.81	1.01	1.14	1.24	1.29		1.00
	2	-	-	0.50	0.81	1.01	1.14	1.24		0.94
	3	-	-	-	0.50	0.81	1.01	1.14		0.87
O	1	-	-	-	-	0.50	0.81	1.01		0.77
	2	-	-	-	-	-	0.50	0.81		0.66
	3	-	-	-	-	-	-	0.50		0.50
N	1	0.91	-	-	-	-	-	-		0.91
	2	1.00	0.91	-	-	-	-	-		0.96
	3	1.09	1.00	0.91	-	-	-	-		1.00
D	1	1.18	1.09	1.00	0.91	-	-	-		1.05
	2	1.24	1.18	1.09	1.00	0.91	-	-		1.08
	3	1.28	1.24	1.18	1.09	1.00	0.91	-		1.12
J	1	1.30	1.28	1.24	1.18	1.09	1.00	0.91		1.14
	2	1.29	1.30	1.28	1.24	1.18	1.09	1.00		1.20
	3	1.24	1.29	1.30	1.28	1.24	1.18	1.09		1.23
F	1	1.14	1.24	1.29	1.30	1.28	1.24	1.18		1.24
	2	1.01	1.14	1.24	1.29	1.30	1.28	1.24		1.21
	3	0.81	1.01	1.14	1.24	1.29	1.30	1.28		1.15
M	1	0.50	0.81	1.01	1.14	1.24	1.29	1.30		1.04
	2	-	0.50	0.81	1.01	1.14	1.24	1.29		1.00
	3	-	-	0.50	0.81	1.01	1.14	1.24		0.94

Table 2.2.20 Crop Coefficient of Second Paddy

Month	Ten Day Period	1	2	3	4	5	6	7		Average
A	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
M	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
J	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
J	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
A	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
S	1	-	-	-	-	-	-	-		-
	2	0.91	-	-	-	-	-	-		0.91
	3	1.00	0.91	-	-	-	-	-		0.96
O	1	1.09	1.00	0.91	-	-	-	-		1.00
	2	1.18	1.09	1.00	0.91	-	-	-		1.05
	3	1.24	1.18	1.09	1.00	0.91	-	-		1.08
N	1	1.28	1.24	1.18	1.09	1.00	0.91	-		1.12
	2	1.30	1.28	1.24	1.18	1.09	1.00	0.91		1.14
	3	1.29	1.30	1.28	1.24	1.18	1.09	1.00		1.20
D	1	1.24	1.29	1.30	1.28	1.24	1.18	1.09		1.23
	2	1.14	1.24	1.29	1.30	1.28	1.24	1.18		1.24
	3	1.01	1.14	1.24	1.29	1.30	1.28	1.24		1.21
J	1	0.81	1.01	1.14	1.24	1.29	1.30	1.28		1.15
	2	0.50	0.81	1.01	1.14	1.24	1.29	1.30		1.04
	3	-	0.50	0.81	1.01	1.14	1.24	1.29		1.00
F	1	-	-	0.50	0.81	1.01	1.14	1.24		0.94
	2	-	-	-	0.50	0.81	1.01	1.14		0.87
	3	-	-	-	-	0.50	0.81	1.01		0.77
M	1	-	-	-	-	-	0.50	0.81		0.66
	2	-	-	-	-	-	-	0.50		0.50
	3	-	-	-	-	-	-	-		-

Table 2.2.21 Crop Coefficient of Sugar Cane

Month	Ten Day Period	1	2	3	4	5	6	7	8	9	10	1'	2'	3'	4'	5'	6'	7'	8'	9'	10'	Average
	1	0.62	0.59	0.57	0.55	-	-	-	-	-	-	0.46	0.52	0.59	0.62	0.66	0.69	0.72	0.75	0.77	0.79	0.64
A	2	0.64	0.62	0.59	0.57	0.55	-	-	-	-	-	0.39	0.46	0.52	0.59	0.62	0.66	0.69	0.72	0.75	0.77	0.60
	3	0.66	0.64	0.62	0.59	0.57	0.55	-	-	-	-	0.33	0.39	0.46	0.52	0.59	0.62	0.66	0.69	0.72	0.75	0.58
	1	0.68	0.66	0.64	0.62	0.59	0.57	0.55	-	-	-	-	0.33	0.39	0.46	0.52	0.59	0.62	0.66	0.69	0.72	0.58
M	2	0.71	0.68	0.66	0.64	0.62	0.59	0.57	0.55	-	-	-	-	0.33	0.39	0.46	0.52	0.59	0.62	0.66	0.69	0.58
	3	0.72	0.71	0.68	0.66	0.64	0.62	0.59	0.57	0.55	-	-	-	-	0.33	0.39	0.46	0.52	0.59	0.62	0.66	0.58
	1	0.74	0.72	0.71	0.68	0.66	0.64	0.62	0.59	0.57	0.55	-	-	-	-	0.33	0.39	0.46	0.52	0.59	0.62	0.59
J	2	0.75	0.74	0.72	0.71	0.68	0.66	0.64	0.62	0.59	0.57	-	-	-	-	-	0.33	0.39	0.46	0.52	0.59	0.60
	3	0.77	0.75	0.74	0.72	0.71	0.68	0.66	0.64	0.62	0.59	-	-	-	-	-	-	0.33	0.39	0.46	0.52	0.61
	1	0.78	0.77	0.75	0.74	0.72	0.71	0.68	0.66	0.64	0.62	-	-	-	-	-	-	-	0.33	0.39	0.46	0.63
J	2	0.80	0.78	0.77	0.75	0.74	0.72	0.71	0.68	0.66	0.64	-	-	-	-	-	-	-	-	0.33	0.39	0.66
	3	0.81	0.80	0.78	0.77	0.75	0.74	0.72	0.71	0.68	0.66	-	-	-	-	-	-	-	-	-	0.33	0.70
	1	0.82	0.81	0.80	0.78	0.77	0.75	0.74	0.72	0.71	0.68	-	-	-	-	-	-	-	-	-	-	0.76
A	2	0.83	0.82	0.81	0.80	0.78	0.77	0.75	0.74	0.72	0.71	-	-	-	-	-	-	-	-	-	-	0.77
	3	0.84	0.83	0.82	0.81	0.80	0.78	0.77	0.75	0.74	0.72	-	-	-	-	-	-	-	-	-	-	0.79
	1	0.85	0.84	0.83	0.82	0.81	0.80	0.78	0.77	0.75	0.74	-	-	-	-	-	-	-	-	-	-	0.80
S	2	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.78	0.77	0.75	-	-	-	-	-	-	-	-	-	-	0.81
	3	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.78	0.77	-	-	-	-	-	-	-	-	-	-	0.82
	1	0.87	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.78	-	-	-	-	-	-	-	-	-	-	0.83
O	2	0.87	0.87	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	-	-	-	-	-	-	-	-	-	-	0.84
	3	0.87	0.87	0.87	0.87	0.86	0.85	0.84	0.83	0.82	0.81	-	-	-	-	-	-	-	-	-	-	0.85
	1	0.87	0.87	0.87	0.87	0.87	0.86	0.85	0.84	0.83	0.82	-	-	-	-	-	-	-	-	-	-	0.86
N	2	0.86	0.87	0.87	0.87	0.87	0.87	0.86	0.85	0.84	0.83	-	-	-	-	-	-	-	-	-	-	0.86
	3	0.85	0.86	0.87	0.87	0.87	0.87	0.87	0.86	0.85	0.84	-	-	-	-	-	-	-	-	-	-	0.86
	1	0.84	0.85	0.86	0.87	0.87	0.87	0.87	0.87	0.86	0.85	-	-	-	-	-	-	-	-	-	-	0.86
D	2	0.83	0.84	0.85	0.86	0.87	0.87	0.87	0.87	0.87	0.86	-	-	-	-	-	-	-	-	-	-	0.86
	3	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.87	0.87	0.87	-	-	-	-	-	-	-	-	-	-	0.86
	1	0.79	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.87	0.87	-	-	-	-	-	-	-	-	-	-	0.85
J	2	0.77	0.79	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.87	-	-	-	-	-	-	-	-	-	-	0.84
	3	0.75	0.77	0.79	0.82	0.83	0.84	0.85	0.86	0.87	0.87	-	-	-	-	-	-	-	-	-	-	0.83
	1	0.72	0.75	0.77	0.79	0.82	0.83	0.84	0.85	0.86	0.87	-	-	-	-	-	-	-	-	-	-	0.81
F	2	0.69	0.72	0.75	0.77	0.79	0.82	0.83	0.84	0.85	0.86	-	-	-	-	-	-	-	-	-	-	0.79
	3	0.66	0.69	0.72	0.75	0.77	0.79	0.82	0.83	0.84	0.85	-	-	-	-	-	-	-	-	-	-	0.77
	1	0.62	0.66	0.69	0.72	0.75	0.77	0.79	0.82	0.83	0.84	0.55	-	-	-	-	-	-	-	-	-	0.73
M	2	0.59	0.62	0.66	0.69	0.72	0.75	0.77	0.79	0.82	0.83	0.57	0.55	-	-	-	-	-	-	-	-	0.70
	3	0.52	0.59	0.62	0.66	0.69	0.72	0.75	0.77	0.79	0.82	0.59	0.57	0.55	-	-	-	-	-	-	-	0.66

Table 2.2.22 Crop Coefficient of Paddy
(ALT-2)

Month	Ten Day Period	1	2	3	4	5	6	7		Average
A	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	0.91	-	-	-	-	-	-		0.91
M	1	1.00	0.91	-	-	-	-	-		0.96
	2	1.09	1.00	0.91	-	-	-	-		1.00
	3	1.18	1.09	1.00	0.91	-	-	-		1.05
J	1	1.24	1.18	1.09	1.00	0.91	-	-		1.08
	2	1.28	1.24	1.18	1.09	1.00	0.91	-		1.12
	3	1.30	1.28	1.24	1.18	1.09	1.00	0.91		1.14
J	1	1.29	1.30	1.28	1.24	1.18	1.09	1.00		1.20
	2	1.24	1.29	1.30	1.28	1.24	1.18	1.09		1.23
	3	1.14	1.24	1.29	1.30	1.28	1.24	1.18		1.24
A	1	1.01	1.14	1.24	1.29	1.30	1.28	1.24		1.21
	2	0.81	1.01	1.14	1.24	1.29	1.30	1.28		1.15
	3	0.50	0.81	1.01	1.14	1.24	1.29	1.30		1.04
S	1	0.91	0.50	0.81	1.01	1.14	1.24	1.29		0.99
	2	0.91	0.91	0.50	0.81	1.01	1.14	1.24		0.93
	3	1.00	0.91	0.91	0.50	0.81	1.01	1.14		0.90
O	1	1.09	1.00	0.91	0.91	0.50	0.81	1.01		0.89
	2	1.18	1.09	1.00	0.91	0.91	0.50	0.81		0.91
	3	1.24	1.18	1.09	1.00	0.91	0.91	0.50		0.98
N	1	1.28	1.24	1.18	1.09	1.00	0.91	0.91		1.09
	2	1.30	1.28	1.24	1.18	1.09	1.00	0.91		1.14
	3	1.29	1.30	1.28	1.24	1.18	1.09	1.00		1.20
D	1	1.24	1.29	1.30	1.28	1.24	1.18	1.09		1.23
	2	1.14	1.24	1.29	1.30	1.28	1.24	1.18		1.24
	3	1.01	1.14	1.24	1.29	1.30	1.28	1.24		1.21
J	1	0.81	1.01	1.14	1.24	1.29	1.30	1.28		1.15
	2	0.50	0.81	1.01	1.14	1.24	1.29	1.30		1.04
	3		0.50	0.81	1.01	1.14	1.24	1.29		1.00
F	1	-	-	0.50	0.81	1.01	1.14	1.24		0.94
	2	-	-	-	0.50	0.81	1.01	1.14		0.87
	3	-	-	-	-	0.50	0.81	1.01		0.77
M	1	-	-	-	-	-	0.50	0.81		0.66
	2	-	-	-	-	-	-	0.50		0.50
	3	-	-	-	-	-	-	-		-

Table 2.2.23 Crop Coefficient of Polowijo
(ALT-2)

Month	Ten Day Period	1	2	3	4	5	6	7		Average
A	1	0.61	0.71	0.73	0.77	0.71	0.61	0.46		0.66
	2	0.47	0.61	0.71	0.73	0.77	0.71	0.61		0.66
	3	-	0.47	0.61	0.71	0.73	0.77	0.71		0.67
M	1	-	-	0.47	0.61	0.71	0.73	0.77		0.66
	2	-	-	-	0.47	0.61	0.71	0.73		0.63
	3	-	-	-	-	0.47	0.61	0.71		0.60
J	1	-	-	-	-	-	0.47	0.61		0.54
	2	-	-	-	-	-	-	0.47		0.47
	3	-	-	-	-	-	-	-		-
J	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
A	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
S	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
O	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
N	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
D	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	-	-	-	-	-	-	-		-
J	1	-	-	-	-	-	-	-		-
	2	-	-	-	-	-	-	-		-
	3	0.35	-	-	-	-	-	-		0.35
F	1	0.46	0.35	-	-	-	-	-		0.41
	2	0.61	0.46	0.35	-	-	-	-		0.47
	3	0.71	0.61	0.46	0.35	-	-	-		0.53
M	1	0.77	0.71	0.61	0.46	0.35	-	-		0.58
	2	0.73	0.77	0.71	0.61	0.46	0.35	-		0.61
	3	0.71	0.73	0.77	0.71	0.61	0.46	0.35		0.62

Table 2.2.24 Crop Coefficient of Paddy (ALT-3)

Month	Ten Day Period	1	2	3	4	5	6	7	1'	2'	3'	4'	5'	6'	7'	Average
	1	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91		1.08
A	2	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91	1.08
	3	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	1.08
	1	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.08
M	2	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.08
	3	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.08
	1	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.08
J	2	1.28	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.08
	3	1.30	1.28	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.08
	1	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.08
J	2	1.24	1.29	1.30	1.28	1.24	1.18	1.09	0.91	0.91	-	0.50	0.81	1.01	1.14	1.07
	3	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.00	0.91	0.91	-	0.50	0.81	1.01	1.06
	1	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.09	1.00	0.91	0.91	-	0.50	0.81	1.06
A	2	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.18	1.09	1.00	0.91	0.91	-	0.50	1.05
	3	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.24	1.18	1.09	1.00	0.91	0.91	-	1.05
	1	-	0.50	0.81	1.01	1.14	1.24	1.29	1.28	1.24	1.18	1.09	1.00	0.91	0.91	1.05
S	2	0.91	-	0.50	0.81	1.01	1.14	1.24	1.30	1.28	1.24	1.18	1.09	1.00	0.91	1.05
	3	0.91	0.91	-	0.50	0.81	1.01	1.14	1.29	1.30	1.28	1.24	1.18	1.09	1.00	1.05
	1	1.00	0.91	0.91	-	0.50	0.81	1.01	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.06
O	2	1.09	1.00	0.91	0.91	-	0.50	0.81	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.07
	3	1.18	1.09	1.00	0.91	0.91	-	0.50	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.08
	1	1.24	1.18	1.09	1.00	0.91	0.91	-	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.11
N	2	1.28	1.24	1.18	1.09	1.00	0.91	0.91	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.06
	3	1.30	1.28	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.08
	1	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.08
D	2	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.08
	3	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.08
	1	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.08
J	2	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91	-	0.50	1.08
	3	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91	-	1.08
	1	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	0.91	1.08
F	2	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.00	1.08
	3	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.09	1.08
	1	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.18	1.08
M	2	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.24	1.08
	3	1.24	1.18	1.09	1.00	0.91	-	0.50	0.81	1.01	1.14	1.24	1.29	1.30	1.28	1.08

2.2.4 Percolation

As has been clarified by the soil survey, the soil with fine texture and massive structure is scattered almost over the entire project area, and in addition, the ground water table there is relatively higher than was anticipated. Accordingly, subsurface layer in the paddyfield is supposed to be rather impervious. Soil details are given in the relevant section.

Based on the local soil survey results relating to the texture and structure as well as the estimated data on percolation in other project area in and around Central Java, we have decided upon 1.0 mm/day in dry season and 0.5 mm/day in rainy season as the percolation in the project area.

2.2.5 Effective Rainfall

Daily rainfall data collected for the period of 20 years at six gauging stations in the project area have been used for estimating an effective rainfall. (See Fig.2.2.8) The effectiveness of rainfall depends on several factors such as the amount and intensity of rainfall, the characteristic of the soil, the rate of consumptive use and the irrigation practice. Accordingly, empirical and practical judgement is necessary in estimating the effective rainfall.

Two estimation procedures have been used in conformity with the prevailing irrigation practices adopted in the project area, namely, flooding irrigation in the paddy field and furrow irrigation in the sugarcane field.

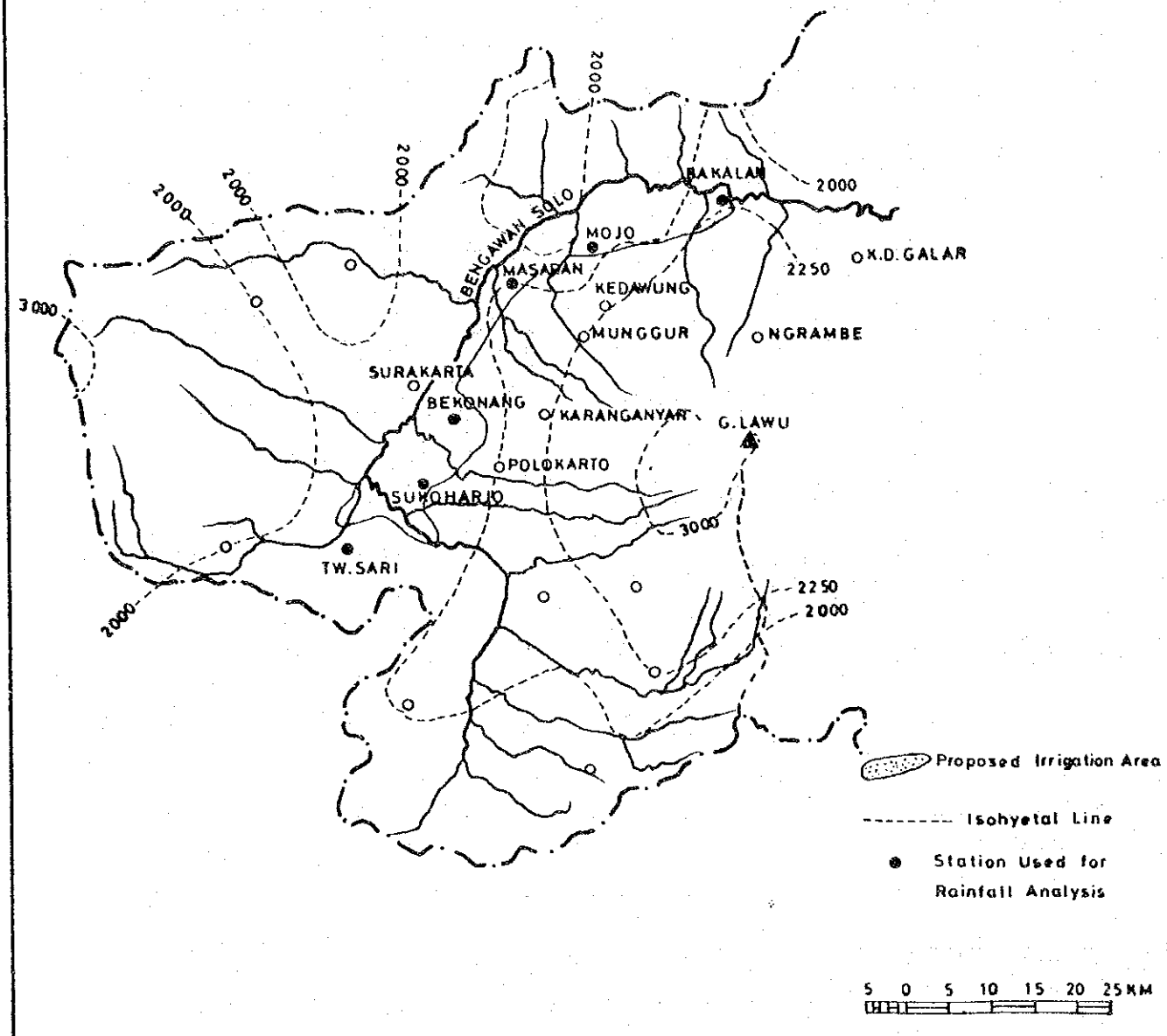
a) Effective rainfall in the paddyfield

The daily rainfall beyond 50 mm was disregarded as far as the precipitation in excess of 50 mm is concerned, as such water is doomed to flow into the drainage ditches without being detained in the paddyfield. The rainfall less than 5 mm was also eliminated, because it would not replace the daily evaporation. That means, the daily rainfall less than 50 mm but more than 5 mm minus 20 % was assumed as an effective rainfall. Thus, 69 % to 71 % of total yearly rainfall in the basic year was estimated as the effective rainfall in the paddyfield.

b) Effective rainfall in the sugarcane field

The consumptive use of 9 mm per day in dry season and 7 mm per day in rainy season was assumed empirically to estimate the effective rainfall in the sugarcane field. The rainfall more than the crop's daily consumptive requirement was treated as an excess rainfall, that means, rainfall above 9 mm per day in dry season and 7 mm per day in rainy season, was deleted as ineffective rainfall. The outcomes based on such procedure show around 55 % to 68 % of the total yearly rainfall in the basic year as an effective rainfall.

Fig 2.2.8 Location Map of Rainfall Station



PROYEK BENGAWAN SALA

DATA HIDROLOGI

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A. BENGAWAN SALA HULU

Table 2.2.25 Effective Rainfall in The Design Year (1967/1968)

Unit: mm/day

Month	10-Day Period	Karanganyar Region		Sragen Region		Dengkeng Region	
		For Paddy	For Sugar Cane & Polowijo	For Paddy	For Sugar Cane & Polowijo	For Paddy	For Polowijo
A	1	9.1	7.0	2.7	3.6	8.2	7.0
	2	0.7	1.0	1.3	2.0	0.8	1.0
	3	1.1	1.3	2.0	3.0	1.1	1.4
M	1	-	0.1	0.3	0.3	-	-
	2	1.0	1.0	1.6	2.0	1.3	1.7
	3	-	0.4	-	-	-	-
J	1	-	-	-	-	-	-
	2	-	-	-	-	-	-
	3	-	-	-	-	-	-
J	1	-	-	-	-	-	-
	2	-	-	-	-	-	-
	3	-	-	-	-	-	-
A	1	-	-	-	-	-	-
	2	-	-	-	-	-	-
	3	-	-	-	-	-	-
S	1	-	-	-	-	-	-
	2	-	-	-	-	-	-
	3	0.7	0.8	0.6	0.8	-	-
O	1	0.8	1.4	1.8	2.4	1.6	2.0
	2	-	0.2	0.4	0.9	-	-
	3	0.9	1.1	0.2	0.3	1.5	1.9
N	1	5.0	7.0	2.7	3.8	9.4	7.0
	2	3.2	4.0	3.1	5.1	1.9	2.4
	3	5.7	7.0	6.6	7.0	5.6	7.0
D	1	8.7	7.0	4.5	6.2	11.2	7.0
	2	4.9	6.2	3.5	5.0	5.8	7.0
	3	7.2	7.0	6.9	7.0	12.0	7.0
J	1	11.7	7.0	3.7	5.1	13.7	7.0
	2	4.1	5.3	11.9	7.0	2.5	3.3
	3	6.7	7.0	9.9	7.0	8.1	7.0
F	1	4.6	5.9	10.5	7.0	7.4	7.0
	2	5.4	7.0	9.3	7.0	1.5	2.7
	3	8.2	7.0	5.8	7.0	5.0	6.7
M	1	8.7	7.0	7.9	7.0	10.8	7.0
	2	6.4	7.0	7.3	7.0	7.4	7.0
	3	12.4	7.0	13.5	7.0	17.8	7.0
Annual		1,172mm	1,127mm	1,180mm	1,105mm	1,346mm	1,071mm
Actual Rainfall		1,640mm		1,673mm		1,956mm	
Percentage		71%	69%	71%	66%	69%	55%

Fig.2.2.9 Effective Rainfall for Paddy in Every Ten-Day Period
(Karanganyar Region) 1967/1968

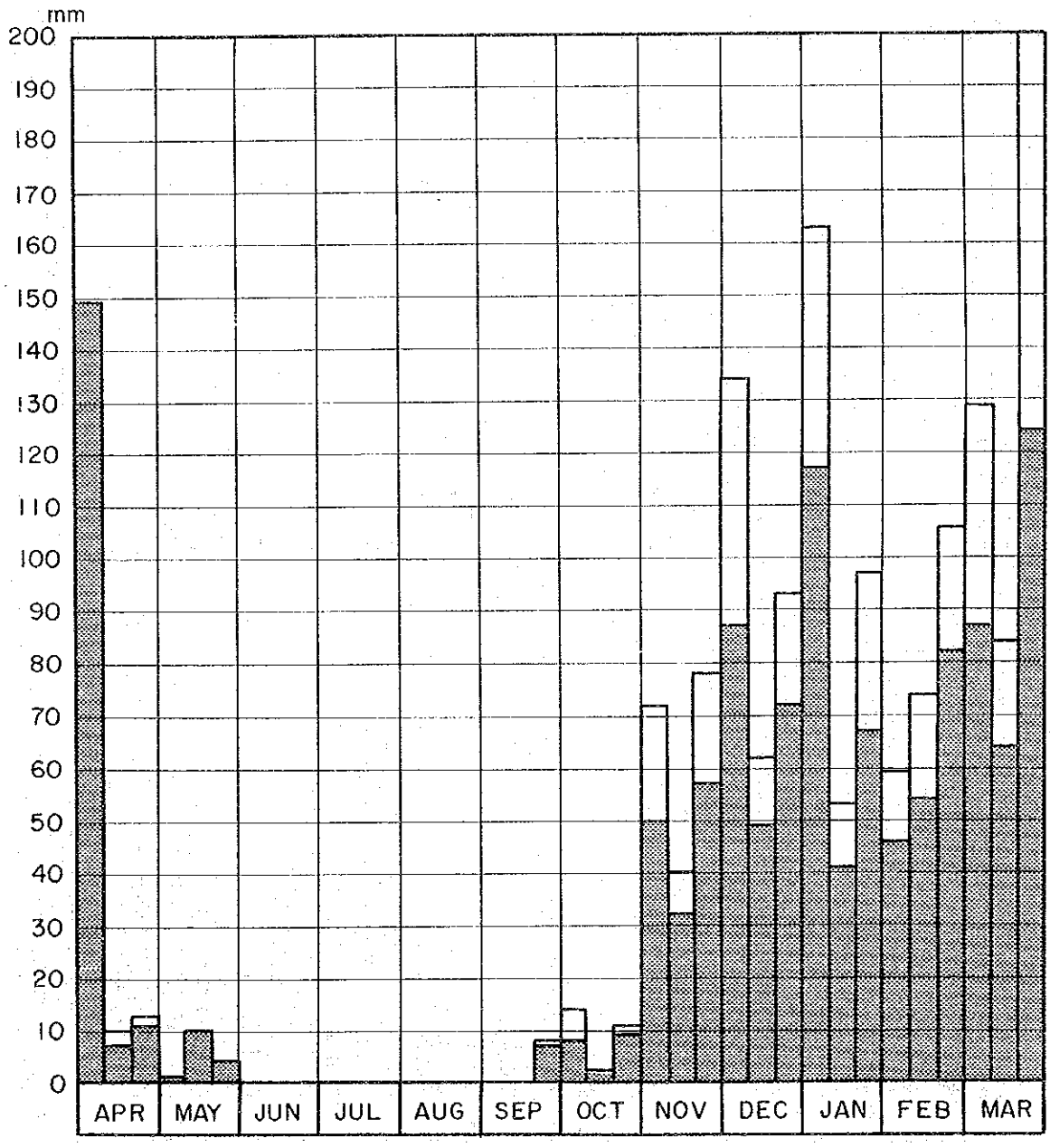


Fig. 2.2.10

Effective Rainfall for Sugar Cane in Every Ten-Day Period

(Karanganyar Region) 1967/1968

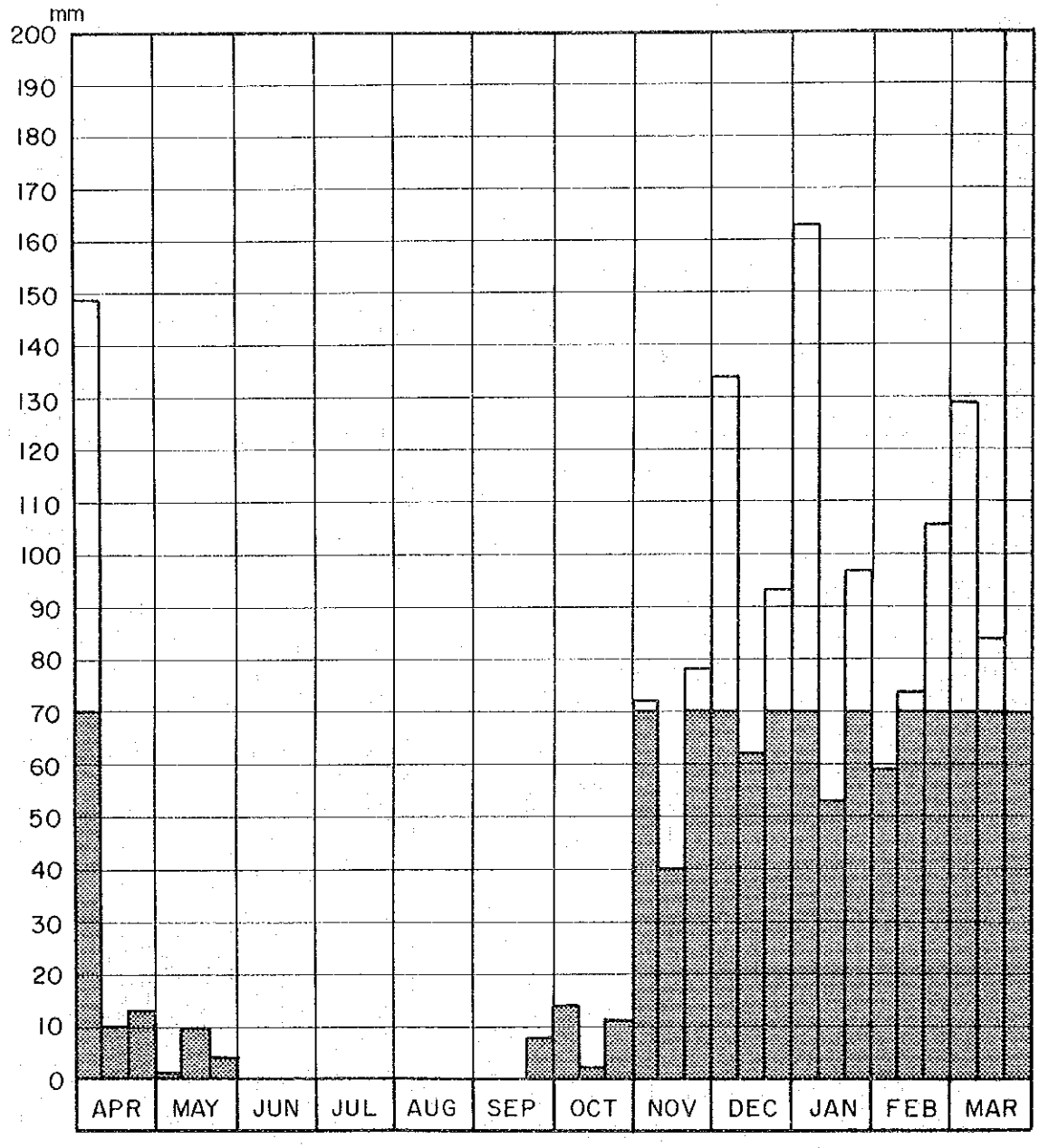


Fig. 2.2.11 Effective Rainfall for Paddy in Every Ten-Day Period
(Sragen Region) 1967/1968

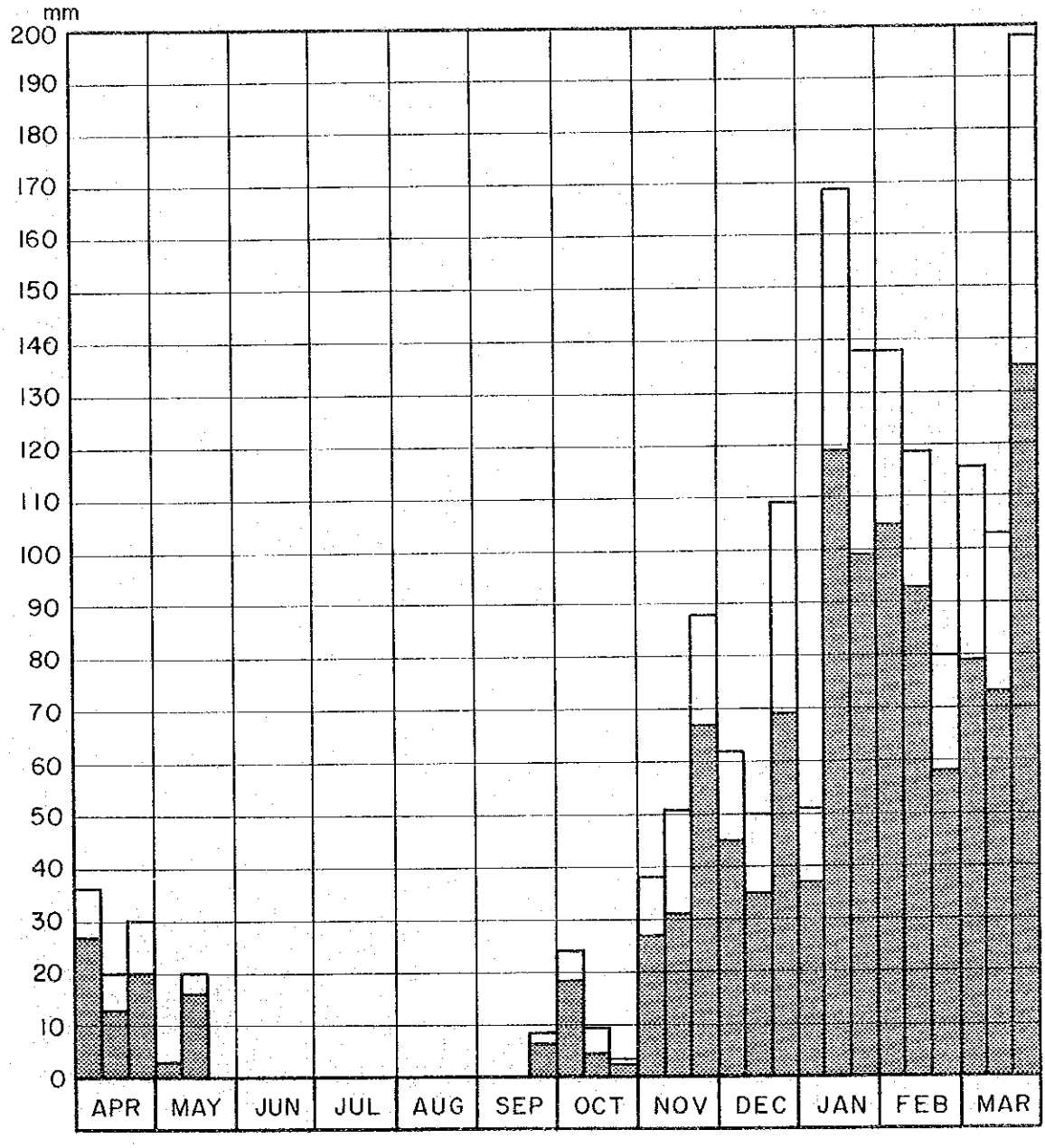


Fig.2.2.12 Effective Rainfall for Sugar Cane in Every Ten-Day Period
(Sragen Region) 1967/1968

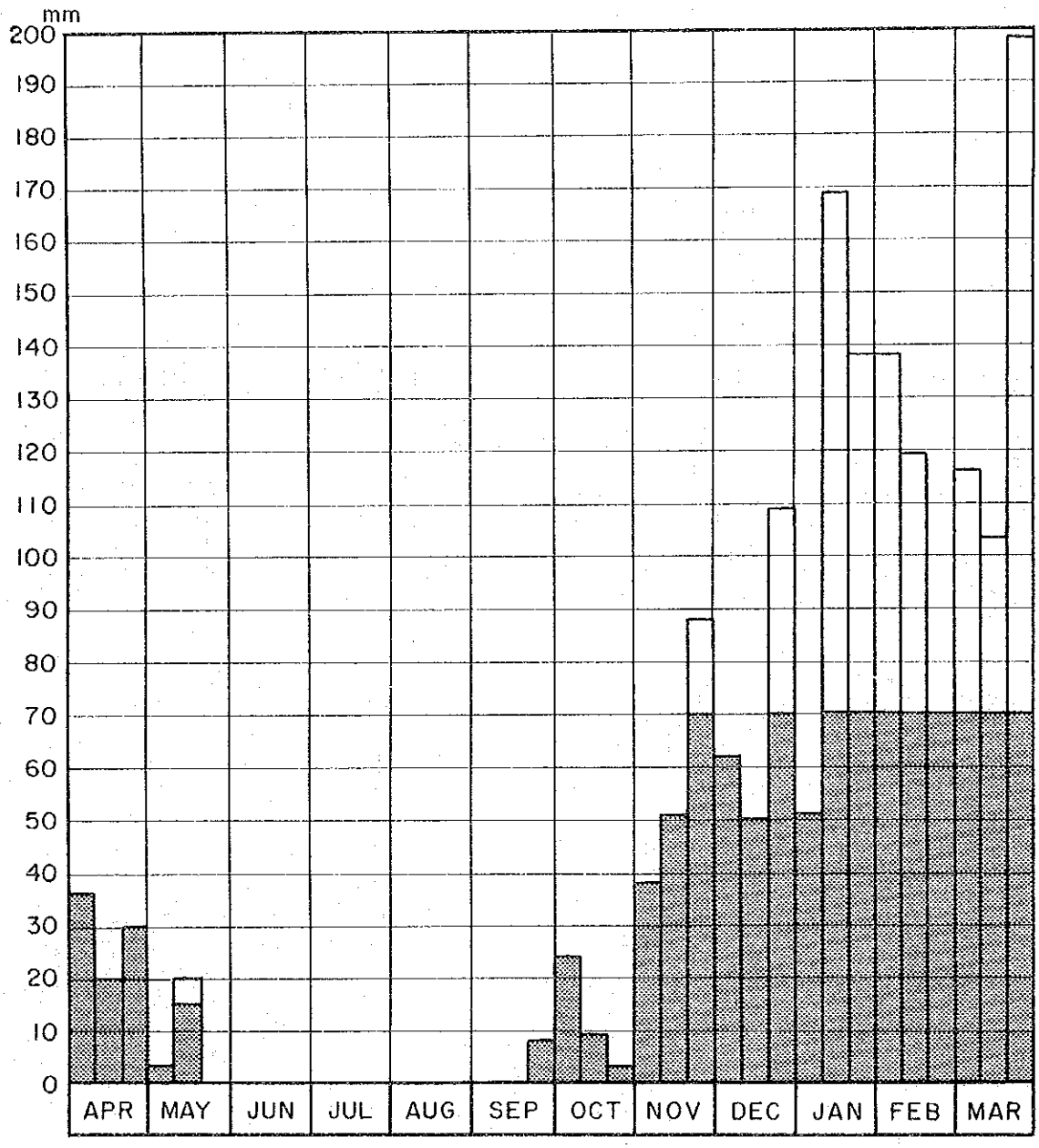


Fig. 2.2.13

Effective Rainfall for Paddy in Every Ten-Day Period

(Denkeng Region) 1967/1968

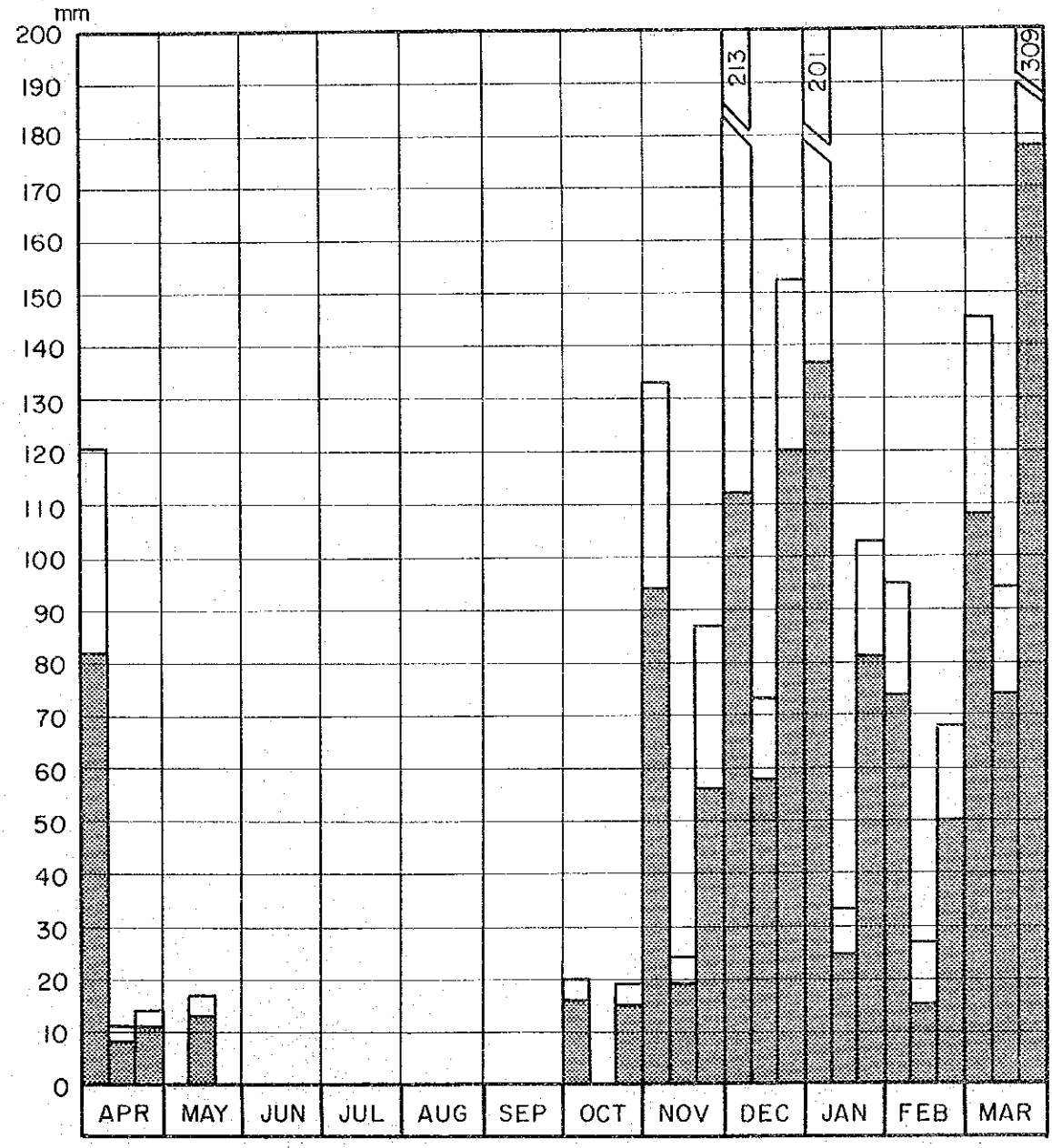
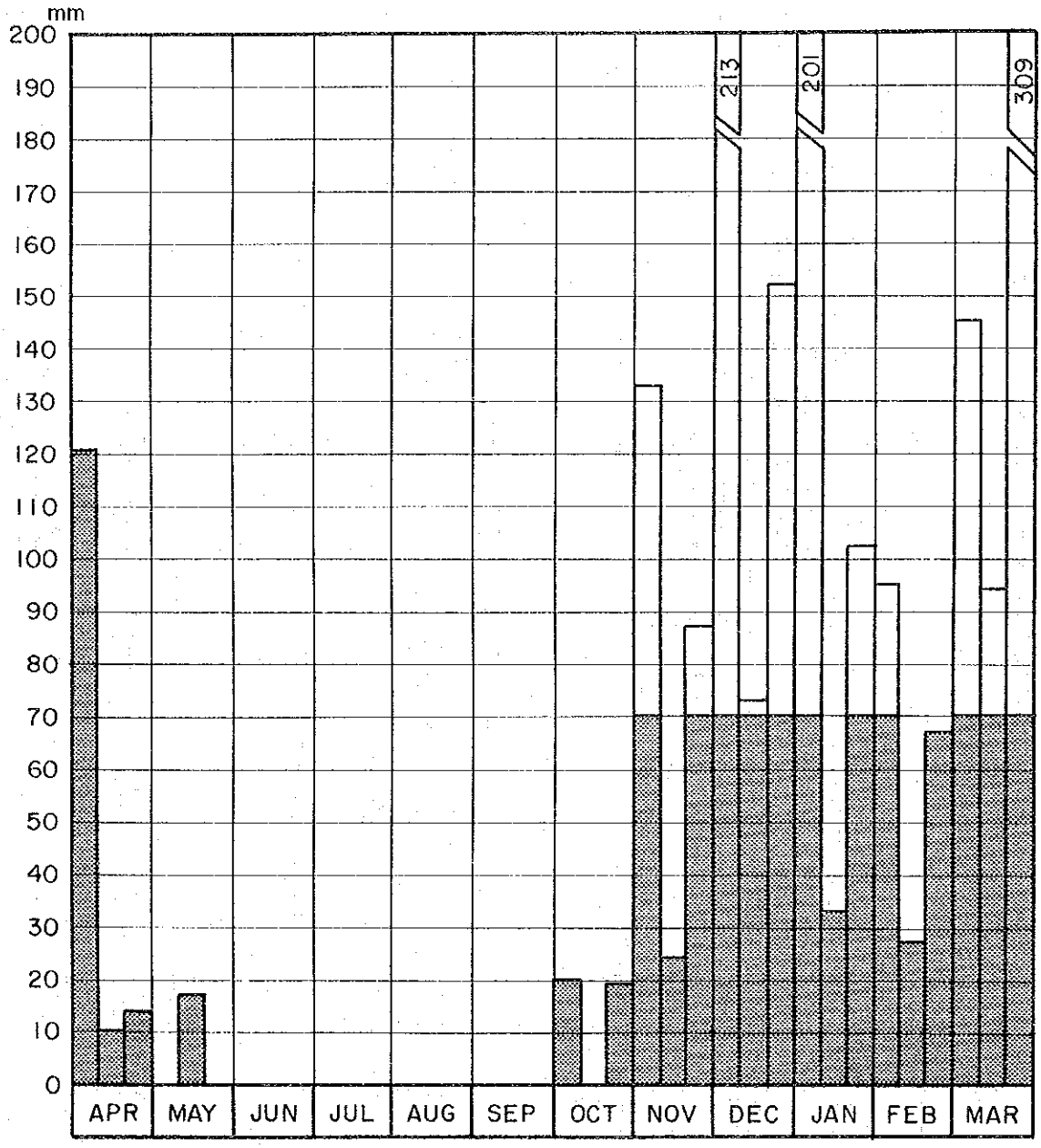


Fig. 2.2.14 Effective Rainfall for Polowijo in Every Ten-Day Period
(Dengkeng Region) 1967/1968



Calculations to obtain 10-day effective rainfall for both paddy-field and sugarcane field have been made for three Regions covered by the Project:

Karanganyar region: Stations at Bekonang, Sukoharjo and Tawansari;

Sragen region: Stations at Bakalan, Mojo and Masaran;

Dengkeng region: Station at Tawansari

Effective rainfall for the design year is as shown in Table 2.2.25 and Figs. 2.2.9 through 2.2.14.

2.2.6 Water Losses

a) Farm waste /1

The magnitude of the allowance to be made for the farm waste depends on a number of physical as well as water management factors.

As paddy field dikes and spill-ways are expected to be better maintained, water distribution will be made more equitable.

Farm waste on paddy field and sugarcane field in the project area is assumed at 10 % and 15 % in dry season and 5 % and 10 % in rainy season, respectively, of the water requirement.

b) Conveyance losses /2

Ponding Method recommended by ADB has been adopted for the estimation of the seepage losses along the channels.

Total seepage losses caused on the way from the intake to the farm have been computed at 11 % of the irrigation requirement for Karanganyar Region, 15 % for Sragen Region, and 13 % for Dengkeng Region.

Evapotranspiration of the weeds growing along the channels and the operational and accidental wastes will be largely controllable by efficient management and maintenance in the future and, therefore, approximately 100 % of the seepage losses has been attributed to such loss as categonized by ADB.

/1 Farm waste is the quantity of water losses on farm due to seepage, leakage, over-application of water and spillage.

/2 Conveyance losses include farm ditch losses.

Table 2.2.26 Calculation Sheet of Conveyance Losses by Ponding Method

1. Seepage rate (silty clay loam) = $0.080m^3/m^2/day$

Intake - T.0.22 in Upper Solo Main Canal (canal ... Type III, L=32 km)

2. Wetted perimeter = 18.6m
3. Wetted area = $18.6m \times 32,000m = 595,200m^2$
4. Seepage loss = $595,200 \times 0.080 = 47,616m^3/day$
   = $0.551m^3/sec$

$$\text{Karanganyar region} = 0.551 \times \frac{10,100ha}{10,100ha + 9,500ha} = 0.284m^3/sec$$

Sragen region = $0.551 - 0.284 = 0.267m^3/sec$

T.0. 22 - T.0. 36 in Upper Solo Main Canal (Canal ... Type VI, L=30 km)

5. Wetted perimeter = 10.5m
6. Wetted area = $10.5m \times 30,000 = 315,000m^2$
7. Seepage loss = $315,000 \times 0.080 = 25,200m^3/day$
   = $0.292m^3/sec$

Dengken Main Canal (Canal ... Type II, L=31 km)

8. Wetted perimeter = 7.1m
9. Wetted area = $7.1 \times 31,000 = 220,100m^2$
10. Seepage loss = $220,100 \times 0.080 = 17,608m^3/day$
    = $0.204m^3/sec$

Secondary Canal (Canal ... Type III, L=8m/ha)

11. Wetted perimeter = 3.8m
12. Wetted area = $3.8 \times 1,000 = 3,800m^2/km$
13. Seepage loss = $3,800 \times 0.080 = 304m^3/day/km$
    = $3.52 \times 10^{-3}\ m^3/sec/km$

Karanganyar region = $3.52 \times 10^{-3} \times 80km = 0.282m^3/sec$

Sragen region = $3.52 \times 10^{-3} \times 77km = 0.271m^3/sec$

Dengkeng region = $3.52 \times 10^{-3} \times 29km = 0.102m^3/sec$

Tertiary and Farmditch (L = 40m/ha)

14. Wetted perimeter = 2.0m
15. Wetted area = $2.0 \times 1,000 = 2,000m^2/km$
16. Seepage loss = $2,000 \times 0.08 = 160m^3/day/km$
    = $1.85 \times 10^{-3}\ m^3/sec/km$

Karanganyar region = $1.85 \times 10^{-3} \times 400km = 0.740m^3/sec$

Sragen region = $1.85 \times 10^{-3} \times 380km = 0.703m^3/sec$

Dengkeng region = $1.85 \times 10^{-3} \times 144km = 0.266m^3/sec$

Total seepage losses

17. Karanganyar region = $0.284 + 0.282 + 0.740 = 1.306m^3/sec$
18. Sragen region = $0.267 + 0.292 + 0.271 + 0.703 = 1.533m^3/sec$
19. Dengkeng region = $0.204 + 0.102 + 0.266 = 0.572m^3/sec$

Rate of seepage loss

20. Karanganyar region = $1.31/(13.0-1.31) = 11\%$
21. Sragen region = $1.53/(11.5-1.53) = 15\%$
22. Dengkeng region = $0.57/(5.0-0.57) = 13\%$

Total conveyance losses		Rate (%)
Karanganyar region	$1.31 \times 2 = 2.62m^3/sec$	$2.62/(13.0-2.62) = 25\%$
Sragen region	$1.53 \times 2 = 3.06m^3/sec$	$3.06/(11.5-3.06) = 36\% \div 35\%$
Dengkeng region	$0.57 \times 2 = 1.14m^3/sec$	$1.14/(5.0-1.14) = 30\%$

Consequently, in calculating the total diversion requirement, 25 % of the irrigation requirement for Karanganyar Region, 30 % for Dengkeng Region, and 35 % for Sragen Region have been added as an aggregate amount of the conveyance losses.

Calculation of conveyance losses is presented in the following Table.

2.2.7 Diversion Requirement and Storage Capacity

The diversion requirement is the total of the irrigation requirement and the water losses in the irrigation system.

The calculations of the unit irrigation requirements, the irrigation requirement and the diversion requirements by the three alternatives in the design year (1967/1968) are shown in Table 2.2.29 to 2.2.60. The results are shown in Table 2.2.64.

The storage capacity required for the Wonogiri reservoir is calculated based on the water balance between the diversion requirement and inflow at the Wonogiri dam site, as shown in Tables 2.2.61 to 2.2.63.

The above results are presented in Fig.2.2.15 to 2.2.18.

Besides the alternative 4/1 in the design year and the three alternatives in 1961/1962 are calculated for reference, the results are shown in Table 2.2.65, Fig.2.2.19, Table 2.2.66 and Fig.2.2.20.

Table 2.2.27 Peak Diversion Requirement (ALT-3)

Region	Area (ha)	Div.Req. (m^3/sec)	Unit (l/sec/ha)	Month
Karanganyar	10,100	12.912	1.28	Early Sep.
Sragen	9,500	11.357	1.20	Middle Sep.
Dengkeng	3,600	5.184	1.44	Early Sep.
Whole area	23,200	29.426	1.27	Early Sep.

/1: The alternative 4 is a middle course of ALT-3 and ALT-2. (2/3 area ... ALT-3, 1/3 area ... ALT-2)