THE REPUBLIC OF INDONESIA

MINISTRY OF PUBLIC WORKS AND ELECTRIC POWER

DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT

FEASIBILITY STUDY
ON
THE WAY RAREM IRRIGATION PROJECT

— STUDY REPORT —

MARCH 1976

JAPAN INTERNATIONAL COOPERATION AGENCY

TOKYO

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CONTENTS OF STUDY REPORT

PART I. CLIMATE

1.1 General

Way Rarem Area is located around 4° ∿ 5° of south latitude and belongs to the equator climatic zone. On account of this location, the Area is affected by the westerly wind (the NE seasonal wind) and the trade wind (the SE seasonal wind), therefore, the Area has the change of wet season and dry season. The NE seasonal wind occurs from December to March and it causes much rainfall in the area.

The Way Rarem Area is roughly surrounded by the next four meteorological station, namely, Menggala (near the lower benefited area, EL 30m), Bandarjaya (near Way Seputih, EL48m), Kasui (upstream of Way Umpu, EL200m) and Pajarbulan (upstream of Way Besai, EL810m).

The meteorological items which these stations observe are temperature, humidity, rainfall, wind, sunshine, evaporation and others, but the items commonly observed at these stations are air temperature, humidity and rainfall.

The annual ranges of each meteorological item except rainfall are generally small in the torrid zone. Therefore, as for the irrigation planning, the necessary meteorological factors in point of agriculture are presummed from the data of two stations locating at Menggala and Bandarjaya which are adjacent to the benefited area.

1.2 Temperature

Mean monthly air temperatures of each station are as follows:

Table 1-2-1 Mean Monthly Temperature

°C

Station	Period	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Menggala	1972∿74	26.8	27.0	27.2	27.6	27.5	27.2	27.3	27.5	27.3	27.7	28.0	27.2
Bandarjaya	1971∿74	26.4	26.7	27.0	27.7	27.5	26.8	27.1	27.1	26.9	27.3	27.3	27.1
Kasui	1974	-	-	26.2	26.5	26.1	25.3	24.5	24.7	25.2	25.3	25.0	24.1
Pajarbulan	1974	-	-	21.9	22.7	22.5	20.7	19.4	19.8	20.6	20.7	20.9	20.4

Mean monthly air temperature of benefited area which is obtained by the mean value of each year at Menggala and Bandarjaya is as follows:

Table 1-2-2 Mean Monthly Temperature in the Benefited Area

°C

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
27.1	26.6	26.8	27.1	27.7	27.3	26.9	27.1	27.2	26.9	27.4	27.3	27.0

1.3 <u>Rainfall</u>

Mean monthly rainfalls at each station are shown in Table 1.3.1. In the hilly district adjacing the benefited area, the annual rainfall is averagely 2500mm, on the other hand, it is about 2800mm in the catchment areas of rivers. The rainfall of 70% (about 1700mm) falls in the benefited area from November to April which can be referred to as wet season.

Table 1-3-1 Mean Monthly Rainfall

No.	Station	El.	Period	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Year	Rainy Season Nov-Apr	Dry Season May-Oct
R244	Menggala	18m	1917-1975	400	321	344	253	161	125	95	79	119	129	250	350	2626	1918	708
R224	Gedong ratu	12	1972-1974	318	313	380	243	285	98	98	87	106	162	206	374	2670	1834	836
R238	Gunung batin	35	1973-1974	273	218	282	214	204	149	58	155	245	172	213	390	2573	1590	983
A10	Tatakaraya	35	1973-1974	168	253	315	194	260	90	116	147	205	151	263	285	2447	1478	969
R122	Kayuparis	35	1972-1974	279	322	467	115	169	81	20	96	147	88	186	326	2296	1695	601
-	DAYA ITOH	50	1972-1975	307	301	278	218	224	86	45	116	152	148	227	360	2462	1691	771
R209	Tl. Buyut	82	1930-1974	341	296	348	321	214	122	95	107	108	168	237	387	2744	1930	814
R220	Ketapang	50	1971-1974	215	188	268	130	171	48	54	77	114	141	288	273	1967	1362	605
R222	Kotabumi	32	1918-1975	347	269	309	249	170	118	98	89	106	148	223	321	2447	1718	729
R205	" (D.P.U)	28	1952-1975	332	290	313	270	186	106	119	99	132	156	279	300	2582	1784	798
R235	Nakau	40	1952-1974	344	280	345	248	198	111	86	65	120	175	234	331	2537	1782	755
R237	Pekurun	70	1973-1975	347	421	140	285	156	37	120	165	256	105	253	245	2530	1691	839
R207	Chahayanegri	100	1972-1974	235	317	262	127	166	93	20	113	114	95	225	207	1974	1373	601
A25	B.K.Kemuning	265	1952-1974	384	362	419	309	252	118	105	87	88	131	237	370	2862	2081	781
R225	Srimenanti	320	1972-1975	596	394	380	286	298	285	99	113	268	195	366	307	3587	2329	1063
R234	Sumberujaya	800	1972-1975	241	268	238	325	315	118	96	142	220	204	273	370	2810	1715	1095
R232	Kebun Tebu	-	1973-1974	118	144	154	527	193	123	212	196	465	345	293	162	2932	1398	1534

(mm)

1.4 Evaporation

Mean monthly evaporations by class A Pan are as follows.

Table 1-4-1 Mean Monthly Evaporation

Station	Period	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Menggala	1972-1974	4.7	4.4	4.8	4.8	4.5	4.3	4.6	4.3	4.7	5.6	5.0	4.8
Bandarjaya	1971-1974	1.8	1.6	1.6	1.7	1.7	1.7	2.4	3.0	3.1	3.3	3.0	2.9
Kasui	1974	-	-	-	-	-	-	4.8	3.9	5.6	4.3	5.4	3.4
Pajarbulan	1974	-	-	-	-	-	6.2	5.1	4.0	4.5	3.7	3.5	4.2

(mm/day)

The records of evaporation observed at each station have big dispersion because the period of observation is short and the gauge has supposedly the instrumental error. From the above table the mean monthly evaporation in the benefited area is considered as 4-5mm/day. The evaporation index calculated by Modified Penman Equation is 4.3mm/day. Accordingly, the yearly evaporation in the benefited area is assumed to be about 1600mm.

1.5 Solar Radiation

The sunshine hours at each station are as follows.

Table 1-5-1 Sunshine Hours

Station	Period	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Menggala	1972-1974	4.4	5.2	5.3	6.0	5.3	5.8	6.5	6.1	5.6	5.4	4.8	4.3
Bandarjaya	1971-1974	5.9	7.0	6.4	6.3	6.4	6.0	8.2	7.3	6.2	6.4	5.5	5.7
Kasui	1974			6.9	7.5	7.3	7.0	6.1	5.6	6.5	6.0	4.9	4.9
Pajarbulan	1974			6.1	6.2	5.8	6.2	4.9	5.6	5.5	4.4	3.6	4.6

(hour/day)

The relative duration of sunshine in the benefited area is assumed by the data at Bandarjaya as follows.

Table 1-5-2 Relative Duration of Sunshine

Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
48	57	53	53	53	54	70	62	53	56	47	39

(Period 1971-73, %)

The yearly sunshine hours at Bandarjaga is as follows

6.4 hr/day x 365 days ≑ 2,300 hr/year

1.6 Others Factors

1.6.1 Relative humidity

Mean monthly relative humidities at each station are as follows:

Table 1-6-1 Mean Monthly Relative Humidity

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Menggala	84	83	83	84	84	84	82	80	79	77	78	84
Bandarjaya	79	81	81	80	82	77	74	78	79	76	77	79
Kasui	-	-	86	88	92	92	87	81	78	80	79	81
Pajabulan	-	-	87	86	88	83	86	89	88	87	87	88

(%)

Mean monthly relative humidity for the calculation of the water requirement is obtained as follows by using the data from 1971 to 1974 at Menggala and Bandarjaya.

Table 1-6-2 Mean Monthly Relative Humidity in the Benefited Area

Relative	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Humidity	81	82	82	83	82	80	77	78	79	77	79	81

(%)

1.6.2 Wind velocity and wind direction

1. Wind velocity

Table 1-6-3 Mean Monthly Wind Velocity

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Menggala	60	54	51	51	52	56	68	68	66	66	53	52
Bandarjaya	-	-	-	-	-	-	-	11	8	9	9	9
Kasui	-	-	-	-	-	-	64	69	68	61	57	52
Pajarbulan	-	-	-	-	-	62	54	55	49	62	75	57

(Km/day)

2. Wind direction

Table 1-6-4 Wind Direction

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Kasui							SE	SE	SE	SE		
Pajarbulan						NE	NE	NE	NE			

The data at Menggala is applied to the wind velocity in the benefited area. The yearly mean wind velocity is about 58 Km/day. There are few observation data about wind direction. Therefore, the special characteristics are not clear, but it is generally assumed that the benefited area has NW wind in wet season and SE in dry season from the general tendency in the South Sumatora.

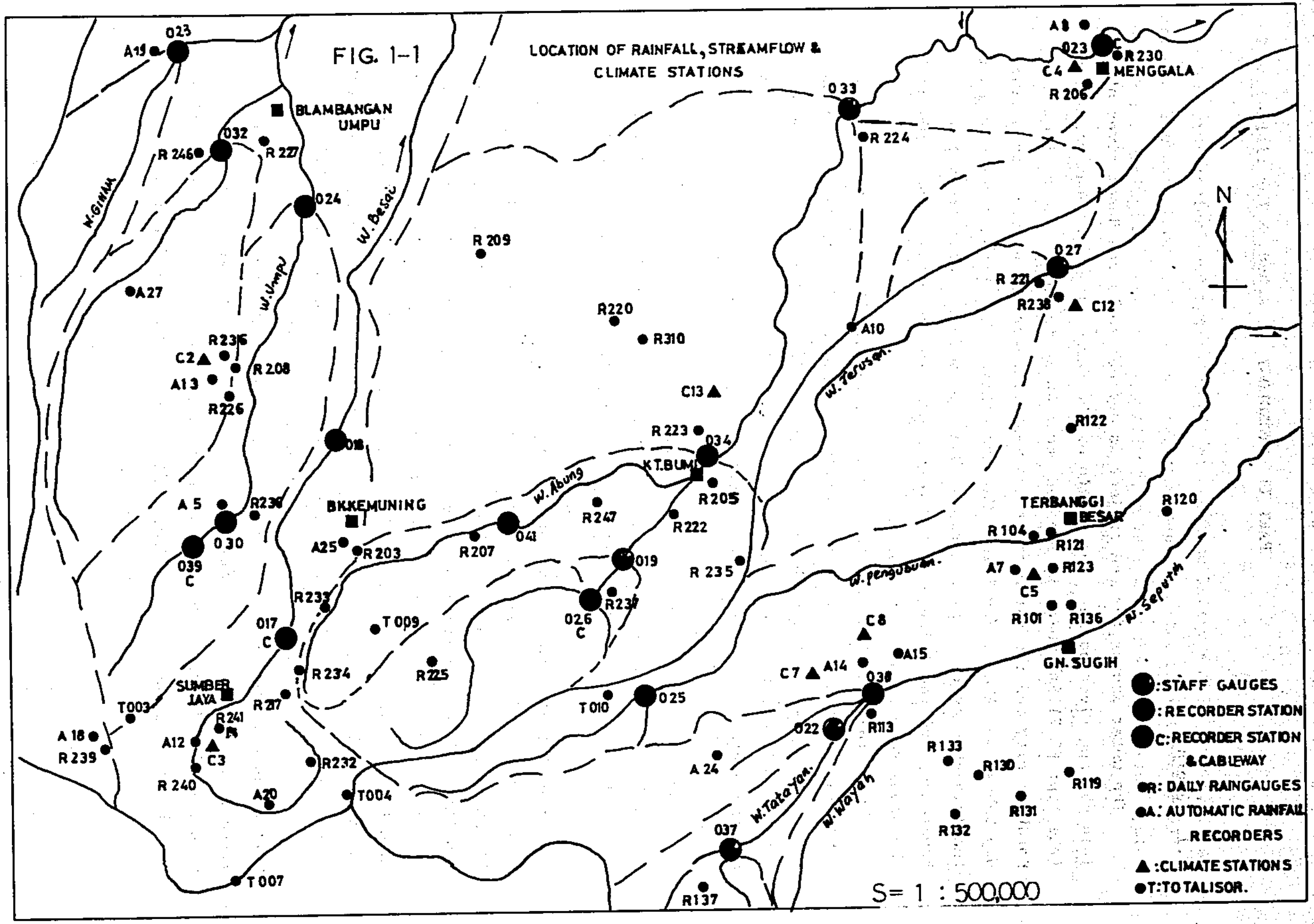


FIG. 1-1

LOCATION OF RAINFALL, STREAMFLOW & CLIMATE STATIONS

PART II HYDROLOGY

2.1 General

The water source for the project is decided to be the Rasem river of the Tulangbawang river basin. The origin of the Rarem river is Tebak mountains (the top: EL 2115m) which is located about 40 km in the southwest from Kotabumi city and the Rarem river has many tributaries, namely, Way Galing, Way Sabuk, Way Abung, Way Tulung Mas and others. The Rarem river changes to the Tulangbawang river at Pagerdowo about 10 km in the downstream from Panaragan, and the Tulangbawang river reaches to the estuary about 100 km in the downstream from Pagerdowo.

The total length of the Rarem river (including Way Kiri which is the river in the downstream from the confluence with Way Tulung Mas to Pagerdowo) is about 154 km and the slope of the river bed is averagely 1/150. When the river is divided into the mountainous, hilly and flat parts, the length (L) and the average slope (I) of the river are as follows.

Mountainous part	(as far as Pekurun):	L = 44 km, I = 1/40
Hilly part	(as far as Kotabumi):	L = 20 km, I = 1/1000
Flat part	(as far as the confluence):	L = 90 km, I = 1/8000

The proposed dam site is located at Pekurun about 16 km in the southwest from Kotabumi city and the catchment area is 328 km^2 which mainly consists of 195 km^2 for the Rarem river and 135 km^2 for the Galing river. The plantation condition of the catchment area consists of forest and a part of grass land.

The conservation of the catchment area is managed to the local government except the small part under the Kekutanan office. Since 1969, however, the cutting of the tree has been rapidly sprawled and it is said that 70 - 80% of the catchment area has no function as the reserved forest in 1974.

The yearly rainfall is about 2500mm at Kotabumi and about 2800mm at Bekitkemuning. Therefore, it can be considered that there is the yearly difference of about 300mm between the flat area and the mountainous part. Each specific discharge of the catchment areas is respectively 0.05 $m^3/sec/km^2$ for the mountainous area and 0.03 $m^3/sec/km^2$ for the benefit area.

2.2 Materials and Methods

The hydrological and meteorogical data were collected mainly from P.3.S.A. office. The data from 1918 can be used with respect to the monthly rainfall, but other hydrological data are generally from 1971 when the observation system was arranged under the Lampung Hydrological Network Program. The discharge observation about Way Sekampung, Way Seputeh and other rivers, however, has been carried out from 1968 and the data for 7 years can be used about these rivers.

2.2.1 River discharge

Non-excess probable monthly discharges of 1/5 year (20%) are assumed from the discharge data for 4 years at Pekurun of the Rarem river.

1. Data used

1) 10 days and monthly discharge at Pekurun

8, Apr. 1971 - 19, Sep. 1972 : estimated, 14 month

20, Sep. 1972 - 31, Dec. 1974 : observed, 27 month

2) 10 days and monthly rainfall at Kotabumi

May 1918 - Dec. 1941 : monthly rainfall

Jan. 1951 - Dec. 1974 : 10 days and monthly rainfall

3) 10 days and monthly rainfall at Bekitkemuning

Jan. 1952 - Dec. 1958 : monthly rainfall

Jan. 1959 - Jun. 1968 : 10 days and monthly rainfall

Jan. 1972 - Jul. 1973 : 10 days and monthly rainfall

Jul. 1974 - Dec. 1974 : monthly rainfall

4) Monthly rainfall in the catchment area of vicinity

Srimenanti	Jan. 1972 - Dec. 1973, Jul. 1974 - Dec. 1974
Chahayanegri	Jan. 1972 - Sep. 1974
Pekurun	Aug. 1973 - Dec. 1974
Lubuay Atas	Jun. 1973 - Dec. 1974
Talang Bayur	Jan. 1974 - Dec. 1974
Tangkit Inas	Jan. 1974 - Dec. 1974
Kebun Tebu	Jan. 1974 - Dec. 1974

2. Method of assumption

1) The areal rainfall of the catchment area was calculated by using the monthly rainfall data of the stations surrounding the area. The monthly run off coefficient of the catchment area was assumed by this areal rainfall and the monthly discharge at Pekurun.

2) Monthly and every 10 days correlations between rainfall and discharge were ascertained on the following groups.

   a. Monthly correlation : discharge at Pekurun and areal rainfall

   b. -ditto- : -ditto- and rainfall at Kotabumi

   c. -ditto- : -ditto- and rainfall at Bekitkemuning

   d. 10 days correlation : -ditto- and rainfall at Kotabumi

   e. -ditto- : -ditto- and rainfall at Bekitkemuning

3) In the above groups, the connections of the discharge at Pekurun with the areal rainfall and the rainfall at Bekitkemuning were turned out to have considerable correlations at monthly level.

4) Accordingly, the monthly rainfall at Bekitkemuning which has the rainfall data for a considerable period was changed to the areal rainfall by using the regression line and the shape of Tank was studied by using the areal rainfall.

5) As there was a high correlation between the discharges calculated by this Tank and the discharges observed, the discharges for the period which has the rainfall data were obtained by using the Tank.

6) The non-excess probable monthly discharge of 1/5 year at the proposed dam site was assumed by Thomas plot of the monthly discharges obtained in accordance with the above procedure.

2.2.2 Flood discharge

The flood discharge at the proposed dam site was obtained by applying the rational formula to the probable daily rainfall at Bekitkemuning.

The probability of the design flood discharge is taken as 1/1000 year for rockfill dam. It is generally said that the discharge calculated by the rational formula shows excessive value. Therefore, the observed data and designed examples in the other area were checked.

2.3 Rainfall Analysis

2.3.1 Probable rainfall

According to the results of plotting to logarithmic probability graph using Thomas Plot method, probable rainfall of 1/5 year at Kotabumi and Bekitkemuning are as follows.

Table 2-3-1 Probable Rainfall of 1/5 Year

	Kotabumi	Bekitkemuning
Jan.	252 mm/month	255 mm/month
Feb.	190	260
Mar.	236	290
Apr.	156	240
May	115	130
Jun.	54	54
July	42	37
Aug.	32	16
Sep.	36	25
Oct.	69	55
Nov.	126	130
Dec.	225	280
Total	1,533	1,772

Table 2-3-2 Yearly Rainfall at Bekitkemuning

n=16	year	Rainfall	$1-\frac{i}{n+1}$
		mm	
1	1955	3,674	0.94
2	1959	3,528	0.88
3	1964	3,371	0.82
4	1966	3,320	0.76
5	1956	3,285	0.71
6	1953	3,009	0.65
7	1954	2,995	0.59
8	1952	2,887	0.53
9	1967	2,670	0.47
10	1960	2,658	0.41
11	1957	2,591	0.35
12	1962	2,567	0.29
13	1963	2,292	0.24
14	1965	2,225	0.18
15	1961	2,078	0.12
16	1972	1,741	0.06
mean		2,806	

Table 2-3-3

Monthly Rainfall at Bukitkemuning

n=19	$1-\frac{i}{n+1}$	Jan.	Feb.	Mar.	Apr.	May	July	Nov.	n=18	$1-\frac{i}{n+1}$	Jun.	Aug.	Sep.	Oct.	Dec.
1	0.95	637	616	617	496	428	358	463	1	0.95	225	223	325	313	520
2	0.90	607	567	583	434	395	261	416	2	0.89	224	159	191	284	520
3	0.85	507	523	575	363	386	152	324	3	0.84	203	141	178	257	506
4	0.80	504	432	567	359	382	146	322	4	0.79	196	136	164	231	497
5	0.75	479	424	523	347	380	131	317	5	0.74	171	125	133	209	443
6	0.70	471	417	523	346	377	127	314	6	0.68	151	123	122	184	437
7	0.65	453	407	478	345	318	117	291	7	0.63	144	118	104	184	387
8	0.60	406	374	467	337	302	104	281	8	0.58	142	107	86	139	379
9	0.55	370	356	449	334	259	97	240	9	0.53	101	101	62	128	364
10	0.50	368	329	444	319	238	94	240	10	0.47	92	86	58	89	360
11	0.45	344	315	425	318	210	84	227	11	0.42	81	82	51	88	312
12	0.40	343	313	346	299	210	75	194	12	0.37	80	65	48	81	309
13	0.35	339	311	329	256	190	65	179	13	0.32	78	50	33	81	308
14	0.30	338	299	328	253	164	60	161	14	0.26	76	32	26	63	304
15	0.25	281	298	318	247	159	52	156	15	0.21	65	18	6	19	297
16	0.20	266	251	311	238	139	42	116	16	0.16	56	4	0	0	268
17	0.15	239	220	297	238	111	28	108	17	0.11	20	2	0	0	236
18	0.10	216	214	212	212	84	5	82	18	0.05	14	0	0	0	214
19	0.05	135	207	172	137	50	1	71							
Total		7303	6873	7964	5878	4782	1999	4502	Total		2119	1572	1587	2350	6661
Mean		384	362	419	309	252	105	237	Mean		118	87	88	131	370

Fig. 2-3-1 Yearly rainfall at Bekitkemuning

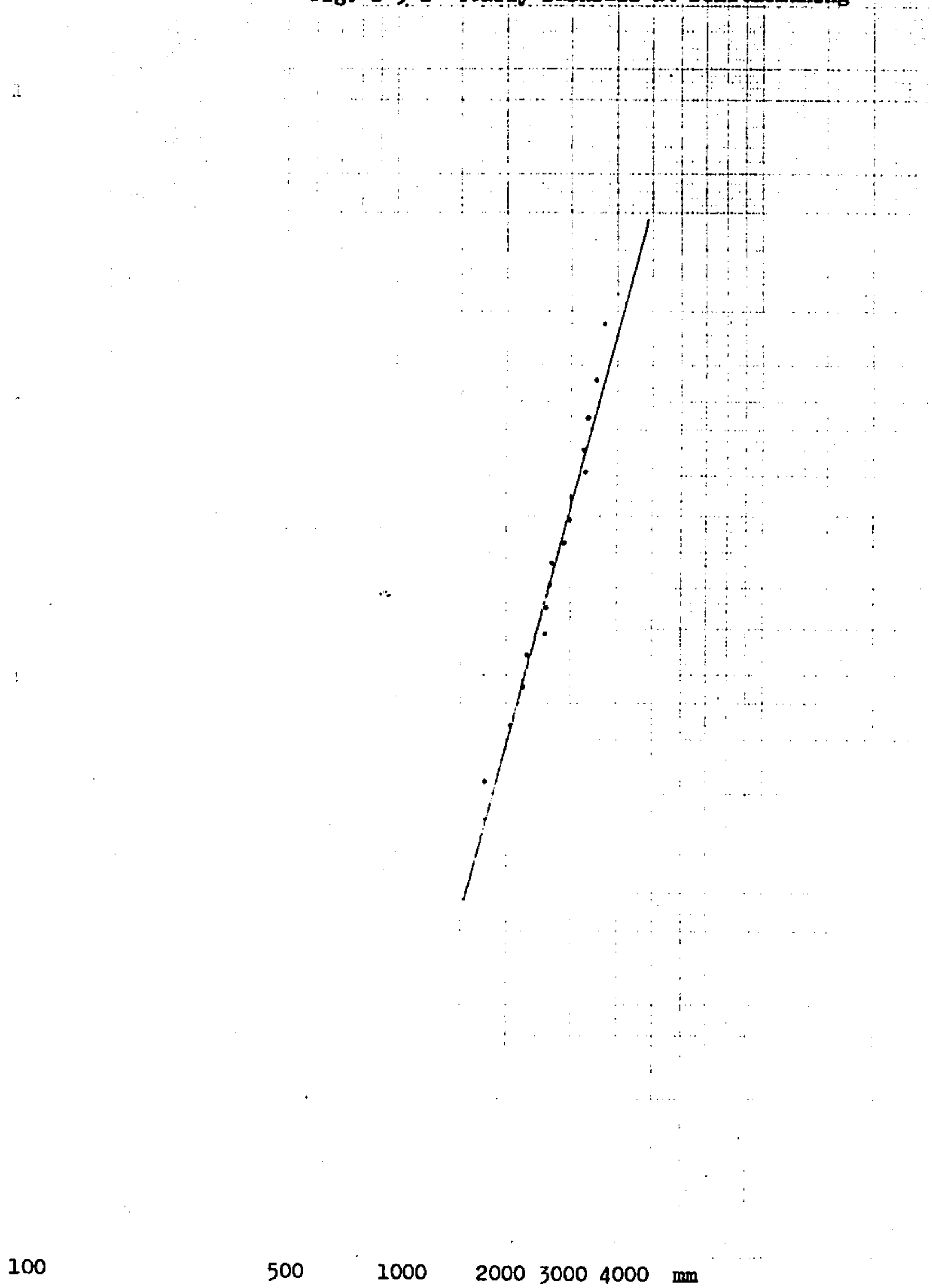


Table 2-3-1 and 2-3-3 give the monthly rainfalls of the 1 in 5 year probability at both places and Table 2-3-2 shows the probable yearly rainfalls at Bekitkemuning. The yearly rainfall of the 1 in 5 year probability is respectively 2100mm at Kotabumi and 2250mm at Bekitkemuning.

2.3.2 Rainfall in the catchment area

Monthly areal rainfalls which are calculated by the data for 3 years (1972 - 1974) of the rainfall stations in the vicinity of the catchment area are shown in Table 2-3-4. The calculation depends on the average of the rainfalls at each station because of a few data.

Yearly rainfall is 2400mm to 2900mm and it is more than the yearly rainfalls at Kotabumi and Bekitkemuning in the same year by 300mm to 900mm.

Considering from the correlation between the monthly rainfalls at Bekitkemuning and the areal rainfalls for 3 years, the monthly rainfall in the catchment area is assumed to be 1.2 times of the monthly rainfall at Bekitkemuning. Therefore, the yearly rainfall of 1/5 year probability in the catchment area is taken to be about 2700mm in comparison with that of Bekitkemuning.

Table 2-3-4

Monthly Rainfall of Catchment Area

STA.	No.	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Srimenanti	R225	1972	738	367	367	280	344	0	3	15	0	20	236	207	2577
Chahayanegri	R207	1972	431	344	501	196	108	36	0	85	6	4	251	214	2176
Mean			585	356	434	238	226	18	2	50	3	12	244	211	2379
Srimenanti	R225	1973	475	558	302	388	396	285	-	64	303	234	511	295	-
Chahayanegri	R207	"	159	309	184	55	237	120	10	212	151	186	198	199	2020
Pekurun	R237	"	-	-	-	-	-	-	-	213	248	111	307	229	-
Lebuay Atas	T004	"	-	-	-	-	-	192	53	205	431	138	190	130	-
Mean			317	434	243	222	317	199	32	174	283	167	302	213	2903
Srimenanti	R225	1974	-	-	-	-	-	-	164	259	501	332	350	418	-
Chahayanegri	R207	"	116	297	101	130	154	124	51	42	184	-	-	-	-
Pekurun	R237	"	286	373	245	287	153	37	120	117	263	99	199	260	2439
Lebuay Atas	T004	"	-	121	← 525 →		210	140	327	255	280	306	201	363	-
Talang Bayur	T009	"	237	187	200	← 375 →		188	280	200	159	260	413	239	2738
Tangkit Inas	T010	"	293	262	(300)	(340)	(360)	(200)	(110)	(100)	251	60	290	368	2934
Kebun Tebu	R232	"	118	144	154	527	193	114	281	281	465	331	344	225	3177
Mean			210	231	200	321	214	134	190	179	300	231	300	312	2822

2.3.3. Maximum daily rainfall

The past maximum daily rainfall is 208mm/day at Kotabumi (1919-1974) and 210mm/day at Bekitkemuning (1952-1974) as listed in Table 2-3-6 and 2-3-8.

The next results are obtained by ploting the past daily rainfall on the probability graph.

Table 2-3-5 Probable Maximum Daily Rainfall

Probability	Kotabumi	B.T.Kemuning
1/2 year	110 mm/day	120 mm/day
1/5	140	150
1/10	160	175
1/20	180	190
1/50	205	220
1/100	220	235
1/200	240	255
1/500	265	280
1/1000	280	295

Table 2-3-6 Past Maximum Daily Rainfall at Kotabumi 225 a Station

Year	Month	Day	Rainfall	Year	Month	Day	Rainfall
			mm				mm
1918			-	1951	Oct.	10	121
1919	Jan.		109	1952	May	18	129
1920	Jan.		113	1953	Jan.	17	102
1921	Sep.		110	1954	Apr.	7	135
1922	Feb.		90	1955	Oct.	19	129
1923	Oct.		88	1956	Sep.	5	91
1924	Jan.		95	1957	Jul.	3	114
1925			-	1958	Dec.	24	153
1926	Aug.		112	1959	Nov.	29	133
1927	Apr.		162	1960	Jan.		109
1928	Feb.		72	1961	Aug.	1	208
1929	Dec.		147	1962	Oct.	8	117
1930	Oct.		162	1963	Jan.	19	115
1931	Feb.		100	1964	Dec.	6	153
1932	Jan.		135	1965	Jan.	2	56
1933	May		102	1966	Nov.	30	82
1934	Jun.		142	1967	Dec.	20	90
1935	Mar.		84	1968	Nov.	11	152
1936	Dec.		110	1969	Mar.	6	94
1937	Jan. July		72	1970	Feb.	19	183
1938	May		80	1971	Oct.	28	120
1939			-	1972	Dec.	26	62
1940	Feb.		111	1973			-
1941	Feb.		68	1974	Nov.	27	108

Table 2-3-7 Probable Daily Rainfall at Kotabumi by Thomas Plot, 1918 - 1974

n	$\frac{i}{n+1}$	Daily Rainfall	Period of Record		n	$\frac{i}{n+1}$	Daily Rainfall	Period of Record	
		mm					mm		
1	0.02	208	1961	Aug.	25	0.56	109	1919	Jan.
2	0.04	183	1970	Feb.	26	0.58	109	1960	Jan.
3	0.07	162	1927	Apr.	27	0.60	108	1974	Nov.
4	0.09	162	1930	Oct.	28	0.62	102	1933	May
5	0.11	153	1958	Dec.	29	0.64	102	1953	Jan.
6	0.13	153	1964	Dec.	30	0.67	100	1931	Feb.
7	0.16	152	1968	Nov.	31	0.69	95	1924	Jan.
8	0.18	147	1929	Dec.	32	0.71	94	1969	Mar.
9	0.20	142	1934	Jun.	33	0.73	91	1956	Sep.
10	0.22	135	1932	Jan.	34	0.76	90	1922	Feb.
11	0.24	135	1954	Apr.	35	0.78	90	1967	Dec.
12	0.27	133	1959	Nov.	36	0.80	88	1923	Oct.
13	0.29	129	1952	May	37	0.82	84	1935	Mar.
14	0.31	129	1955	Oct.	38	0.84	82	1966	Nov.
15	0.33	121	1951	Oct.	39	0.87	80	1938	May
16	0.36	120	1971	Oct.	40	0.89	72	1928	Feb.
17	0.38	117	1962	Oct.	41	0.91	72	1937	Jan.Jul.
18	0.40	115	1963	Jan.	42	0.93	68	1941	Feb.
19	0.42	114	1957	Jul.	43	0.96	62	1972	Dec.
20	0.44	113	1920	Jan.	44	0.98	56	1965	Jan.
21	0.47	112	1926	Aug.					
22	0.49	111	1940	Feb.	Total		5,020		
23	0.51	110	1921	Sep.	Mean		114		
24	0.53	110	1936	Dec.					

Note; Period of 1925, 1939 and 1973 are excluded for the shortage of data.

Fig. 2-3-2 Daily rainfall at Kotabumi

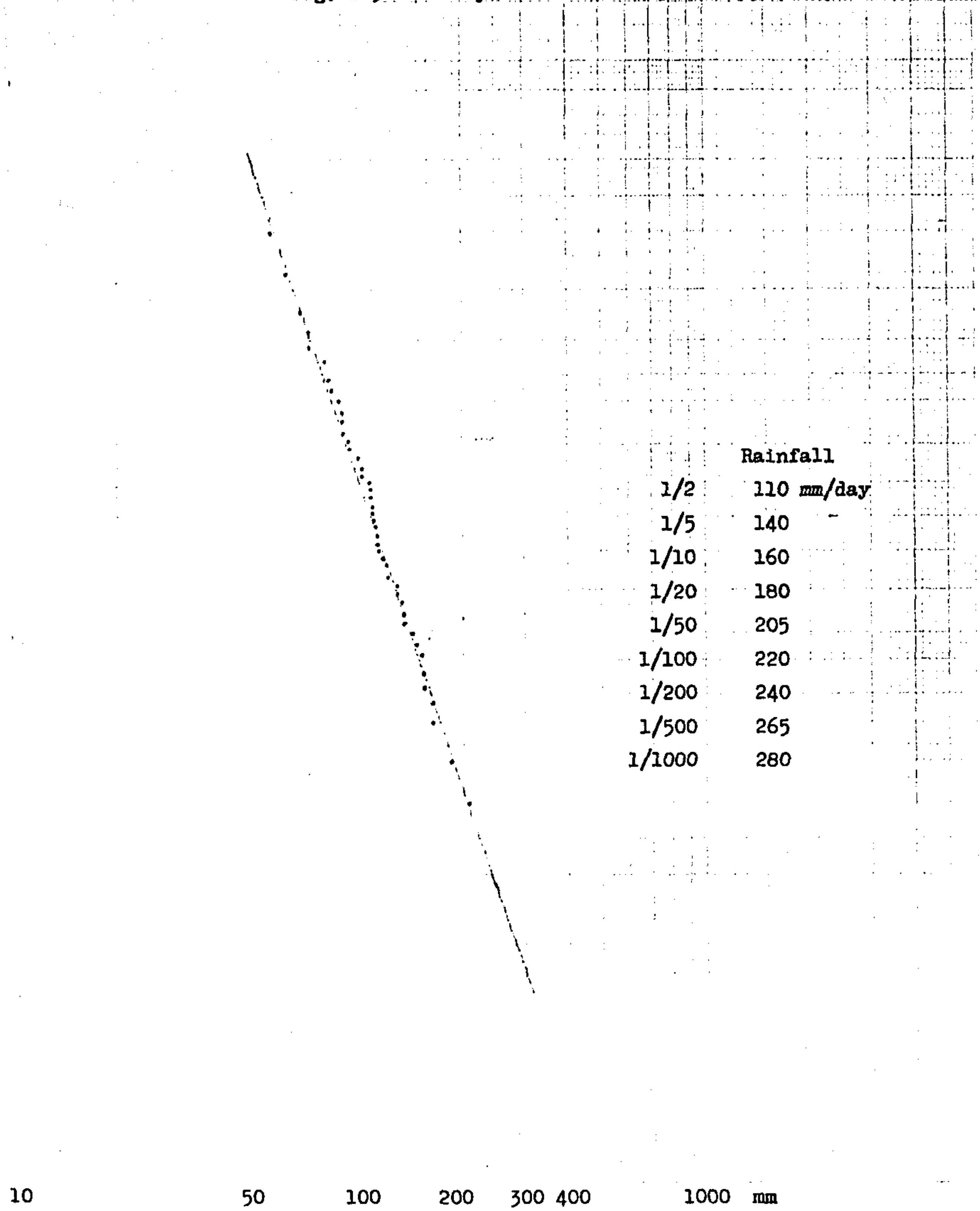
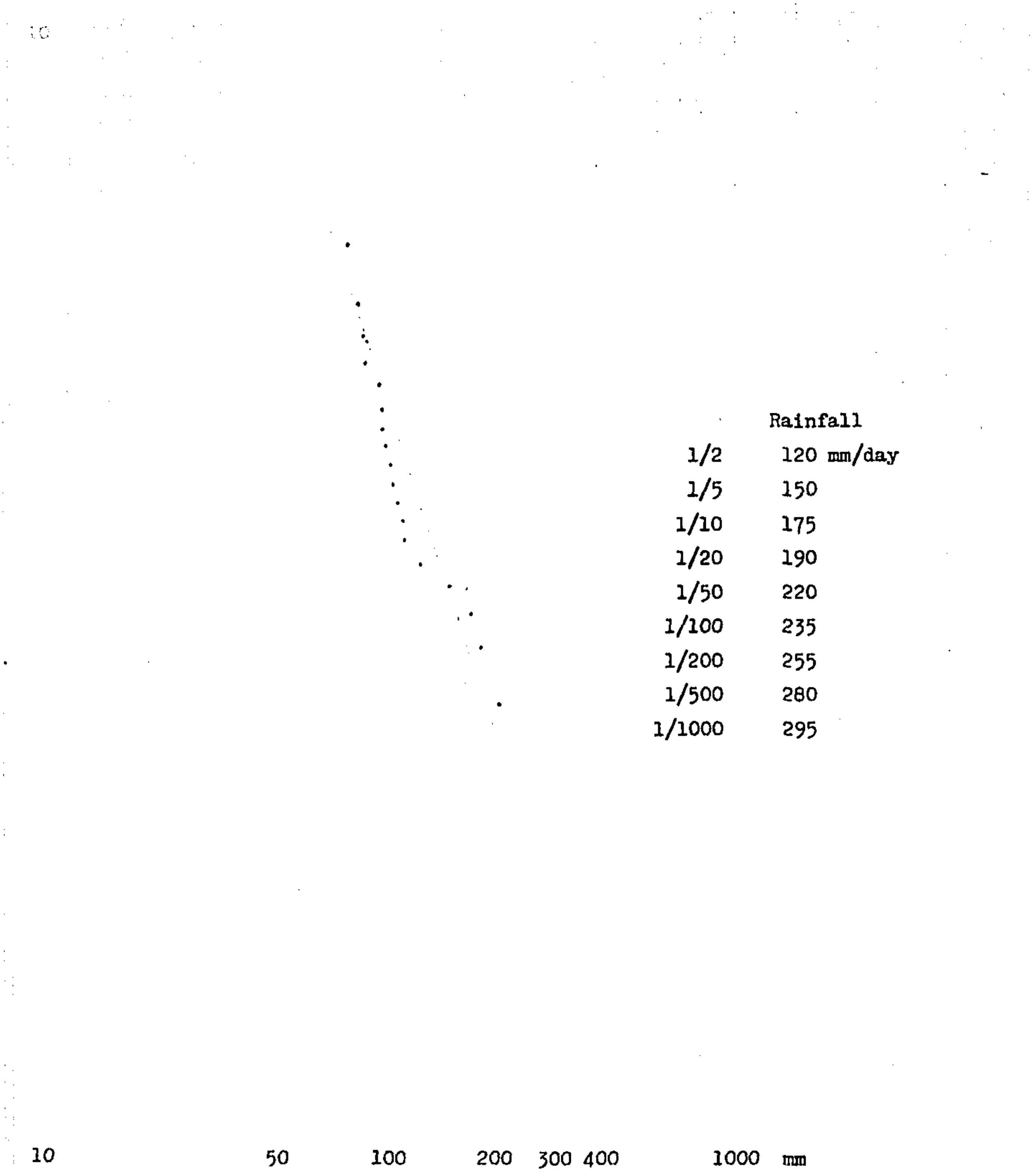


Table 2-3-8 Past Maximum Daily Rainfall at Bekitkemuning

Year	Month	Day	Rainfall	n	$\frac{i}{n+1}$	Daily Rainfall	Period of Record	
			mm			mm		
1952	Jan.		86	1	0.05	210	1967	Feb.
1953	Jan.		105	2	0.11	186	1963	Mar.
1954	Dec.		78	3	0.16	174	1961	Jan.
1955	Mar.		96	4	0.21	151	1968	Mar.
1956	Feb.		113	5	0.26	125	1962	Nov.
1957	Jan.		84	6	0.32	113	1956	Feb.
1958	Apr.		109	7	0.37	112	1964	Sep.
1959	Dec.	25	100	8	0.42	109	1958	Apr.
1960	Dec.	20	98	9	0.47	105	1953	Jan.
1961	Jan.	8	174	10	0.53	104	1965	Dec.
1962	Nov.	29	125	11	0.58	100	1959	Dec.
1963	Mar.	3	186	12	0.63	98	1960	Dec.
1964	Sep.	8	112	13	0.68	98	1966	Aug.
1965	Dec.	25	104	14	0.74	96	1955	Mar.
1966	Aug.	7	98	15	0.79	87	1972	May
1967	Feb.	17	210	16	0.84	86	1952	Jan.
1968	Mar.	29	151	17	0.89	84	1957	Jan.
1972	May	21	87	18	0.95	78	1954	Dec.
1973			-	Total		2,116		
1974			-	Mean		118		

Fig. 2-3-3 Daily rainfall at Bekitkemuning



	Rainfall
1/2	120 mm/day
1/5	150
1/10	175
1/20	190
1/50	220
1/100	235
1/200	255
1/500	280
1/1000	295

2.4 Streamflow analysis

2.4.1 Daily and monthly discharges

1. Discharge record.

Daily discharge at the confluence of Way Rarem and Way Galing which is located about 450m in the upstream of the dam site has been observed by P.3.S.A. office from Sep. 1972 and the discharge data at the same place can be assumed by using the water level record at Tanjunkemala which was observed by DPUTL for a period from Apr. 1971 to Sep. 1972. The following table shows the above record.

Table 2-4-1

Monthly discharge at Pekurun in m^3/S

	1971	1972	1973	1974	Mean
Jan.	-	41.80	10.59	15.66	22.68
Feb.	-	21.40	13.62	22.50	19.17
Mar.	-	33.60	24.64	16.27	24.84
Apr.	28.60	20.30	20.16	21.02	22.52
May	17.60	21.10	19.54	14.64	18.22
Jun.	12.90	11.50	14.48	7.75	11.66
July	10.10	6.70	8.16	7.73	8.17
Aug.	7.60	6.10	7.74	9.00	7.61
Sep.	6.80	4.80	12.59	10.47	8.67
Oct.	8.90	3.73	9.17	11.60	8.35
Nov.	19.40	4.78	12.72	12.54	12.36
Dec.	32.10	7.80	37.26	19.08	24.06
Total		183.61	190.67	168.26	188.31
Year		15.30	15.89	14.02	15.69

From the table the yearly runoff is as follows:

$15.69 m^3/s \times 365 \text{ days} \times 86{,}400 \text{ sec} = 494{,}800{,}000 m^3/\text{year}$

$494{,}8000{,}000 m^3 \div 328 \text{ km}^2 = 1{,}509 \text{mm/year}$

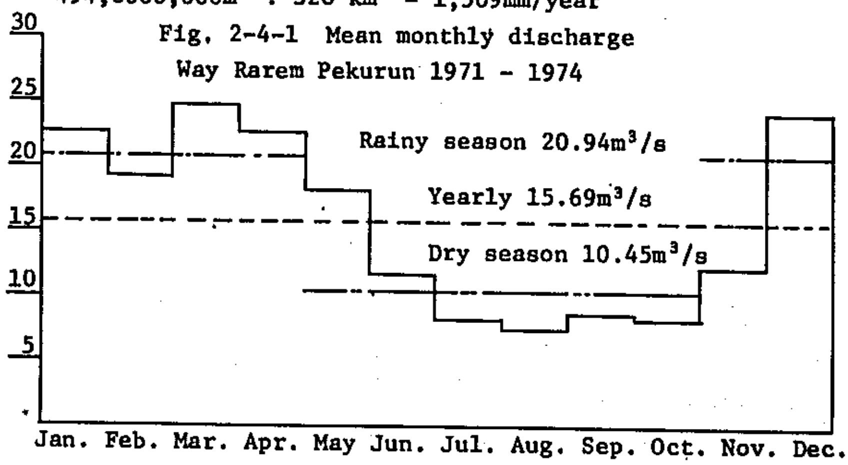
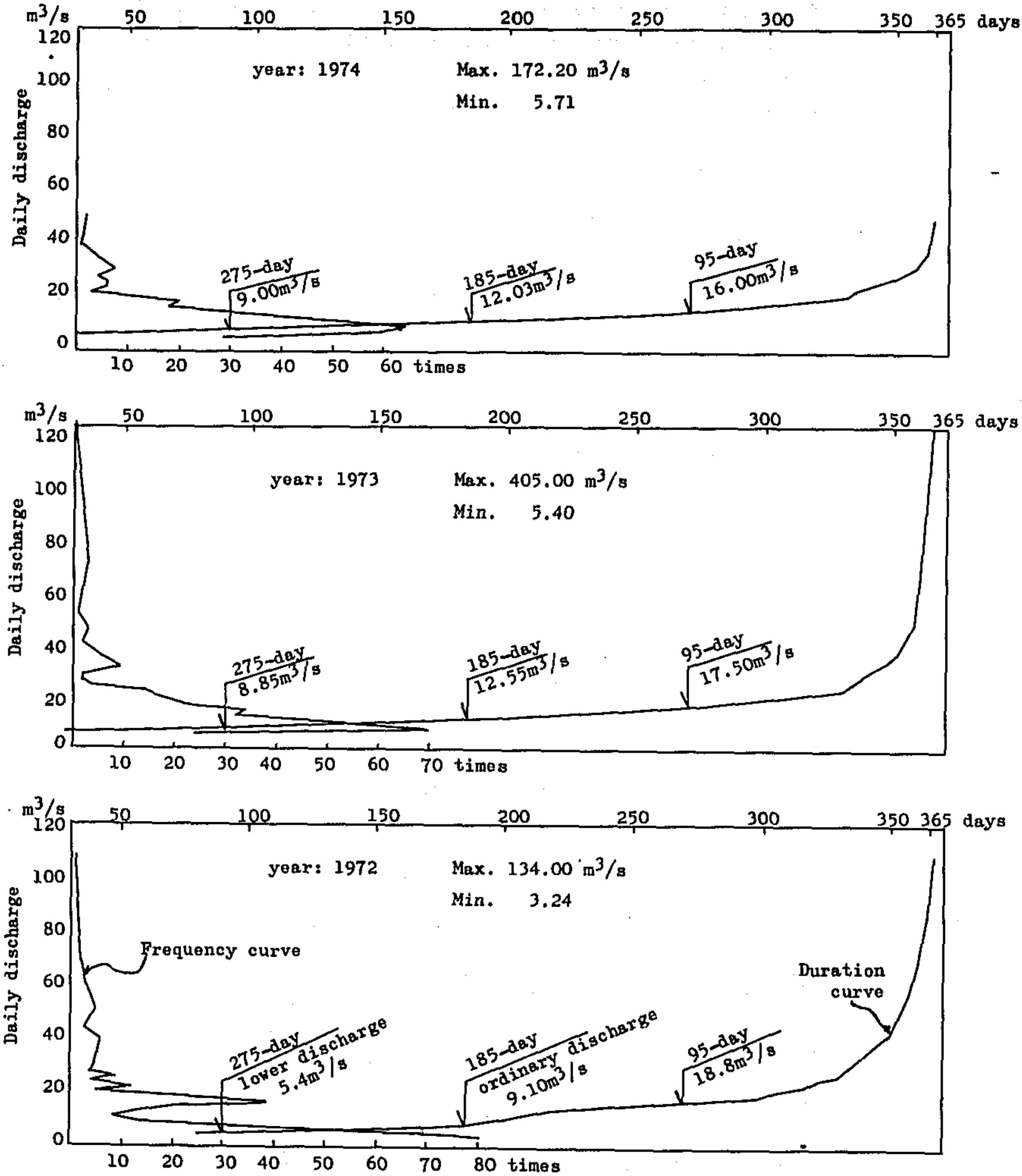


Fig. 2-4-1 Mean monthly discharge
Way Rarem Pekurun 1971 - 1974

Fig. 2-4-2 Frequency and duration curve at Pekurun



Discharge - duration curve from 1972 to 1974 are as in Fig. 2-4-2 and the flow conditions of each year are as follows.

Table 2-4-2 Discharge - Duration at Pekurun

Item	Description	Year		
		1972	1973	1974
		m^3/S	m^3/S	m^3/S
Max. dis.	Maximum discharge is defined as a maximum instantaneous for each terms, and not a daily maximum discharge.	134.0	405.0	172.2
95-day dis.	The discharge shows the flow available within 95 days a year	18.8	17.5	16.0
Ordinary dis.	The discharge shows the flow available within 185 days a year	9.1	12.6	12.0
Lower dis.	The discharge shows the flow available within 275 days a year	5.4	8.9	9.0
Draughty dis.	The discharge shows the flow available within 355 days a year	3.6	6.6	6.4
Min. dis.	Minimum discharge shows a minimum instantaneous for each terms, and not a daily minimum discharge	3.2	5.4	5.7
Annual mean discharge		15.30	15.89	14.02
Yearly dis.		480,000,000 m^3	500,000,000 m^3	440,000,000 m^3

2. *Assumption of mean daily discharge at Pekurun*

The correlation of the water level records at Tanjunkemala (Sep. 20, 1972 - Oct. 31, 1973) and the mean daily discharge at Pekurun in the same terms is calculated.
Overlapping terms are 14 months.

The water level records at Tanjunkemala are divided into three groups, that is, 0-0.50 m, 0.51-1.50 m and 1.51 - 6.00 m, and the above correlations for these three groups are calculated. As the result shows considerably high correlation, the mean daily discharges at Pekurun (Apr. 8, 1971 - Sep. 19, 1972) are obtained by the regression line.

3. Runoff coefficient

The monthly runoff coefficients in the catchment area from 1972 to 1974 are assumed by the data of the areal rainfall and the runoff at Pekurun in the same terms. The result is shown in the following table.

Table 2-4-3 Runoff Coefficient in Catchment Area

Year	Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Mean
1972	Rainfall(mm)	585	356	434	238	226	18	2	50	3	12	244	211	2379	198
	Runoff(mm)	341	163	274	160	172	91	55	50	38	30	38	64	1476	123
	Coefficient (%)	0.58	0.46	0.63	0.67	0.75	-	-	-	-	-	0.11	0.30	0.62	
1973	Rainfall	317	434	243	222	317	199	32	174	283	167	302	213	2903	242
	Runoff	86	100	201	159	160	117	67	63	99	75	101	304	1532	128
	Coefficient	0.27	-	0.83	0.72	0.50	0.59	-	0.36	0.35	0.45	0.33	-	0.53	
1974	Rainfall	210	231	200	321	214	134	190	179	300	231	300	312	2822	235
	Runoff	128	166	133	166	120	61	63	73	83	95	99	156	1343	112
	Coefficient	0.61	0.72	0.67	0.52	0.56	0.46	0.33	0.41	0.28	0.41	0.33	0.50	0.48	
	Mean of Coef.	0.49	0.59	0.71	0.64	0.61	0.53	0.33	0.39	0.32	0.43	0.26	0.40	0.54	
	Assumption of Coefficient	0.5	0.6	0.7	0.6	0.6	0.5	0.3	0.4	0.3	0.4	0.3	0.4	0.47	

4. Correlation of rainfall and discharge

As a result of calculation in the article 2.5.2, the following findings are obtained.

1) The correlation of 10 days discharge at Pekurun and 10 days rainfall at Kotabumi is not found.
2) Rather, the monthly rainfall at Bekitkemuning has more correlation than that of Kotabumi.
3) There are considerable correlations among the monthly discharge at Pekurun, the areal rainfall in the catchment area and the monthly rainfall at Bekitkemuning.

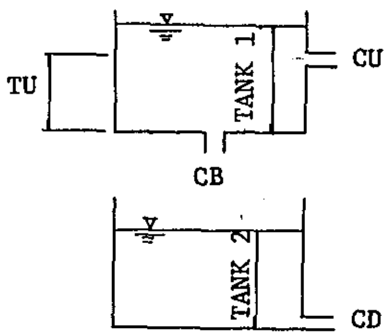
Therefore, the areal rainfall changed from the rainfall is applied to the Tank model method.

5. Tank model

The principal ingredients flowing to river from pricipitation are represented as next three components, namely, surface flow, subsurface flow and base flow. According to the Tank model method, the storage phenomena due to these components are shown as the storage height in the Tank and the runoff system can be shown as a simple model.

In this report, the ingredients are taken as two components, namely, surface flow and base flow, the following Tank of a series - two steps are presumed and the monthly discharges are calculated by throwing the monthly rainfall into the Tank.

Fig. 2-4-3 Tank model



The rainfalls are thrown into the upper Tank and the surface flow is expressed by the following equation.

Surface flow = (TANK 1 - TU) x CU

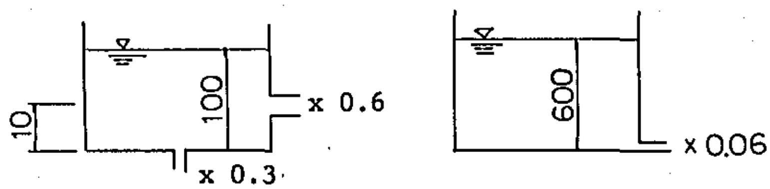
The volume of TANK 1 x CB is supplied into the lower Tank and storaged. The base flow is obtained as follows.

Base flow = TANK 2 x CD

As a result of the various studies, the following tank is assumed.

Coefficient of outlets : CU = 0.6, CB = 0.3 and CD = 0.06
Original storage height: TANK 1 = 100 mm
TANK 2 = 600 mm
Height of outlet : TU = 10 mm

Fig. 2-4-4 Assumed Tank



6. Calculated discharge by the Tank

The surface flow which is including the subsurface flow and the base flow are calculated as follows by using the monthly rainfall at Bekitkemuning.

Table 2-4-4 Calculation for Decision of Tank Model (1972-1973)

YEAR	MONTH	RAIN	TANK U1	TANK D1	TANK 2	QF	Q	Q-OB
		(MM)	(MM/MH)	(MM/MH)	(MM/MH)	(MM/MH)	(M3/S)	(MM/MH)
1972	Jan.	560.	222.01	0.0	42.84	264.8	32.43	341.0
	Feb.	298.	127.84	0.0	44.28	172.1	22.53	163.0
	Mar.	370.	166.29	0.0	46.80	213.1	26.09	274.0
	Apr.	294.	120.55	0.0	47.79	168.3	21.30	160.0
	May	189.	78.31	0.0	47.45	125.8	15.40	172.0
	Jun.	17.	11.03	0.0	45.11	56.1	7.10	91.0
	Jul.	1.	0.0	0.0	42.57	42.6	5.21	55.0
	Aug.	2.	0.0	0.0	40.15	40.1	4.92	50.0
	Sep.	0.	0.0	0.0	37.83	37.8	4.79	38.0
	Oct.	0.	0.0	0.0	35.63	35.6	4.36	30.0
	Nov.	84.	10.72	0.0	33.99	44.7	5.66	38.0
	Dec.	254.	60.34	0.0	33.94	94.3	11.55	64.0
1973	Jan.	257.	81.28	0.0	34.52	115.8	14.18	86.0
	Feb.	354.	133.88	0.0	36.65	170.5	23.12	100.0
	Mar.	205.	97.48	0.0	37.56	135.0	16.54	201.0
	Apr.	411.	156.05	0.0	40.16	196.2	24.83	159.0
	May	195.	84.00	0.0	40.45	124.5	15.24	160.0
	Jun.	241.	79.01	0.0	40.58	119.6	15.13	117.0
	Jul.	33.	12.09	0.0	38.68	50.8	6.22	67.0

Fig. 2-4-5

***** WAY-RAREM *****

*** COMPARISON OBSERVED AND CALCULATED VALUE ***

YEAR	MONTH	QF	Q-OB
1972	JAN.	265.	341.
	FEB.	172.	163.
	MAR.	213.	274.
	APR.	168.	160.
	MAY.	126.	172.
	JUN.	56.	91.
	JUL.	43.	55.
	AUG.	40.	50.
	SEP.	38.	38.
	OCT.	36.	30.
	NOV.	45.	38.
	DEC.	94.	64.
1973	JAN.	116.	86.
	FEB.	171.	100.
	MAR.	135.	201.
	APR.	196.	159.
	MAY.	124.	160.
	JUN.	120.	117.
	JUL.	51.	67.

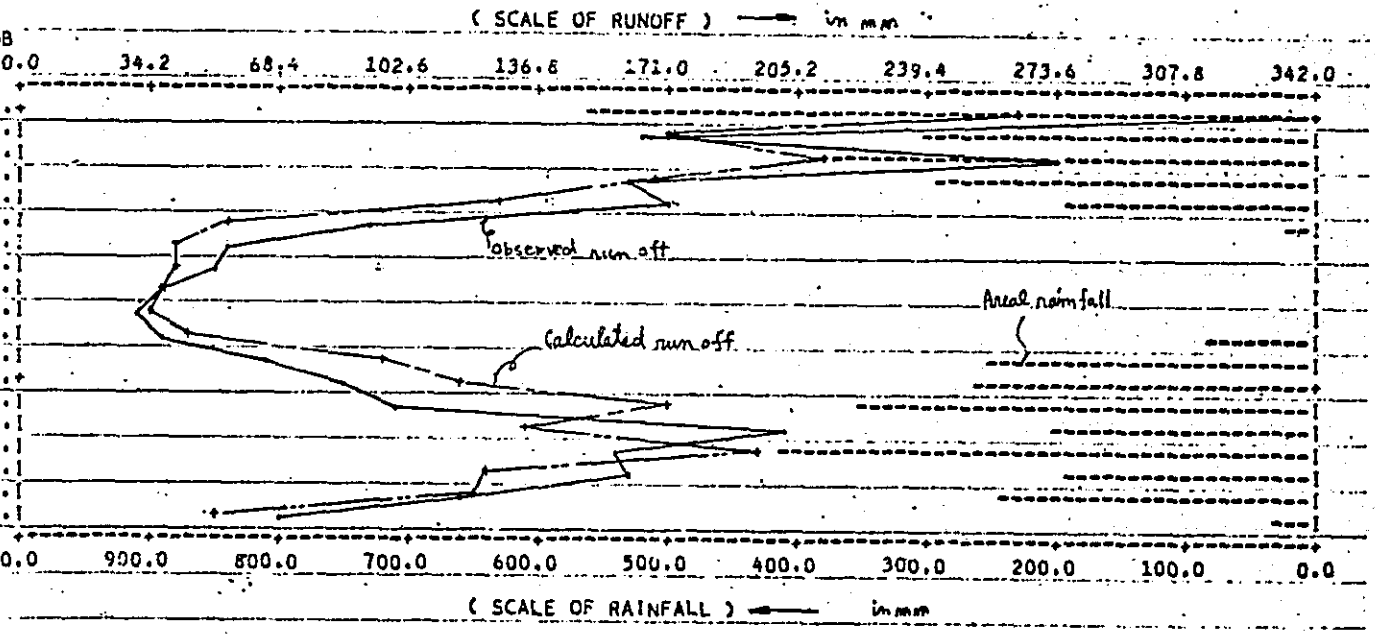


Table 2-4-5 Calculation of Discharge by Assumed Tank Model (1974)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Year	Mon.	Rain-fall	Rainfall	TANK 1	Run-off coef.	TANK 1	WQU 1	WB 1	TANK 1	TANK 2	TANK 2	WQD 2	TANK 2	QF	Q	Q
			3x1.189	(10)		5+4x6	(7-10)x0.6	7x0.3	7-8-9	(14)	11+9	12x0.06	12-13	8+13		(15.2 m³/s)
		mm	mm	mm		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	
1974	Jul.	146	173.60	100.00	0.30	152.08	82.25	45.62	21.21	600.00	645.62	38.74	606.88	123.99	124.	(15.2
	Aug.	118	140.30	21.21	0.40	77.33	40.40	23.20	13.73	606.88	630.08	37.80	592.28	78.20	78	9.6
	Sep.	178	211.64	13.73	0.30	77.22	40.33	23.17	13.72	592.28	615.45	36.93	578.52	77.26	77	9.8
	Oct.	184	218.78	13.72	0.40	101.23	54.74	30.37	16.12	578.52	608.89	36.53	572.36	91.27	91	11.1
	Nov.	291	346.00	16.12	0.30	119.92	65.95	35.98	17.99	572.36	608.34	36.50	571.84	102.45	102	13.0
	Dec.	360	428.04	17.99	0.40	189.21	107.52	56.76	24.93	571.84	628.60	37.72	590.88	145.24	145	17.8

Note: First output of July 1974 is not used because the output includes error for first input.

Table 2-4-6 Comparative Table of Calculated and Observed Discharge

Year	Month	Bekit.K. Rainfall	Areal Rainfall	Calculated Discharge	Observed Discharge
		mm	mm	m^3/S	m^3/S
1972	Jan.	471	560	(32.43)	41.8 *
	Feb.	251	298	22.53	21.4 *
	Mar.	311	370	26.09	33.6 *
	Apr.	247	294	21.30	20.3 *
	May	159	189	15.40	21.1 *
	Jun.	14	17	7.10	11.5 *
	July	1	1	5.21	6.7 *
	Aug.	2	2	4.92	6.1 *
	Sep.	0	0	4.79	4.8 *
	Oct.	0	0	4.36	3.73
	Nov.	71	84	5.66	4.78
	Dec.	214	254	11.55	7.80
1973	Jan.	216	257	14.18	10.59
	Feb.	298	354	23.12	13.62
	Mar.	172	205	16.54	24.64
	Apr.	346	411	24.83	20.16
	May	164	195	15.24	19.54
	Jun.	203	241	15.13	14.48
	July	28	33	6.22	8.16
1974	July	146	174	(15.2)	7.73
	Aug.	118	140	9.6	9.00
	Sep.	178	212	9.8	10.47
	Oct.	184	219	11.1	11.60
	Nov.	291	346	13.0	12.54
	Dec.	360	428	17.8	19.08

Note; 1.

* mark shows the discharge at Pekurun which were assumed by the observed water level at Tanjungkemala.

Note; 2

( ) mark shows the first output. This value is not used because first output is calculated including big error.

Table 2-4-7 Calculation of the correlation between Calculated and Observed monthly discharge at Pekurun

n	X	$Xi-\overline{X}$	$(Xi-\overline{X})^2$	$\frac{Xi-\overline{X}}{SX}$	y	$yi-\overline{y}$	$(yi-\overline{y})^2$	$\frac{yi-y}{Sy}$	$(\frac{Xi-X}{SX})(\frac{yi-y}{Sy})$
1	(32.43)				(41.80)				
2	22.53	9.25	85.5625	1.366	21.40	7.67	58.8289	1.035	1.4138
3	26.09	12.81	164.0961	1.892	33.60	19.87	394.8169	2.682	5.0743
4	21.30	8.02	64.3204	1.185	20.30	6.57	43.1649	0.887	1.0511
5	15.40	2.12	4.4944	0.313	21.10	7.37	54.3169	0.995	0.3114
6	7.10	-6.18	38.1924	-0.913	11.50	-2.23	4.9729	-0.301	0.2748
7	5.21	-8.07	65.1249	-1.192	6.70	-7.03	49.4209	-0.949	1.1312
8	4.92	-8.36	69.8896	-1.235	6.10	-7.63	58.2169	-1.030	1.2721
9	4.79	-8.49	72.0801	-1.254	4.80	-8.93	79.7449	-1.205	1.5111
10	4.36	-8.92	79.5664	-1.318	3.73	-10.00	100.0000	-1.350	1.7793
11	5.66	-7.62	58.0644	-1.126	4.78	-8.95	80.1025	-1.208	1.3602
12	11.55	-1.73	2.9929	-0.256	7.80	-5.93	35.1649	-0.800	0.2048
13	14.18	0.90	0.8100	0.133	10.59	-3.14	9.8596	-0.424	-0.0564
14	23.12	9.84	96.8256	1.454	13.62	-0.11	0.0121	-0.015	-0.0218
15	16.54	3.26	10.6276	0.482	24.64	10.91	119.0281	1.472	0.7095
16	24.83	11.55	133.4025	1.706	20.16	6.43	41.3449	0.868	1.4808
17	15.24	1.96	3.8416	0.290	19.54	5.81	33.7561	0.784	0.2274
18	15.13	1.85	3.4225	0.273	14.48	0.75	0.5625	0.101	0.0276
19	6.27	-7.06	49.8436	-1.043	8.16	-5.57	31.0249	-0.752	0.7843
20	(15.2)			-	(7.73)			-	
21	9.6	-3.68	13.5424	-0.544	9.00	-4.73	22.3729	-0.638	0.3471
22	9.8	-3.48	12.1104	-0.514	10.47	-3.26	10.6276	-0.440	0.2262
23	11.1	-2.18	4.7524	-0.322	11.60	-2.13	4.5369	-0.287	0.0924
24	13.0	-0.28	0.0784	-0.041	12.54	-1.19	1.4161	-0.161	0.0066
25	17.8	4.52	20.4304	0.668	19.08	5.35	28.6225	0.722	0.4823
Total	305.47		1054.0715				1261.9148		19.6901

$$\overline{X} = \frac{\Sigma xi}{n} = \frac{305.47}{23} = 13.28 \qquad Sx = \sqrt{\frac{\Sigma(Xi-\overline{X})^2}{n}} = \sqrt{\frac{1054.0715}{23}} = 6.77$$

$$\overline{y} = \frac{\Sigma yi}{n} = \frac{315.69}{23} = 13.73 \qquad Sy = \sqrt{\frac{\Sigma(yi-\overline{y})^2}{n}} = \sqrt{\frac{1261.9148}{23}} = 7.41$$

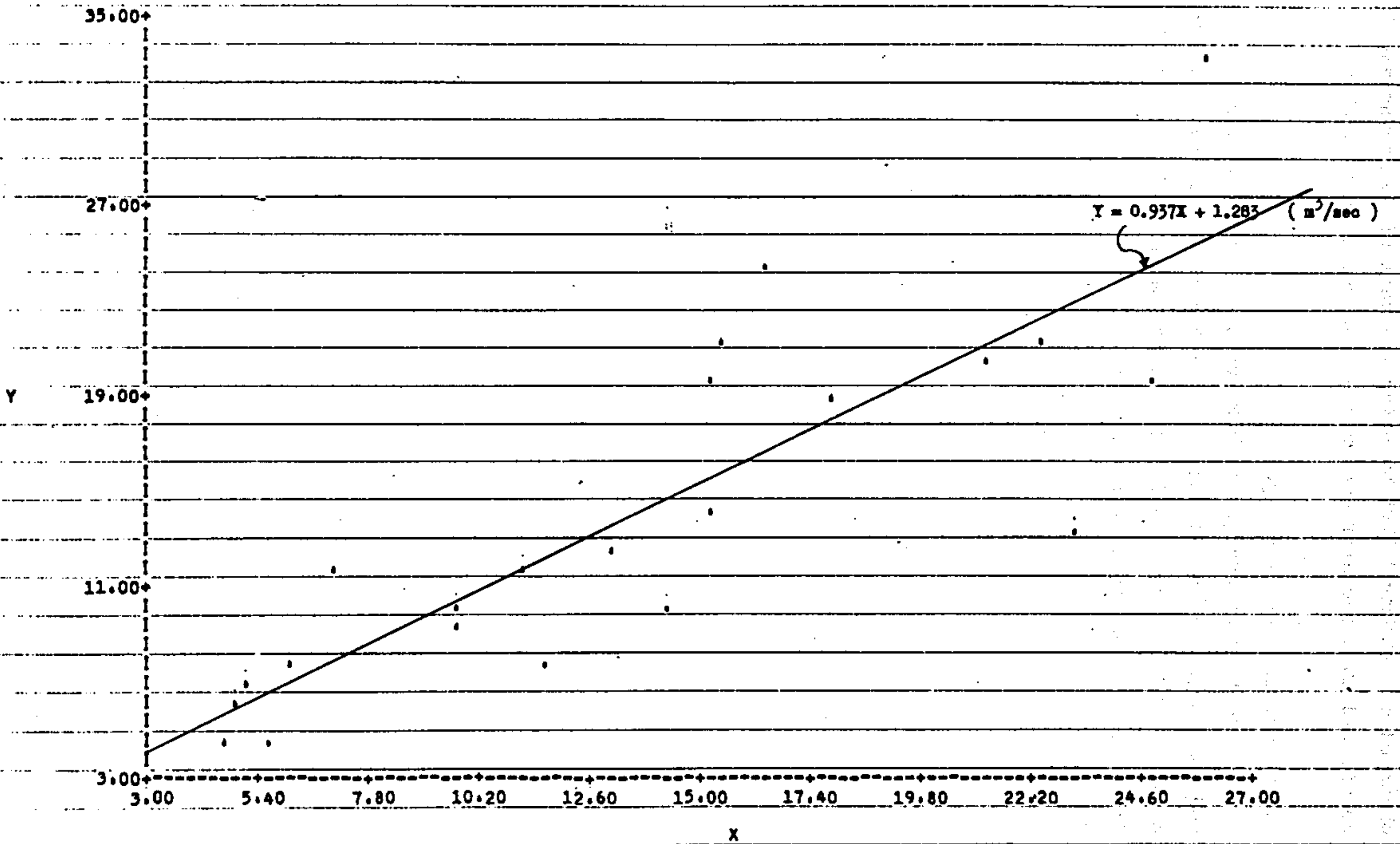
$$r = \frac{1}{n}\sum_{t=1}^{n}\left(\frac{Xi-\overline{X}}{Sx}\right)\left(\frac{yi-\overline{y}}{Sy}\right) = \frac{1}{23} \times 19.6901 = 0.856$$

Fig. 2-4-6

*** CORRELATION BETWEEN CALCULATED AND OBSERVED DISCHARGE BY TANK METHOD ***

X... CALCULATED MONTHLY DISCHARGE AT PEKURUN
Y... OBSERVED MONTHLY DISCHARGE AT PEKURUN

KAIKICHOKUSEN SIKI Y = A*X+B (Regression line)



(Correlation coefficient)
SOKAN KEISU = 0.856
KAIKI KEISU A= 0.937
B= 1.283

COMMENT OF SIGNAL
. = SINGLE
+ = DOUBLE
* = TRIPLE
# = CUT OF DATA

The correlation coefficient of the calculated discharge and the observed one is found 0.86 by using the data of 23 months and it is considered that the afore-mentioned Tank model is available.

7. Calculation of discharge

The monthly discharges at Pekurun are assumed by the above Tank and the monthly rainfall data (1952-1968) at Bekitkemuning. The data of Jun. 1958, however, is lacked and the mean monthly rainfall, that is, 118 mm of Jun. is taken for this month.

Table 2-4-8 Calculation of Discharge by Tank Model (1952-1968)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Year	Mon.	Rain-fall	Rainfall	TANK 1	Run-off coef.	TANK 1	WQU 1	WB 1	TANK 1	TANK 2	TANK 2	WQD 2	TANK 2	QF
			3x1.189	(10)		5+4x6	(7-10)x0.6	7x0.3	7-8-9	(14)	11+9	12x0.06	12-13	8+13
		mm	mm	mm		mm	mm	mm	mm	mm	mm	mm	mm	mm
1952	Jan.	607	721.72	100.00	0.50	460.86	270.52	138.26	52.08	600.00	738.26	44.30	693.96	314.82
"	Feb.	424	504.14	52.08	0.60	354.56	206.74	106.37	41.45	693.96	800.33	48.02	752.31	254.76
"	Mar.	467	555.26	41.45	0.70	430.13	252.08	129.04	49.01	752.31	881.35	52.83	828.47	304.96
"	Apr.	256	304.38	49.01	0.60	231.64	132.98	69.49	29.17	828.47	897.96	53.88	844.08	186.86
"	May	139	165.27	29.17	0.60	128.33	71.00	38.50	18.83	844.08	882.58	52.96	829.62	123.96
"	Jun.	76	90.36	18.83	0.50	64.01	32.40	19.20	12.41	829.62	848.82	50.93	797.89	83.33
"	Jul.	84	99.87	12.41	0.30	42.37	19.42	12.71	10.24	797.89	810.60	48.64	761.96	68.06
"	Aug.	86	102.25	10.24	0.40	51.14	24.68	15.34	11.12	761.96	777.30	46.64	730.66	71.32
"	Sep.	122	145.06	11.12	0.30	54.64	26.78	16.39	11.47	730.66	747.05	44.82	702.23	71.60
"	Oct.	89	105.82	11.47	0.40	53.80	26.28	16.14	11.38	702.23	718.37	43.10	675.27	69.38
"	Nov.	240	285.36	11.38	0.30	96.99	52.19	29.10	15.70	675.27	704.37	42.26	662.11	94.45
"	Dec.	297	353.13	15.70	0.40	156.95	88.17	47.09	21.69	662.11	709.20	42.55	666.65	130.72
1953	Jan.	637	757.39	21.69	0.50	400.39	234.23	120.12	46.04	666.65	786.77	47.21	739.56	281.44
"	Feb.	313	372.16	46.04	0.60	269.34	155.60	80.80	32.94	739.56	820.36	49.22	771.14	204.82
"	Mar.	329	391.18	32.94	0.70	306.77	178.06	92.03	36.68	771.14	863.17	51.79	811.38	229.85
"	Apr.	319	379.29	36.68	0.60	264.25	152.55	79.28	32.42	811.38	890.66	53.44	837.22	205.99
"	May	238	282.98	32.42	0.60	202.21	115.33	60.66	26.22	837.22	897.88	53.87	844.01	169.20
"	Jun.	171	203.32	26.22	0.50	127.88	70.73	38.36	18.79	844.01	882.37	52.94	829.43	123.67
"	Jul.	65	77.29	18.79	0.30	41.98	19.19	12.59	12.20	829.43	842.02	50.52	791.50	69.71

- The rest is omitted -

Table 2-4-9 Monthly Discharge Data at Pekurun (Calculated & Observed)

The name of Station :
Number of Station :

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
n	19	20	20	21	21	21	20	20	20	20	20	20	18
1952	-	33.4	37.4	23.7	15.2	10.6	8.3	8.7	9.1	8.5	12.0	16.0	-
1953	34.5	27.8	28.2	26.1	20.7	15.7	8.5	10.3	7.7	7.6	14.1	19.3	220.5
1954	19.0	25.7	27.1	21.2	27.4	12.0	10.3	9.8	8.3	10.3	18.5	22.2	211.8
1955	25.1	26.9	43.7	30.6	19.1	17.1	17.0	10.3	15.7	15.1	16.0	17.8	254.4
1956	29.6	29.5	29.1	33.3	30.2	16.7	10.3	11.8	10.0	16.6	13.9	16.2	247.2
1957	18.7	20.9	42.8	24.6	19.6	12.7	13.9	9.2	8.1	8.9	11.2	16.6	207.2
1958	21.7	44.5	48.3	39.0	26.6	15.0	10.6	15.1	9.0	15.7	16.2	20.0	281.7
1959	27.8	40.6	42.7	27.9	32.5	17.1	10.3	8.0	7.7	11.0	18.3	25.0	268.9
1960	18.8	32.0	27.5	28.3	20.2	12.0	10.1	11.0	10.4	9.0	11.0	21.5	211.8
1961	28.6	21.7	20.5	20.8	21.3	18.1	8.4	7.7	5.9	5.3	7.8	13.3	179.4
1962	20.8	26.6	28.6	26.5	12.1	10.0	9.1	10.4	6.5	12.2	11.8	16.2	190.8
1963	20.9	19.3	32.8	27.1	28.2	9.2	7.0	6.5	5.4	7.5	8.1	15.8	187.8
1964	20.7	30.1	40.2	29.4	25.3	11.3	8.9	9.5	11.2	12.3	13.8	24.0	236.7
1965	23.7	30.4	36.2	17.2	9.8	10.7	6.2	5.5	6.5	5.5	9.0	23.4	184.1
1966	29.1	26.1	37.1	27.0	14.0	13.5	9.8	11.6	10.7	16.9	15.3	20.0	231.1
1967	12.7	40.4	36.7	28.9	29.1	11.8	8.4	6.3	6.1	5.6	9.4	23.9	219.3
1968	23.6	32.5	44.9	22.5	29.3	19.7	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	28.6	17.6	12.9	10.1	7.6	6.8	8.9	19.4	32.1	-
1972	41.8	21.4	33.6	20.3	21.1	11.5	6.7	6.1	4.8	3.73	4.78	7.80	183.61
1973	10.59	13.62	24.64	20.16	19.54	14.48	8.16	7.74	12.59	9.17	12.72	37.26	190.67
1974	15.66	22.50	16.27	21.02	14.64	7.75	7.73	9.00	10.47	11.60	12.54	19.08	168.26
Total	443.35	565.92	544.18	544.18	453.48	279.83	189.79	182.14	172.96	201.40	255.84	407.44	3,875.24
Average	23.33	28.30	25.91	25.91	21.59	13.33	9.49	9.11	8.65	10.07	12.79	20.37	215.29

8. Designed discharge

The monthly discharges of the 1 in 5 year probability are taken for the irrigation planning. These discharges are obtained as in the following table by the Thomas ploting of the calculated discharge in accordance with the afore-mentioned Tank and the observed discharge on the logarithmic probability paper.

Table 2-4 -10 Designed discharge

Month	Discharge
Jan.	16.5 m^3/S
Feb.	21.5
Mar.	25.0
Apr.	21.0
May	15.0
Jun.	9.8
July	7.4
Aug.	6.8
Sep.	6.2
Oct.	5.8
Nov.	8.8
Dec.	14.5
Total	158.3
Mean	13.19 m^3/S

$13.19\ m^3/S \times 365\ \text{days} \times 86400\ \text{Sec.} = 416{,}000{,}000\ m^3/\text{year}$

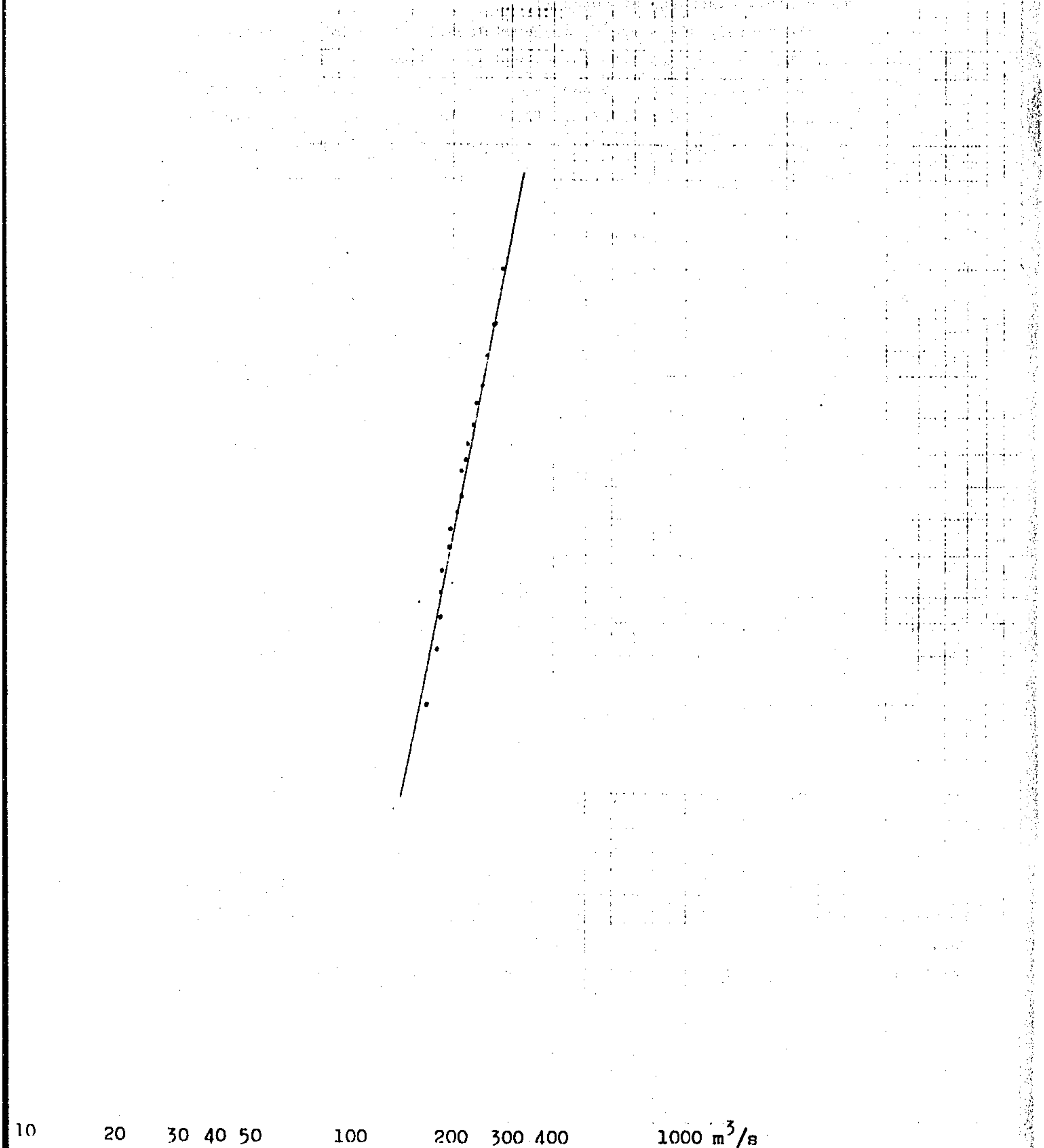
$416{,}000{,}000\ m^3 \div 328\ km^2 = 1268\ \text{mm/year}$

Table 2-4-11 Probable Monthly Discharge at Peturun

n	$1-\frac{i}{n+1}$	Jan.	$1-\frac{i}{n+1}$	Feb.	Mar.	July	Aug.	Sep.	Oct.	Nov.	Dec.	$1-\frac{i}{n+1}$	Apr.	May	Jun.	$1-\frac{i}{n+1}$	Year
1	0.95	41.8	0.95	44.5	48.3	17.0	15.1	15.7	16.9	19.4	37.26	0.95	39.0	32.5	19.7	0.95	281.7
2	0.90	34.5	0.90	40.6	44.9	13.9	11.8	12.59	16.6	18.5	32.1	0.91	33.3	30.2	18.1	0.89	268.9
3	0.85	29.6	0.86	40.4	43.7	10.6	11.6	11.2	15.7	18.3	25.0	0.86	30.6	29.3	17.1	0.84	254.4
4	0.80	29.1	0.81	33.4	42.8	10.3	11.0	10.7	15.1	16.2	24.0	0.82	29.4	29.1	17.1	0.79	247.2
5	0.75	28.6	0.76	32.5	42.7	10.3	10.4	10.47	12.3	16.0	23.9	0.77	28.9	28.2	16.7	0.74	236.7
6	0.70	27.8	0.71	32.0	40.2	10.3	10.3	10.4	12.2	15.3	23.4	0.73	28.6	27.4	15.7	0.68	231.1
7	0.65	25.1	0.67	30.4	37.4	10.1	10.3	10.0	11.6	14.1	22.2	0.68	28.3	26.6	15.0	0.63	220.5
8	0.60	23.7	0.62	30.1	37.1	10.1	9.8	9.1	11.0	13.9	21.5	0.64	27.9	25.3	14.48	0.58	219.3
9	0.55	23.6	0.57	29.5	36.7	9.8	9.5	9.0	10.3	13.8	20.0	0.59	27.1	21.3	13.5	0.53	211.8
10	0.50	21.7	0.52	27.8	36.2	9.1	9.2	8.3	9.17	12.72	20.0	0.55	27.0	21.1	12.9	0.47	211.8
11	0.45	20.9	0.48	26.9	33.6	8.9	9.0	8.1	9.0	12.54	19.3	0.50	26.5	20.7	12.7	0.42	207.2
12	0.40	20.8	0.43	26.6	32.8	8.5	8.7	7.7	8.9	12.0	19.08	0.45	26.1	20.2	12.0	0.37	190.8
13	0.35	20.7	0.38	26.1	29.1	8.4	8.0	7.7	8.9	11.8	17.8	0.41	24.6	19.6	12.0	0.32	190.67
14	0.30	19.0	0.33	25.7	28.6	8.4	7.74	6.8	8.5	11.2	16.6	0.36	23.7	19.54	11.8	0.26	187.8
15	0.25	18.8	0.29	22.50	28.2	8.3	7.7	6.5	7.6	11.0	16.2	0.32	22.5	19.1	11.5	0.21	184.1
16	0.20	18.7	0.24	21.7	27.5	8.16	7.6	6.5	7.5	9.4	16.2	0.27	21.2	17.6	11.3	0.16	183.61
17	0.15	15.66	0.19	21.4	27.1	7.73	6.5	6.1	5.6	9.0	16.0	0.23	21.02	15.2	10.7	0.11	179.4
18	0.10	12.7	0.14	20.9	24.64	7.0	6.3	5.9	5.5	8.1	17.8	0.18	20.8	14.64	10.6	0.05	168.26
19	0.05	10.59	0.10	19.3	20.5	6.7	6.1	5.4	5.3	7.8	13.3	0.14	20.3	14.0	10.0		
20			0.05	13.62	16.27	6.2	5.5	4.8	3.73	4.78	7.80	0.09	20.16	12.1	9.2		
21												0.05	17.2	9.8	7.75		
	Total	443.35		565.92	678.31	189.79	182.14	172.96	201.40	255.84	407.44	279.83	544.18	453.48	279.83		3,875.24
	Mean	23.33		28.30	33.92	9.49	9.11	8.65	10.07	12.79	20.37	13.33	25.91	21.59	13.33		215.29

Note: above-mentioned discharge are plotted on probability sheets in data book.

Fig. 2-4-7 Yearly discharge at Pekurun



9. Monthly discharge at Kotabumi

The monthly discharge at Kotabumi located 20 km in the downstream from the proposed dam site is assumed as follows.

The water level of the Way Rarem near Kotabumi has been observed since Dec. 1973 under P.3.S.A. office. The catchment area is 913 km^2 at this point and the records in 1974 shown in the following table are available.

Table 2-4-12 Mean discharge at Kotabumi

	Jan.	F	M	A	M	J	J	A	S	O	N	D	Total	Mean
Dis. m^3/s	44.72	75.45	54.67	61.61	42.26	21.09	18.39	19.59	27.67	31.66	38.48	56.10	471.69	40.97
Max. "	84.76	142.50	103.00	129.56	99.90	37.75	47.74	36.44	62.44	72.80	83.62	77.24		
Min. "	28.50	43.36	29.00	25.00	23.00	17.16	11.94	14.28	13.84	21.50	24.75	37.60		

The catchment area at Pekurun is 328 km^2, and the ratio of these catchment areas is 2.8. The monthly discharges at both places and its ratio for 1974 are as follows.

Table 2-4-13 Ratio of discharge

	J	F	M	A	M	J	J	A	S	O	N	D	Total	Mean
Kotabumi	44.72	75.45	54.67	61.61	42.26	21.09	18.39	19.59	27.67	31.66	38.48	56.10		
Pekúyun	15.66	22.50	16.27	21.02	14.64	7.75	7.73	9.00	10.47	11.60	12.54	19.08		
Ratio	2.856	3.353	3,360	2,931	2.887	2,721	2,379	2.177	2,643	2.729	3,069	2.940	34,045	2.837

Yearly mean ratio is 2.837 and therefore, the value is almost the same as the ratio of the catchment area. Consequently, the monthly discharges of the 1 in 5 year probability at Kotabumi can be assumed to be the product of the probable monthly discharge at Pekurun and the ratio of 2.8.

Table 2-4-14 Probable discharge at Kotabumi

	J	F	M	A	M	J	J	A	S	O	N	D	Total	Mean
Pekurun	16.5	21.5	25.0	21.0	15.0	9.8	7.4	6.8	6.2	5.8	8.8	14.5	158.3	13.19
Ratio	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8		
Kotakumi	46.2	60.2	70.0	58.8	42.0	27.4	20.7	19.0	17.4	16.2	24.6	40.6	443.1	36.9

2.4.2 Specific discharge

Mean monthly specific discharges in Lumpung province are as follows.

Table 2-4-15 Specific Discharge

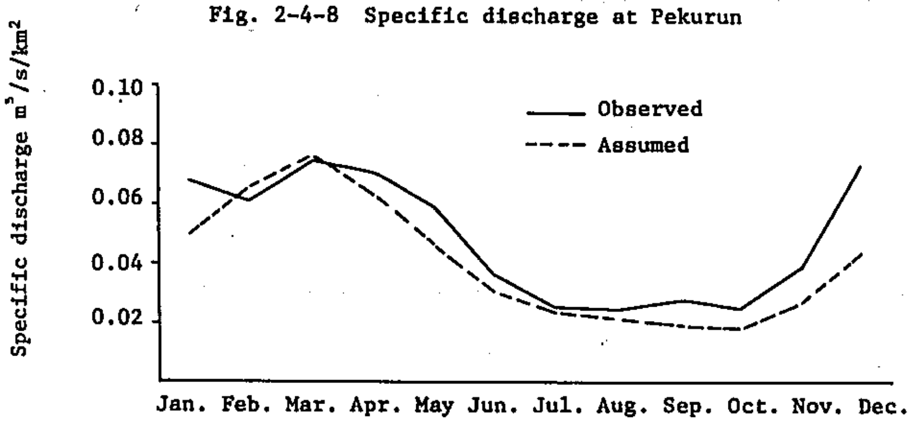
Name	Catch	Period	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
W.Sekanpung														
Kunjir	438 km^2	1968-74	0.068	0.065	0.072	0.070	0.065	0.052	0.043	0.043	0.040	0.035	0.045	0.054
Jurai	682	1968-74	0.064	0.064	0.067	0.063	0.063	0.044	0.039	0.037	0.037	0.032	0.042	0.056
Pujorahayu	1743	1968-74	0.053	0.042	0.054	0.048	0.042	0.024	0.015	0.018	0.022	0.013	0.022	0.035
W.Pengubuan														
Gedoryharto	113	1971-74	0.068	0.055	0.070	0.082	0.080	0.045	0.020	0.017	0.029	0.026	0.045	0.084
W.Waya														
Banywangi	67	1968-74	0.053	0.048	0.058	0.051	0.052	0.034	0.026	0.024	0.026	0.021	0,027	0.043
W.Tatayan														
Sumbersari	75	1968-74	0.054	0.048	0.059	0.060	0.049	0.024	0.013	0.014	0.018	0.017	0.031	0.057
Way Rarem														
Pekurun	328	1971-74	0.068	0.061	0.074	0.071	0.059	0.036	0.025	0.024	0.027	0.025	0.038	0.073

($m^3/S/Km^2$)

Observed and designed specific discharges at Pekurun are as follows.

	J	F	M	A	M	J	J	A	S	O	N	D
Observed dis.	0.068	0.061	0.074	0.071	0.059	0.036	0.025	0.024	0.027	0.025	0.038	0.073
Designed dis.	0.050	0.066	0.076	0.064	0.046	0.030	0.023	0.021	0.019	0.018	0.027	0.044

Fig. 2-4-8 Specific discharge at Pekurun



2.4.3 Flood discharge

The discharge observation of the Rarem river at Pekurun was barely commenced in April 1971 and therefore, there are only four data for the yearly maximum flood discharge. Beisdes, there is no data for hourly rainfall in the catchment area.

Accordingly, the flood discharge is obliged to be calculated by the rational formula, Hasper's method or Melchior method and the past flood records of the rivers in the vicinity are refered to for the determination of the flood discharge.

The design flood discharges for the spillway and the diversion channel of the Rarem dam depend on the probabilities of the 1 in 1000 year and the 1 in 10 year respectively.

In this article, each calculation result is shown and the design flood discharge in the next article.

1. Data required for the calculation of the flood discharges

   (1) Probable daily rainfall

   The daily maximum rainfalls of non-excess probability at Kotabumi and Bekitkemuning are obtained as shown in the following table by using the past yearly maximum daily rainfall records for 44 years at Kotabumi and for 18 years at Bekitkemuning.

Table 2-4-16 Probable daily rainfall

Probability	Kotabumi	Bekitkemuning
1/2 year	110 mm/day	120 mm/day
1/5	140	150
1/10	160	175
1/50	205	220
1/100	220	235
1/500	265	280
1/1000	280	295

The past maximum daily rainfall at Bekitkemuning is 210mm and the average of the past yearly maximum daily rainfalls for 18 years is 118mm. (Refer to Table 2-3-8)

(2) Catchment area

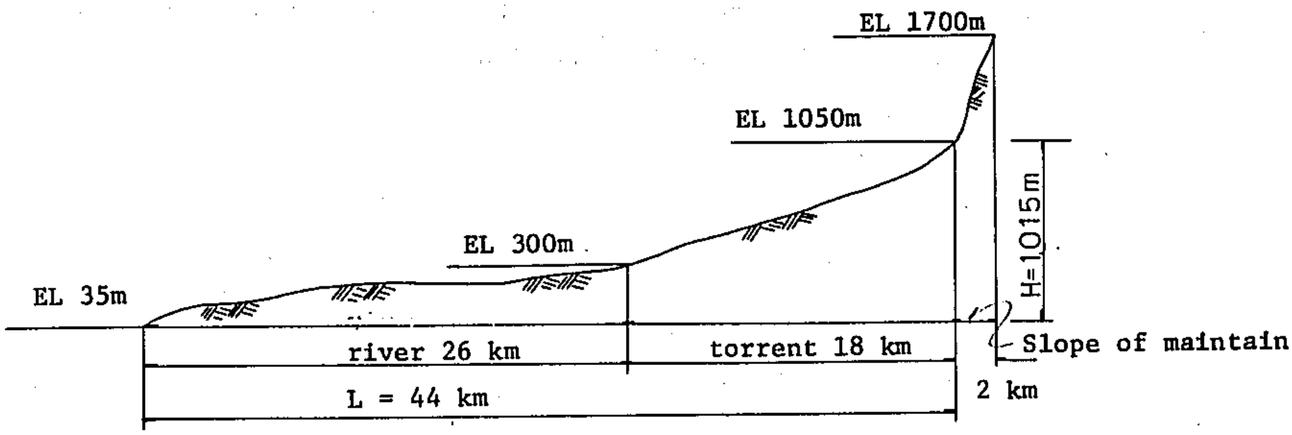
The catchment area is obtained to be 328 Km^2 from the topographic map in a scale of 1/100,000.

Taking the catchment area as a ellipse, the long diameter is 26.0 Km.

(3) Profile of the Rarem river

The profile of the Rarem river is roughly shown as in the following figure.

Fig. 2-4-9 Profile of Way Rarem



Horizontal length of the river	L = 44.0 Km
Difference of the river bed elevations	H = 1,015 m
Average river slope	$i = \frac{1,015}{44,000} = 0.0231$

2. Flood discharge by rational formula

The peak flood discharge by the rational formula is obtained by the following equation

$$Q = 0.2778 \ f \cdot r_t \cdot A$$

in which,
Q: Peak flood discharge (m^3/sec)
f: Runoff coefficient
rt: Mean rainfall intensity within the arrival time of flood (mm/hr)
A: Catchment area (km^2)

Velocity of flood (W) and the arrival time of flood (T) are calculated by Rziha's formula expressed as follows.

$$W = 72 \times \left(\frac{H}{L}\right)^{0.6} = 72 \times \left(\frac{1.015}{44.0}\right)^{0.6} = 7.5 \text{ km/hr}$$

$$T = \frac{L}{W} - \frac{44.0}{7.5} \doteqdot 6 \text{ hr}$$

The mean rainfall itensity within the arrival time of flood (r_t) is obtained by the following equation.

$$r_t = \frac{r24}{24} \left(\frac{24}{T}\right)^n$$

where,
r_t: Mean rainfall intensity within the arrival time of flood (mm/hr)
r24: Maximum daily rainfall (mm)
n: 0.5

Taking the probable maximum daily rainfalls at Bekitkemuning, each rainfall itensity becomes as follows.

Table 2-4-17 Probable rainfall intencity

Probability	r24	r_t
1/2 year	120 mm	10.0 mm/hr.
1/5	150	12.5
1/10	175	14.6
1/50	220	18.3
1/100	235	19.6
1/500	280	23.3
1/1000	295	24.6

Therefore, the peak flood discharge of each probable year by the rational formula and it's specific discharge are obtained as follows.

Table 2-4-18 Flood discharge by rational formula

Probability	Q	Specific discharge
1/2 year	547 m^3/s	1.67 $m^3/s/km^2$
1/5	683	2.08
1/10	798	2.43
1/50	1000	3.05
1/100	1072	3.27
1/500	1274	3.88
1/1000	1345	4.10

3. Flood discharge by Hasper's method

The peak flood discharge by Hasper's method is obtained by the following equation.

$$Q = \alpha.\beta.q.f$$

in which,
- Q: Peak flood discharge (m^3/sec)
- α: Runoff coefficient
- β: Reduction coefficient
- q: Specific discharge ($m^3/sec/km^2$)
- f: Catchment area (km^2)

Runoff coefficient (α), arrival time of flood (t) and reduction coefficient (β) are calculated by the following equations respectively.

$$\alpha = \frac{1 + 0.012f^{0.7}}{1 + 0.075f^{0.7}} = \frac{1 + 0.012 \times 328^{0.7}}{1 + 0.075 \times 328^{0.7}} = 0.32$$

$$t = 0.1\ L^{0.8} \times i^{-0.3} = 0.1 \times 44^{0.8} \times 0.0231^{-0.3} = 6.4\ hr$$

$$\frac{1}{\beta} = 1 + \frac{t + 3.7 \times 10^{-0.4t}}{t^2 + 15} \times \frac{f^{3/4}}{12} = 1 + \frac{6.4 + 3.7 \times 10^{-0.4 \times 6.4}}{6.4^2 + 15,}$$

$$\times \frac{328^{3/4}}{12} = 1.7357$$

$$\beta = 0.58$$

The specific discharge (q) is obtained by the following equations.

$$q = \frac{r}{3.6t}$$

where, r : Mean rainfall intensity within the arrival time of flood, mm

$$r = \frac{tR}{t+1}$$

where, R: Maximum daily rainfall for a certain return period T, mm

$$R = \overline{R} + S \cdot UT$$

where, $\overline{R}$: Average of the past yearly maximum daily rainfalls, mm

S: Standard deviation, mm

UT: Standard variable for the return period

$$S = \frac{Rn - \overline{R}}{U}$$

where, Rn: Past maximum daily rainfall for n years which have records, mm

U: Standard variable for the return period with Rn

$$S = \frac{210-118}{1.85} = 49.73 \text{ (Return period: 19 years)}$$

q and Q are calculated as follows by the above equations when the return period is taken to be 10 years on 1,000 years, respectively.

(1) Peak flood discharge of the 1 in 10 year probability

$$R = 118 + 49.73 \times 1,265 = 181 \text{ mm}$$

$$r = \frac{6.4 \times 181}{6.4 + 1} = 157 \text{ mm}$$

$$q = \frac{157}{3.6 \times 6.4} = 6.81 \text{ m}^3/\text{sec/km}^2$$

$$Q = 0.32 \times 0.58 \times 6.81 \times 328 = 415 \text{ m}^3/\text{sec}$$

(2) Peak flood discharge of the 1 in 1,000 year probability

$$R = 118 + 49.73 \times 5.92 = 412 \text{ mm}$$

$$r = \frac{6.4 \times 412}{6.4 + 1} = 356 \text{ mm}$$

$$q = \frac{356}{3.6 \times 6.4} = 15.45 \text{ m}^3/\text{sec/km}^2$$

$$Q = 0.32 \times 0.58 \times 15.45 \times 328 = 941 \text{ m}^3/\text{sec}$$

4. Flood discharge by Melchoir's method

The peak flood discharge by Melchoir's method is obtained by the following equation.

$$Q = \alpha . q . f$$

in which,
- Q: Peak flood discharge (m^3/sec)
- α: Runoff coefficient, usually $\alpha = 0.52$
- q: Sepcific discharge (m^3/sec/km^2)
- f: Catchment area (km^2)

In case of Melchoir's method, the area (nF) which the catchment area is assumed to be a ellipse is one of the important parameters and the average river slope (i) is expressed by the following equation.

$$nF = \frac{1}{4}\pi ab = \frac{1}{4}\pi ab \times \frac{2}{3}a = \frac{1}{6}\pi a^2$$

$$\pi = \frac{1}{6} \times \pi \times 26.0^2 = 354 \text{ km}^2 \text{ (where, a: long diameter)}$$

$$i = \frac{H}{\lambda} = \frac{10H}{9L} = \frac{10 \times 1.015}{9 \times 44.0} = 0.0256$$

Velocity of flood (V) and the arrival time of flood (T) are expressed as follows:

$$V = 1.31\sqrt[5]{\beta.q.f.i^2}$$

in which, β: Reduction coefficient

β is obtained by the following equation

$$f = \frac{1970}{\beta-0.12} - 3960 + 1720\,\beta$$

Solving the equation, $\beta = 0.8$

q: Approximate value obtained by the table with nF,

$q = 3.3 \text{ m}^3/\text{sec/km}^2$

therefore, $V = 1.31\sqrt[5]{0.8 \times 3.3 \times 328 \times 0.0256^2} = 1.17 \text{ m/sec}$

$$T = \frac{1{,}000L}{60V} = \frac{1{,}000 \times 44.0}{60 \times 1.17} = 627 \text{ min} = 10.4 \text{ hr.}$$

Further, q is obtained to be $3.5 \text{ m}^3/\text{sec/km}^2$ by the figure with T = 10.4 hr and nF = 354 km , therefore,

$$V = 1.31\sqrt[5]{0.8 \times 3.5 \times 328 \times 0.0256^2} = 1.18 \text{ m/sec}$$

$$T = \frac{1{,}000 \times 44.0}{60 \times 1.18} = 621 \text{ min} = 10.4 \text{ hr.}$$

The increase ratio of q is obtained to be 9% from a table and therefore, $q = 3.5 \times 1.09 = 3.82\ m^3/sec/km^2$. The above q is the value which the maximum daily rainfall is taken to be 200 mm and the peak flood discharge of 1/10 or 1/1,000 year probability is respectively calculated as follows.

1/10 year probability's discharge

$$Q = 0.52 \times 3.82 \times \frac{175}{200} \times 328 = 570\ m^3/sec$$

1/1,000 year probability's discharge

$$Q = 0.52 \times 3.82 \times \frac{295}{200} \times 328 = 961\ m^3/sec$$

The past flood records of the rivers in the vicinity of the Rarem river are as follows:

Table 2-4-19 Past flood discharge in Way Rarem and the vicinity river

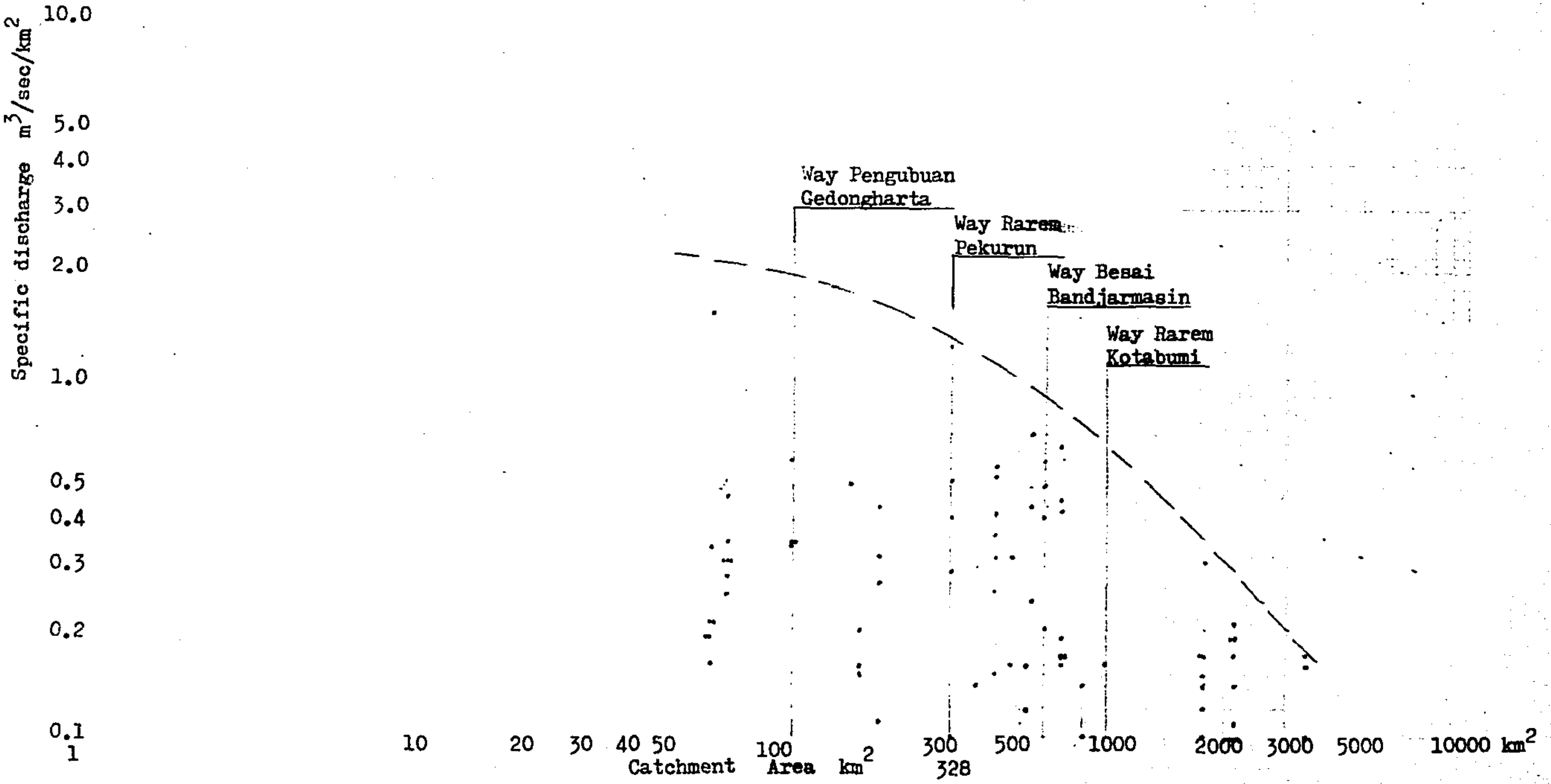
Sta.	River Name	Location	Catch-ment km²	Year	Mon.	Dis-charge m³/s	Specific discharge m³/s/km²	Duration	Remarks
026	W.Rarem	Pekarun	328	1971	Dec.	96	0.29	'72 Apr. - '74 Dec.	estimated
				"	Apr.	87			"
				1972	Mar.	134	0.41		"
				"	Jan.	119			"
				1973	Mar.	405	1.23		
				"	Dec.	197			
				1974	Apr.	172	0.52		
				"	Oct.	104			
034	W. Rarem	Pekarum	913	1974	Feb.	143	0.16	'74 Jan.-Dec.	
				"	Apr.	130			
041	W. Abung	Organ Enain	170	1974	Dec.	86	0.51	'74 May-Dec.	
				"	Nov.	55			
018	W. Besai	Banjarumasin	604	1971	Nov.	245	0.41	'71 Apr.- '74 Dec.	estimated
				"	Dec.	154			"
				1972	May	355	0.59		
				"	Jan.	195			
				1973	Dec.	300	0.50		
				1974	Nov.	122	0.20		
017	W. Besai	Petai	389	1974	Dec.	53	0.14	'74 Sep.-Dec.	
039	W. Umpu	Rantan temiang	203	1973	Dec.	64	0.32	'73 Oct.- '74 Dec.	
				1974	Apr.	54	0.27		
024	W. Umpu	Negri Umpu-batin	559	1972	Dec.	133	0.24	'72 July - '74 Dec.	
				1973	"	390	0.70		
				"	Mar.	310			
				1974	Apr.	244	0.44		

Sta.	River Name	Location	Catch-ment km²	Year	Mon.	Dis-charge m^3/s	Specific discharge $m^3/s/km^2$	Duration	Remarks
027	W. Terucan	Gunung Batin	543	1972	Dec.	12	0.02	'72 Sep.- '74 Dec.	
				1973	Dec.	67	0.12		
				1974	Mar.	87	0.16		
025	W. Pengu-buan	Gedong harta	113	1971	Dec.	40	0.35	'71 Apr.- '74 Dec.	
				1972	May	38	0.34		
				1973	Mar.	67	0.59		
				1974	Mar.	39	0.35		
-	W. Pengu-buan	Trimodadi	180	1938	Jan.	27	0.15	'38 Jan.- '40 Dec.	
				1939	Jan.	36	0.20		
				1940	Jan.	29	0.16		
038	W. Seputih	Nogri Aji tua	493	1973	Mar.	156	0.32	'73 Mar.- '74 Dec.	
				1974	Apr.	77	0.16		
037	W. Tatayan	Sumber sari	75	1968	Mar.	19	0.25	'68 Jan.- '74 Dec.	
				1969	Apr.	23	0.31		
				1970	Aug.	23	0.31		
				1971	Apr.	21	0.28		
				1972	Feb.	23	0.31		
				1973	Mar.	35	0.47		
				1974	Apr.	26	0.35		

Sta.	River Name	Location	Catchment km²	Year	Mon.	Discharge m^3/s	Specific discharge $m^3/s/km^2$	Duration	Remarks
001	W. Sekampung	Kunyir	438	1968	Aug.	116	0.26	'68 Jan.- '74 Dec.	
				1969	Feb.	66	0.15		
				1970	Mar.	141	0.32		
				1971	Nov.	182	0.42		
				1972	May	162	0.37		
				1973	Mar.	250	0.57		
				1974	Apr.	238	0.54		
021	W. Sekampung	W. Jurai	682	1968	May	112	0.16	'68 Jan.- '74 Dec.	
				1969	Dec.	113	0.17		
				1970	Mar.	290	0.43		
				1971	Apr.	115	0.17		
				1972	Jan.	129	0.19		
				1973	Dec.	446	0.65		
				1974	Sep.	313	0.46		
002	W. Waya	Banyuwangi	67	1968	Aug.	13	0.19	'68 Jan.- '74 Dec.	
				1969	Sep.	11	0.16		
				1970	Jan.	14	0.21		
				1971	Nov.	14	0.21		
				1972	May	13	0.19		
				1973	Mar.	101	1.51		
				1974	Apr.	23	0.34		
006	W. Bulok	W. Gatel	790	1973	Sep.	113	0.14	'73 Sep.- '74 Dec.	
				1974	Mar.	46	0.06		
005	W. Tebu	Banjar Agung	205	1973	Dec.	90	0.44	'73 Dec.- '74 Dec.	
				1974	Jul.	22	0.11		

Sta.	River Name	Location	Catch-ment km²	Year	Mon.	Dis-charge m³/s	Specific discharge m³/s/km²	Duration	Remarks
029	Umpu Kanan	Pakuan Ratu	3,427	1972	Dec.	300	0.09	'72 Jun.-	
				1973	Mar.	590	0.17	'74 Dec.	
				1974	Apr.	564	0.16		
012	W. Sekam-pung	Argoguruh	2,155	1959	Dec.	309	0.14	'59 Jul. -	
				1960	Jan.	207	0.10	'73 Apr.	
				1961	Feb.	233	0.11		
				1964	Dec.	136	0.06		
				1965	Jan.	191	0.09		
				1966	Mar.	200	0.09		
				1967	Dec.	162	0.08		
				1968	Mar.	412	0.19		
				1971	Nov.	402	0.19		
				1972	Jan.	391	0.18		
				1973	Mar.	442	0.21		
003	W. Sekampung	Pajorahaya	1,743	1968	Mar.	356	0.17	'68 Jan.-	
				1969	Jan.	295	0.14	'74 Dec.	
				1970	Apr.	364	0.17		
				1971	Nov.	330	0.15		
				1972	Jan.	269	0.12		
				1973	Mar.	658	0.31		
				1974	Feb.	146	0.07		

Fig. 2-4-10 Yeary maximum specific discharge & catchment area (from 20 observatories)



2.4.4 Design flood discharge

The calculation result of the peak flood discharge described in the preceding article is as follows:

Method	1/10 probable discharge (m^3/sec)	1/1,000 probable discharge (m^3/sec)
Rational	798	1,345
Haspers	415	941
Malchoir	570	961

The past maximum record of the specific discharge observed in the rivers in the vicinity of Pekurun is 1.22 m^3/sec/km^2 in case of the catchment area of about 300 km^2 and it is equal to about 400 m^3/sec.

It is generally said that the peak flood discharge in accordance with the rational shows the bigger value in connection with the distribution of rainfall in the catchment area in Indonesia. Therefore, the design flood discharge for the diversion channel of the Rarem dam is assumed to be 600 m^3/sec. On the other hand, the design flood discharge for the spillway is decided to be 1,300 m^3/sec from the viewpoints of the dam's having no regulating function for flood and it's security.

2.5 Related Studies

2.5.1 Droughty discharge

1. Droughty discharge

The rainfall record at Bekitkemuning shows 3 mm from Jul. to Oct. in the dry season in 1972 and the minimum daily discharge in the same period at Pekurun is 3.24 m^3/sec. Therefore, the discharge is considered as the minimum droughty discharge of Way Rarem and it's specific discharge is 0.01 $m^3/sec/km^2$.

The minimum monthly discharges at Pekurun are listed up as in the following table in accordance with the result of tank model calculation. If droughty discharge is defined to be the flow available within 355 days a year, the actual droughty discharge is considered to be smaller by about 20% than the values in the following table.

Table 2-5-1 Minimum Monthly Discharges at Pekurun

Year	Month	Minimum discharge	Year	Month	Minimum discharge
1952	Jul.	8.3 m^3/s/month	1962	Sep	6.5 m^3/s/month
53	Oct.	7.6	63	"	5.4
54	Sep.	8.3	64	Jul.	8.9
55	Aug.	10.3	65	Aug. Oct.	5.5.
56	Sep.	10.0	66	Jul.	9.8
57	"	8.1	67	Oct.	5.6
58	"	9.0	1971	Sep.	6.8
59	"	7.7	72	"	4.8
60	Oct.	9.0	73	Jul.	8.2
61	"	5.3	74	"	7.7
			Mean		7.6

Drought discharge 7.6 x 0.8 = 0.6 m^3/s/month

2. Continuous droughty days

The records of the continuous droughty days for 24 years at Kotabumi are as follows. The rainfall which is less than 5 mm is treated as non-rainfall day and it is counted as the droughty day.

Table 2-5-2 Continuous Drought days

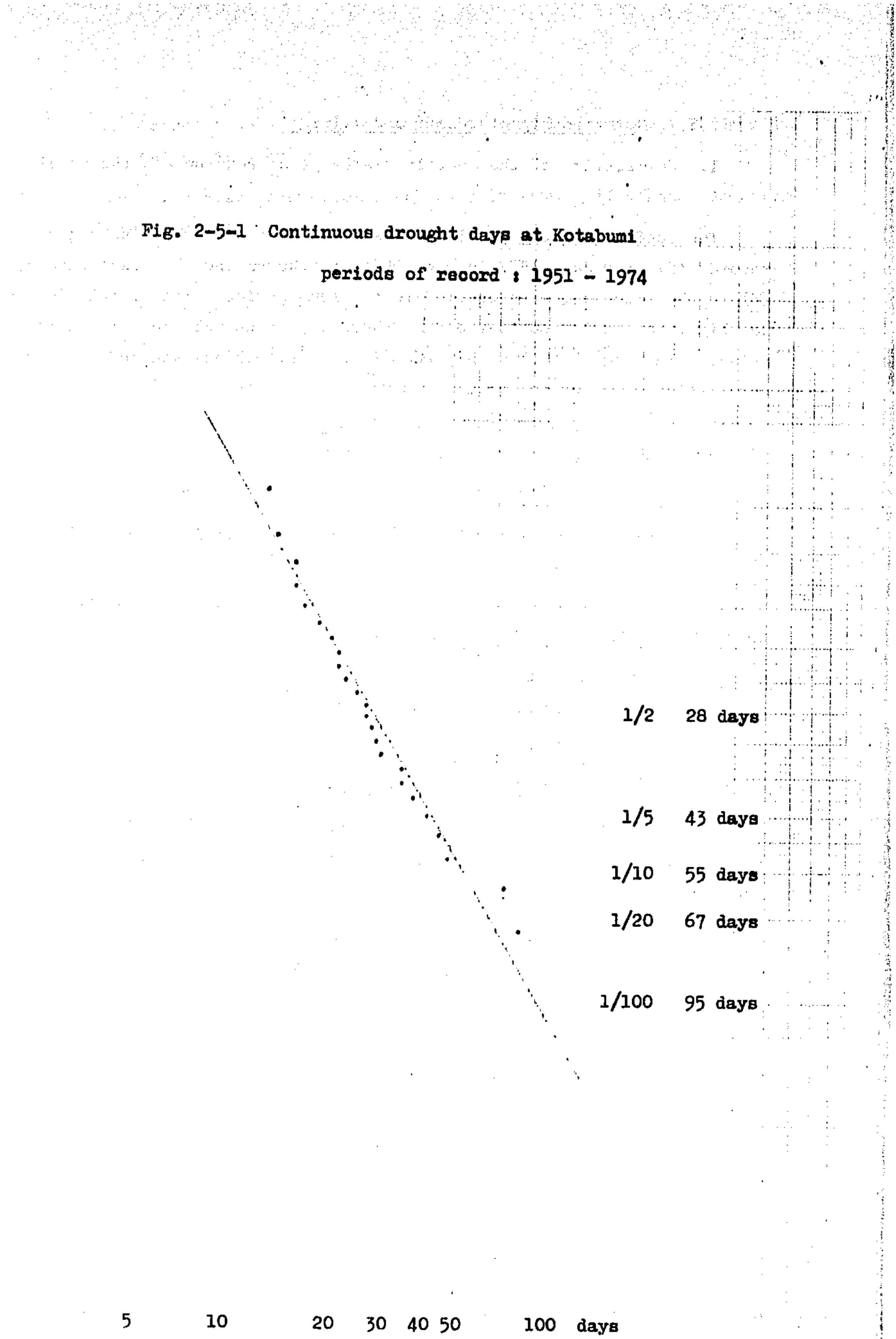
n	Year	Period	Days
1	1951	8 Jun.- 24 Jun.	17
2	1952	26 Jul.- 7 Aug.	13
3	1953	8 Aug.- 14 Sep.	38
4	1954	25 Aug.- 7 Sep.	14
5	1955	21 Sep.- 9 Oct.	19
6	1956	27 Jun.- 17 Jul.	21
7	1957	24 May - 27 Jun.	35
8	1958	3 Sep.- 30 Sep.	28
9	1959	15 Sep.- 26 Oct.	42
10	1960	27 Sep.- 21 Oct.	25
11	1961	7 Sep.- 22 Oct.	46
12	1962	18 Jul.- 8 Aug.	22
13	1963	8 Aug.- 6 Sep.	30
14	1964	14 May - 9 Jun.	27
15	1965	16 Aug.- 3 Oct.	49
16	1966	20 Jul.- 17 Aug.	29
17	1967	6 Aug.- 26 Oct.	82
18	1968	2 Aug.- 17 Aug.	16
19	1969	16 Jul.- 11 Aug.	27
20	1970	28 Jun.- 19 Jul.	21
21	1971	12 Jul.- 27 Jul.	16
22	1972	29 Aug.- 10 Nov.	74
23	1973	30 Jun.- 3 Aug.	35
24	1974	1 Jun.- 23 Jun.	23

Table 2-5-3 Probable Calculation of Continuous Drought Days by Thomas Plot

n	$\frac{i}{n+1}$	Days	Period
1	0.04	82	1967
2	0.08	74	1972
3	0.12	49	1965
4	0.16	46	1961
5	0.20	42	1959
6	0.24	38	1953
7	0.28	35	1957
8	0.32	35	1973
9	0.36	30	1963
10	0.40	29	1966
11	0.44	28	1958
12	0.48	27	1964
13	0.52	27	1969
14	0.56	25	1960
15	0.60	23	1974
16	0.64	22	1962
17	0.68	22	1970
18	0.72	21	1956
19	0.76	19	1955
20	0.80	17	1951
21	0.84	16	1968
22	0.88	16	1971
23	0.92	14	1954
24	0.96	13	1952
Total		750	
Mean		31	

Fig. 2-5-1 Continuous drought days at Kotabumi

periods of record : 1951 - 1974



2.5.2 Relationship of runoff and rainfall

1. Correlation of the monthly discharge at Pekurun and the areal rainfall

The coefficient of correlation is 0.77 in case of the discharge records (X) from Jan. 1972 to Dec. 1974 at Pekurun and the areal rainfall (Y) in the catchment area assumed in the same period. The correlation is not high, but it is considered that there is the correlation of a certain extent. Therefore, the monthly runoff coefficients are assumed by this correlation. (Refer to Table 2-4-3).

Number of data:	N = 34
Correlation coefficient:	γ = 0.77
Regression line:	Y = 1.430 X 53.474

2. Correlation of the monthly rainfall at Kotabumi and the monthly discharge at Pekurun.

The correlation coefficient (γ) is 0.63 for a period from Apr. 1971 to Dec. 1974 and its correlation is low.

Number of data:	N = 43
Correlation coefficient:	γ = 0.63

3. Correlation of the monthly rainfall at Bekitkemuning (X) and the monthly discharge at Pekurun (Y).

The correlation coefficient from Jan. 1972 to Dec. 1974 is 0.75 and it is higher than that of Kotabumi. The records, however, are lacked from Aug. 1973 to Junl 1974.

Number of data:	N = 25
Correlation coefficient:	γ = 0.75
Regression line:	Y = 0.439 X + 39.1

4. Correlation of 10 days rainfall at Kotabumi (X) and 10 days discharge at Pekurun (Y)

The correlation coefficient (Y) is 0.48 from Apr. 1971 to Dec. 1974 and there is no correlation.

Number of data: N = 134

Correlation coefficient: Y = 0.48

5. Correlation of 10 days rainfall at Bekitkemuning (X) and 10 days discharge at Pekurun (Y).

The correlation coefficient (Y) is 0.70 from Jan. 1972 to Jul. 1973 and it is considered that there is the correlation of certain extent.

Number of data: N = 57

Correlation coefficient: Y = 0.70

Regression line: Y = 0.408 x = 18.7

6. Correlation of the monthly rainfall at Bekitkemuning (X) and the areal rainfall (Y).

The correlation coefficient (Y) is 0.88 from Jan. 1972 to Dec. 1974 and it is considered to be high.

Number of data: N = 25

Correlation coefficient: Y = 0.88

Regression line: Y = 1.189 X

Table 2-5-4

*** CORRELATION BETWEEN AREAL RAINFALL AND DISCHARGE-PEKURUN ***

X... MONTHLY DISCHARGE AT PEKURUN IN MM 1972JAN-1974DEC
Y... MONTHLY AREAL RAINFALL IN WAY RAREM BASIN IN MM,328KM2

SOUKAN KEISU .... 0.77 (Correlation coef.)

	NO	X	Y		NO	X	Y			NO	X	Y
1972 Jan.	1	341.000	585.000	1973 Jan.	13	86.000	317.000		1974 Jan.	25	128.000	210.000
Feb.	2	163.000	356.000	Feb.	14	100.000	434.000	¥	Feb.	26	166.000	231.000
Mar.	3	274.000	434.000	Mar.	15	201.000	243.000		Mar.	27	133.000	200.000
Apr.	4	160.000	238.000	Apr.	16	159.000	222.000		Apr.	28	166.000	321.000
May	5	172.000	226.000	May	17	160.000	317.000		May	29	120.000	214.000
Jun.	6	91.000	18.000	Jun.	18	114.000	199.000		Jun.	30	61.000	134.000
July	7	55.000	2.000	July	19	67.000	32.000		July	31	63.000	190.000
Aug.	8	50.000	50.000	Aug.	20	63.000	174.000		Aug.	32	73.000	179.000
Sep.	9	38.000	3.000	Sep.	21	99.000	283.000		Sep.	33	83.000	300.000
Oct.	10	30.000	12.000	Oct.	22	75.000	167.000		Oct.	34	95.000	231.000
Nov.	11	38.000	244.000	Nov.	23	101.000	302.000		Nov.	35	99.000	300.000
Dec.	12	64.000	211.000	Dec.	24	304.000	213.000	¥	Dec.	36	156.000	312.000

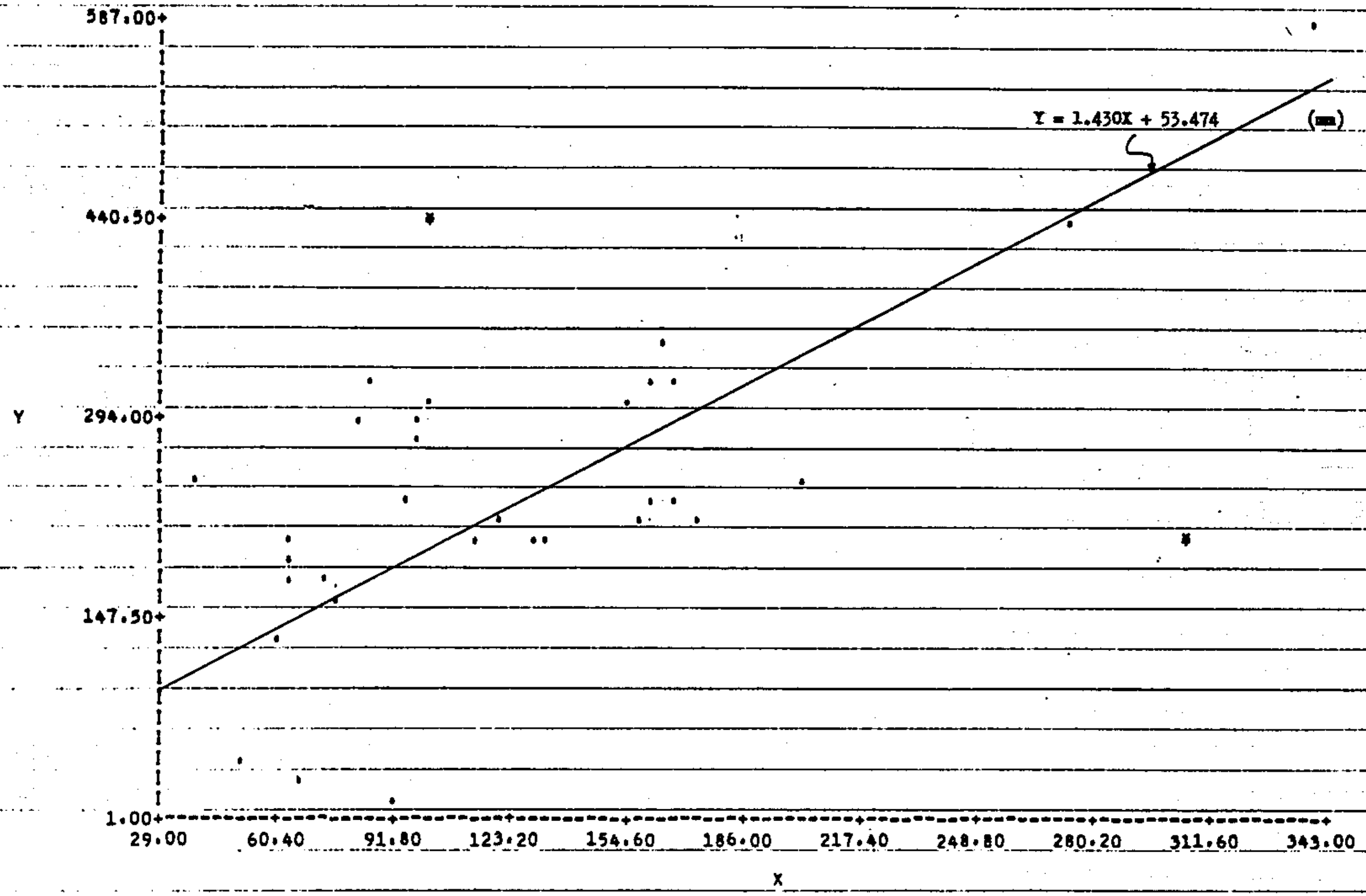
Note: 1. ¥ sign means cut of data.
2. The data of Feb. 1973, No.14 is not used because the run off coefficient is 0.23 in rainy season.
3. The data of Dec. 1973, No. 24 is not used because the run off coefficient is 1.43 in rainy season.

Fig 2-5-2

*** CORRELATION BETWEEN AREAL RAINFALL AND DISCHARGE-PEKURUN ***

X... MONTHLY DISCHARGE AT PEKURUN IN MM 1972JAN-1974DEC
Y... MONTHLY AREAL RAINFALL IN WAY RAREM BASIN IN MM 328KM2

KAIKICHOKUSEN SIKI Y = A*X+B (Regression line)



(Correlation coefficient)
SOKAN KEISU = 0.768
KAIKI KEISU A= 1.430
B= 53.474

COMMENT OF SIGNAL
. = SINGLE
+ = DOUBLE
* = TRIPLE
# = CUT OF DATA

Table. 2-5-5

CORRELATION BETWEEN RAINFALL-BKT AND DISCHARGE-PEKURUN (MONTHLY) ***

X... MONTHLY RAINFALL AT BUKITKEMUNING IN MM 1972 JAN-1974 DEC
Y... MONTHLY DISCHARGE AT PEKURUN IN MM 1972 JAN-1974 DEC

SOUKAN KEISU .... 0.75 (Correlation coef.)

	NO	X	Y		NO	X	Y		NO	X	Y
1972 Jan.	1	4.710	3.410		10	0.010	0.300		18	2.030	1.140
	2	2.510	1.630		11	0.710	0.380	1973 July	19	0.280	0.670
	3	3.110	2.740		12	2.140	0.640	1974 July	20	1.460	0.630
	4	2.470	1.600	1973 Jan.	13	2.160	0.860		21	1.180	0.730
	5	1.590	1.720		14	2.980	1.000		22	1.780	0.830
	6	0.140	0.910		15	1.720	2.010		23	1.840	0.950
	7	0.010	0.550		16	3.460	1.590		24	2.910	0.990
	8	0.020	0.500		17	1.640	1.600		25	3.600	1.560
	9	0.010	0.380								

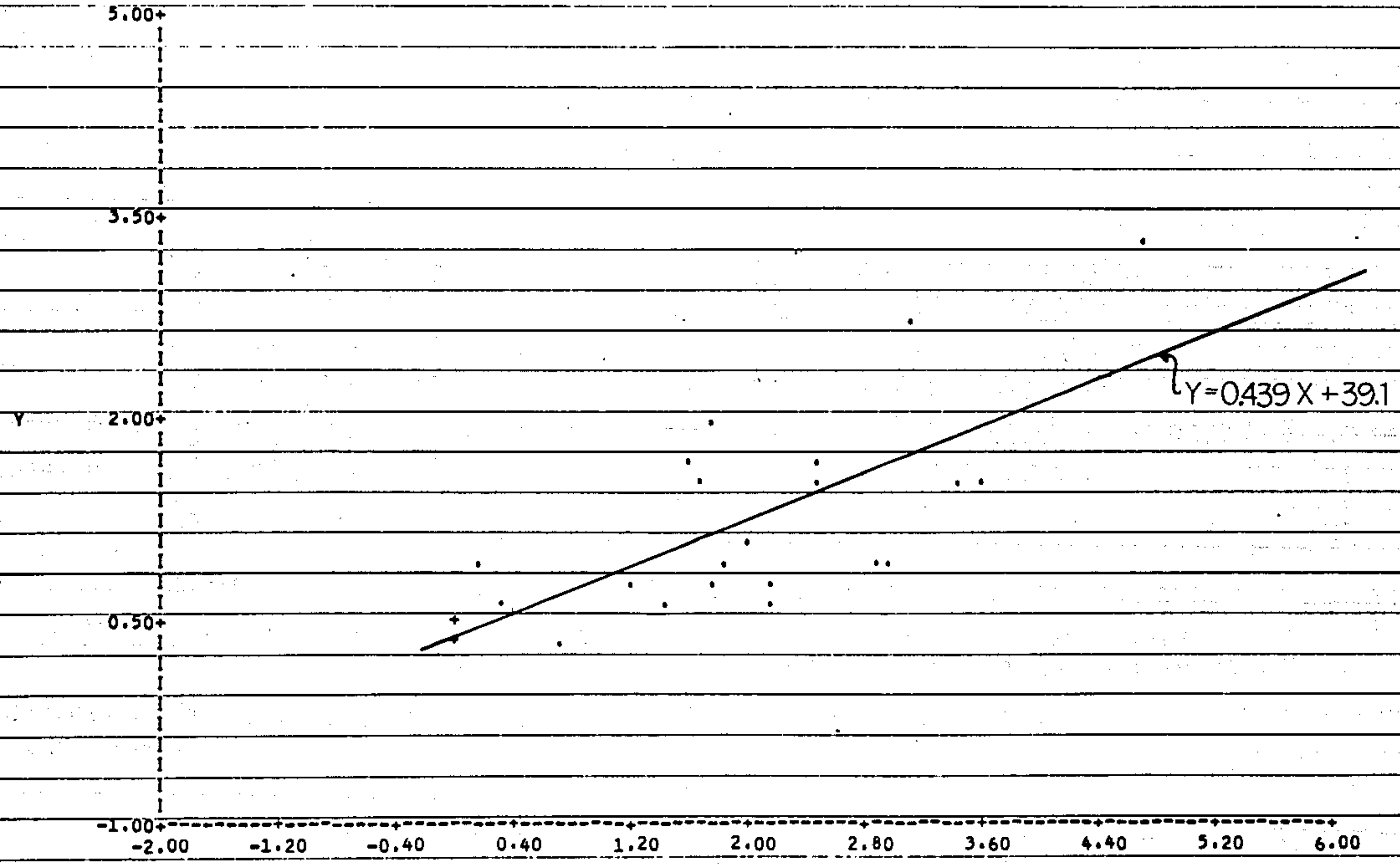
Note: 1. X and Y are shown in 1/100 mm.

Fig. 2-5-2

*** CORRELATION BETWEEN RAINFALL-BKT AND DISCHARGE-PEKURUN (MONTHLY) ***

X... MONTHLY RAINFALL AT BUKITKEMUNING IN MM 1972 JAN-1974 DEC
Y... MONTHLY DISCHARGE AT PEKURUN IN MM 1972 JAN-1974 DEC

KAIKICHOKUSEN SIKI Y = A*X+B



SOKAN KEISU = 0.749
KAIKI KEISU A= 0.439
B= 0.391

COMMENT OF SIGNAL
. = SINGLE
+ = DOUBLE
* = TRIPLE
$ = CUT OF DATA

Table 2-5-6

*** CORRELATION BETWEEN AREAL RAINFALL AND BKT. MONTHLY RAINFALL ***

X... MONTHLY RAINFALL AT BEKITKUMUNING IN MM 1972JAN-1974DEC
Y... MONTHLY AREAL RAINFALL IN WAY RAREM BASIN IN MM 328KM2

SOUKAN KEISU .... 0.88 (Correlation coef.)

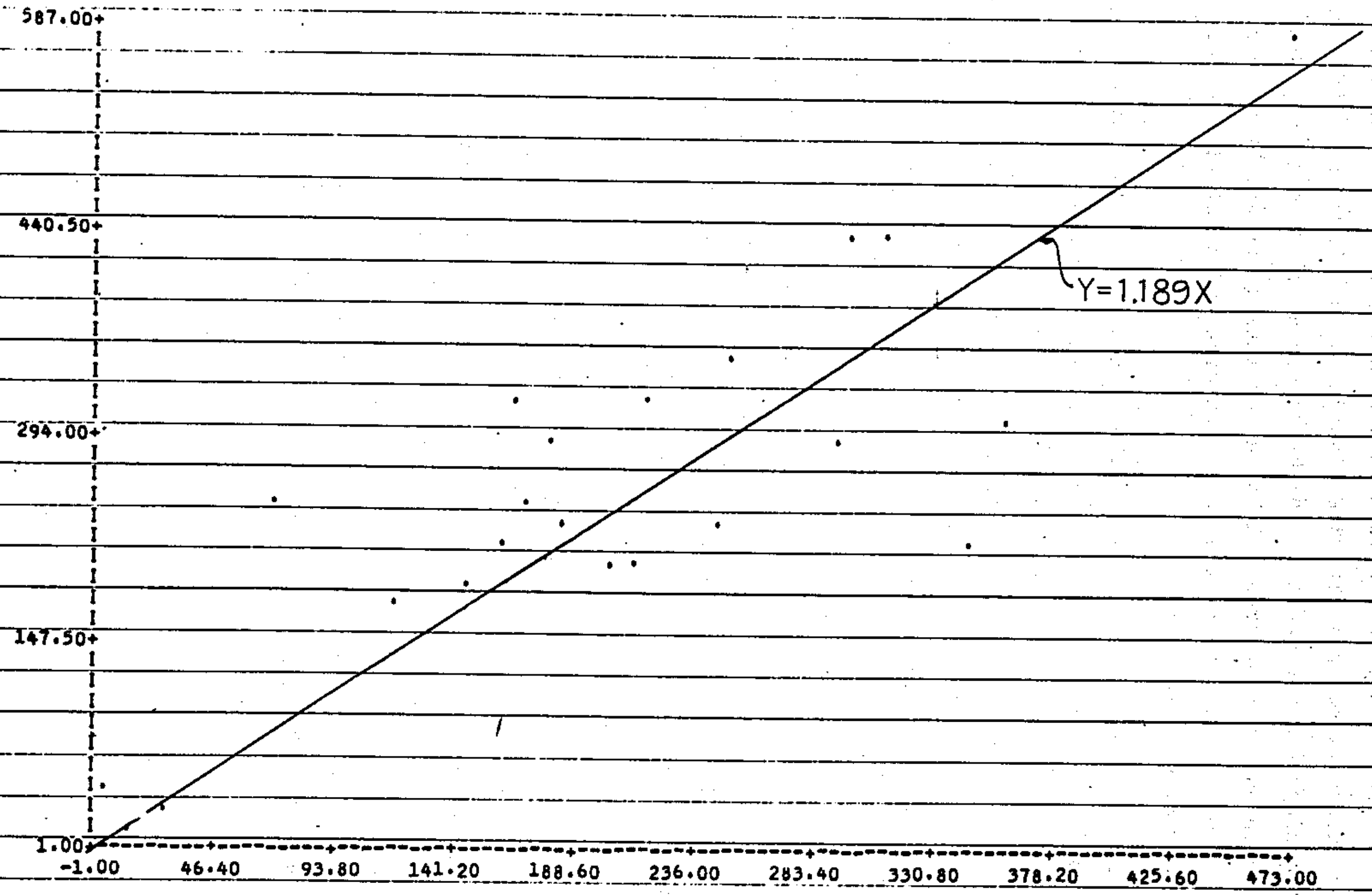
	NO	X	Y		NO	X	Y		NO	X	Y
1972 Jan.	1	471.000	585.000		10	0.100	12.000		18	203.000	199.000
	2	251.000	356.000		11	71.000	244.000	1973 July	19	28.000	32.000
	3	311.000	434.000		12	214.000	211.000	1974 July	20	146.000	190.000
	4	247.000	238.000	1973 Jan.	13	216.000	317.000		21	118.000	179.000
	5	159.000	226.000		14	298.000	434.000		22	178.000	300.000
	6	14.000	18.000		15	172.000	243.000		23	184.000	231.000
	7	1.000	2.000		16	346.000	222.000		24	291.000	300.000
	8	2.000	50.000		17	164.000	317.000		25	360.000	312.000
	9	0.100	3.000								

Fig 2-5-4

*** CORRELATION BETWEEN AREAL RAINFALL AND BKT. MONTHLY RAINFALL ***

X... MONTHLY RAINFALL AT BEKITKUMUNING IN MM 1972JAN-1974DEC
Y... MONTHLY AREAL RAINFALL IN WAY RAREM BASIN IN MM 328KM2

KAIKICHOKUSEN SIKI Y = A*X



SOKAN KEISU = 0.885
KAIKI KEISU A= 1.189
B= 0.0

COMMENT OF SIGNAL
. = SINGLE
+ = DOUBLE
* = TRIPLE
# = CUT OF DATA

PART III. GEOLOGY

3.1 General Description

The project area is located in the east side of the Barisan range. The altitude is not less than 70 m above the sea-level near the dam site, being 60 m and under in the benefited area and becoming 10 m at the north end of that area. A loose undulating topography is being kept from the dam site to the benefited area and a lot of flat surfaces of the summit is remained.

No big river is found except the main stream of the Rarem. There are many cases which valley plains in small scale have been formed at the bottom of ravines on small rivers. On the main stream of the Rarem river, valley plains are found on the upstream side from the dam site, but completely being none between the dam site and the half of the benefited area. Natural levees have been formed along the river in the northern part of the benefited area. This natural levee is being utilized as living area and arable land due to no flooding over this levee being made by normal inundation. Back swamps are constituted between the natural levee and plateau, and this being used as seasonal arable lands by the reason of that this will become upland in the dry period, and below the water surface in the wet period.

3.2 General Geology

South Sumatra region is divided into three structural blocks with several geological structures to parallel with the Barisan range.

Large faults are elongated near the project area from the southeast to the northwest. The fault strikes through the west side of Kotabumi town from Telukbetong. The southwest side of the fault consists in dome structure and forming syncline structure around Kotabumi. The bedrock consists of granite, gneiss, crystalline schist, Tertiary quartz-sadstone.

These are merely denuded upstream of the dam site. Andesite and eruptive rock are piled on the upper part of these rocks, and the tuff, sandstone and mudstone of the Tertiary deposit being piled on the above, and pyroclastic sediment of the Quaternary deposit on the highest part. (See Table 3 - 1, Stratigraphical Scheme of the area).

Since volcanic actions have been vigorous with each age, a great deal of the tuff, pumice is found in the stratum bed, which is caused by volcanic action.

Igneous Rock and Metamorphic Rock

Such rocks are not outcroped in the benefited area. These are outcroped on river scarps of the Kulur and Galing rivers, tributary of the Rarem river, upstream side of the dam site. The kind of rocks is granite, gneiss, quartzite, either being extremely hard, massive.

Volcanic Rock

Rock which is outcroped as mass is mainly andesite, but not being outcroped in the benefited area. The outcroped andesite is found around the dam site and upstream of the Rarem river. A cryptodome of the andesite is existed in the driving channel area, and a small hill of liparite being located on the left bank of the Pengbuan river, the east side of the driving channel.

Sedimentary Rock

The sedimentary rock of the Tertiary deposit is widely distributed in the project area. The lithology consists in the tuff, tuffaceous mudstone, sandstone, mudstone, conglomerate, diatomite etc. and nearly showing horizontal bedding.

Weathered Tuff

The weathered tuff is broadly distributed around the dam site, driving channel and the southern part of the benefited area, and mostly become clay, and having parts of comprising fine grained pumice and quartz.

Table 3-1 Stratigraphical Scheme of Area

Geological Age		Columnar Section	Lithology	Principal locations of outcrops
Quaternary	Alluvium Diluvium		Weathered Volcanic Ash (Loam)	Dam site, main channel
Neogece	Pliocene		Clay with Red and White Bands	Benefit area
			Greyish white fine Sand	
			Alternation of Mudstone, Sandstone and Conglomerate	Main channel
			Tuff and Tuff Breccia	Dam site
	Miocene		Andesite and Tuff Breccia	Dam site
Paleogene			Granite, Gneiss and Quartzite	Upper stream of dam site

The tuff can be classified into 3 kinds. The first is mainly distributed at the dam site and driving channel area, only consisting of the tuff, which was piled by wind. The second is generally existed in the southern part of the benefited area, containing small pieces of quartz and masses of oxidized iron in the tuff, sometimes comprising small pieces of andesite. The third is only found on the slope of valley of the central and northern parts in the benefited area, the quality being practically the same as the second. The colour of the tuff in the three kinds is yellowish brown and porous, so the permeability is high.

Pyroclastic Sediment

This consists of the aggregate of volcanic breccia, tuff breccia, lapilli tuff, partially massive rock of andesite being hold and mainly distributed upstream of the dam site of the Rarem river.

3.3 Regional Description

3.3.1 Dam Site

Drillings were made at 10 holes around the dam site for knowing the subsurface geology. In the result, it is found that the stratigraphic classification in the dam site consists of the volcanic breccia on the lowest part, and the sedimentary layer of the tuff, pumice and tuffaceous sandstone is laid on the above and the weathered tuff on the highest part. The volcanic breccia on the lowest part is none bedding and massive, and is a stratum containing many andesite breccia in 10 cm, maximum diameter in the groundmass, which is constituted with tuff.
On the whole, the qulity is extremely hard but impossible to utilize as rock material due to crushing into small pieces and having few fractures and fissures and minor permeability. The depth of this rock is deeper than 20 m under the alluvium plain on the Rarem river near the dam site.

The alluvial plain on the Rarem river is constituted with the alluvial deposit till 9 m under the surface, and being alternated with the clay stone, sandstone, tuff, pumice tuff under that and horizontally being piled with each layer. These strata have been consolidated, but the permeability is high, and having the value of (1.6 - 3.3) x 10^{-4} cm/sec. However, the value at the lower part becomes small till the order of 1 x 10^{-5} cm/sec.

3.3.2 Main Canal

The surface of the undulating plateau is covered with weathered tuff. Sandstone, mudstone, shale, conglomerate and tuff of the neogene tertiary area alternated under that. These alternate layers are not denuded on the surface of the plateau, merely outcroped on the portion where the weathered tuff was washed by erosion on the slope of valley and the valley bed, and nearly being horizontal layer. The thickness of the weathered tuff on the highest part is 7 - 10 m in the south, and 3 - 4 m in the north. These will be yellowish brown in colour and have become clay, and the permeability being rather high. Under the Tertiary deposit, tuff breccia is laid and not outcroped in the south part (denuded at the dam site), and slightly being outcroped on the valley bed in the north part. The Alluvium deposit on valley plain is mainly constituted with cohesive quality and the thickness of layers are not much thick.

3.3.3 Benefited Area

The ground surface of about 1/3 of the southern part in the area is covered with weathered tuff. 2/3 of the remain is the outcroped area of the Tertiary deposit except the ridge. Natural levees are ranged on the Rarem river which flows along the west and north boundaries in the area and by the Tulang bawang river downstream of the Rarem river.

On the Tertiary deposit which is outcroped on the 2/3 of the northern part in the area, there is where the single layer of grayish white clay which no stratification massive tuff deposit was weathered on the whole is distributed, and where the alternate layer of tuff, mudstone and sand stone is distributed.

The surface of the catchment of the Miring river flowing on the central part of the area is constituted with yellow sandy clay of 0.8 - 1.0 m and under the yellow clay, grayish white clay is laid. The red clay is irregularly contained as massive in this clay and quartz in minute piece of 1 - 2 mm diameter is comprised in this clay. Sand layer is existed under this clay, and this being not much firm, though solidified. The permeability is low in the grayish white clay on the upper part, and rather high in the sand layer on the lower part.

Considering from the stand point of engineering geology, the bearing power is rather weak on the surface in the outcroped area of the grayish white clay layer and the feasibility of flow is easy in case of containing water. In the hill area in the northern part, the bearing power is high and the feasibility of flow is none and the permeability is rather high due to the sandstone being outcroped on the surface.

3.4 Materials for Construction

3.4.1 Rock

Rocks utilizable for construction at the circumference of the project area are igneous rock, metamorphic rock, volcanic rock. Sedimentary rock and tuff in this area being in want of hardness, the utilization as rock material is hardly possible.

Utilizable rocks are found at three places adjacent to the project area, and these three places being upstream of the Galing river, on the left bank of the Pengbuan river in the eastsouth direction of Nakan village, and near the Gunung Anggar village. Among these, one of Gunung Aggar village is under quarrying, and other two places being undeveloped.

The Bukit Butong mountain is located about 5 km upstream from the dam site on the left bank of the Galing river, and this mountain is entirely constituted with andesite, and the mountain crest is flat and extended narrowly to the eastwest and being a separated mountain high in the west and low in the east. The quality of frocks will be different due to places. The lower part is constituted with massive and minute andesite, severely being affected by silicification. In accordance with the results of the laboratory rock mechanical test, the compression test of the andesite at the lower part having no fracture is 1872 kg/cm^2. The andesite on the upper half of the mountain is porous rock and easily fissured in flatwise, and the unconfined compression unit strength is 600 - 700 kg/cm^2. The east slope of the mountain is loose and the mountain foot is covered with thick talus, and this thickness being more than 10 m. The north slope of the mountain is steep, and the foot is covered with thin talus, and rocks on the upper half being outcroped.

The andesite of Gunung Anggar village is now under quarrying. The quality of rocks is partially rather fissured flat, also being part to be fissured massive. This andesite substance is cryptodome structure and no outcrop on the surface is a feature. The andesite having such a structure will be feasible to be found at others with the progress of survey. The distance from the dam site is about 15 km.

Rock located on the left bank of the Pengubuang river is silicified liparite. This rock is porous and firm and forming an independent hill having relative height in 60 - 80 m, which shows almost cone on the flat land along the river and its circumference, 1 - 2 km. The foot of the hill is covered with thick talus and this talus will be used for concrete aggregate.

3.4.2 Aggregate for Concrete

A few places for gathering a great deal of aggregate, specially sand are found.

Unsolidified sandy gravel layer is widely distributed under the alluvial plain around the dam site. In drilling No. 12, sandy gravel layer is laid in 2.05 m between 9.2 m depth till the tuff of the bed rock. In No. 13, 2.8 m depth of the sand gravel layer is existed between 8.4 m depth till the bed rock. Gathering feasible amount is estimated 0.7 m^3 per m^2. As the gathering feasible area bewteen 3.5 m depth in total from 1 km upstream side of the dam axis to 2.5 km at the downstream side is 880,000 m^2 in 4 lots in total, gathering feasible amount becomes 616,000 m^3 and the propotion of sand and gravel is considered to be 1 : 1.

A few amount of sand and gravel is found under the ground of the alluvial plain on the Abung river. Pulan Panggung village is located on the right bank of the Abung river along the road from Kotabumi to Palemban. Sandy gravel layer is distributed on the alluvial plain of the Abung river back of this village. The gravel is round gravel constituted with andesite and quartzite and its amount being not much. The distance from the dam site is about 25 km.

The quartz sandstone is found on the river bed of the Galing river back of Galing village upstream of the Galing river. The quality is excellent, but being less in quantity.

There is quartz sandstone in several places on the river bed of the Pungbuan river but no place feasible of collecting a great deal of sand is found from one place. Now any roads along the river being not existed, the transportation is not convenient. This will be possible to utilize for the main canal work in small scale.

No place yielding gravel is found in the benefited area. The sand is broadly distributed on the whole alluvial plain on the Bakung river and this fine sand is quartz sandstone. The distributed area is wide, but the thickness is about 1 m and the amount mixed with clay being much. This will be utilized for construction work in small scale.

3.4.3 Soil Material

Weathered tuff is adopted for soil material which is covering the surface around the dam site. As this material is broadly distributed at the circumference of the dam site along the main canal and on the surface of 1/3 in the south of the benefited area, it is feasible to collect in the near distance for works. Though the thickness of this layer is 10 m in maximum around the dam site, the practical thickness feasible for the utility is considered to be less than 6 m.

3.5 Earthquake

The Barisan range, which becomes watershed of Indian ocean and Java sea, is simultaneously a typical epicentral belt. Namely the epicentres of whole big earthquakes in 1892 - 1942 were in this area. But more epicentres under the bottom of the sea were occured in the frequency of all earthquakes.

Earthquakes occured in 1903 - 1932 at Sumatora are as follows:

Type	Number of earthquakes
Epicentres on the land	210
Catastropic earthquakes	6
Reported earthquakes in total	1,309
Earthquakes occured with submarine epicentres	1,105

The dam site in the project area is located in the multi-seismic zone as stated above, and being near Semangko zone in the Barisan range where is epicentre zone, a special consideration to the matters of earthquakes was paid on the design of the dam.

PART IV. SOILS AND LAND CLASSIFICATION

4.1 Introduction

The only information on soils in the Project area now available is a reconnaissance map at a scale of 1:250,000 prepared in 1969 from earlier investigation of the Soil Research Institute in Bogor.

However, the results of the said information is too extensive so that it is insufficient for the planning of agricultural development in the Project area. Therefore, the soil survey was carried out to identify major soil groups, to delineate their distribution, to clarify their main features necessary for the selection of adaptable crops, to formulate adequate farming practices, and to evaluate the basic factors of irrigation engineering design. The area covered by the soil survey was about 60,000 ha out of the original governmental planned area of 83,000 ha.

The field soil survey was carried out from July 1974 to August 1974. The laboratory tests of the representative soil samples were carried out in the laboratory of Padjadjaran University. In addition, some soil samples were sent to Tokyo to examine the specific soil features such as cation exchange capacity, total nitrogen, phosphate, absorption coefficient of P_2O_5, lime requirements, specific gravity, etc. They were analyzed at a soil laboratory.

4.2 Procedure of Soil Survey

The field survey was carried out with the use of topographic map of 1:25,000 scale covering the entire governmental original planned area of 83,000 ha. The soil profiles were observed at the rate of one per 500 ha and were described according to the standard defined in the Soil Survey Manual of the United States Department of Agriculture, Handbook 18, 1951. Laboratory tests were mostly made in accordance with the laboratory methods and procedures in the Soil Classification, a Comprehensive System, 7th Approximation by United States Department of Agriculture, 1960. They are as outlined below.

4.2.1 Field work

At a selected site, a pit was dug to a depth of one meter and thereafter auger boring was done for the study of profile features and soil sampling. Additional auger tests were carried out to determine the accurate boundaries between different soil groups. In the course of field works, the soil acidity in pH value, bulk density and moisture contents were determined definitely. The number of essential tests and measurements made are as follows.

Item	Unit	Number
pH test	Soil sample	317
Pitting with auger boring for profile study	Spot	23
Auger boring to delineate major soil group	Spot	98

4.2.2 Laboratory work

Air dried soil samples were pulverized and passed through a two mm diameter roundhole sieve. Soil particles smaller than two mm in diameter were used in the laboratory test. The methods used in the laboratory work are as listed below.

(1) Particle size distribution analysis: Hydrometer method

(2) Soil reaction: Glass electrode meter method using pure water and normal KCl solution

(3) Total carbon: Tyurin's method

(4) Total nitrogen: Kjeldahl method

(5) Cation exchange capacity: N-sodium acetate and N-ammonium acetate schollenberger's method

(6) Exchangeable base: Atomic absorption spectrophotemeter method with leaching extraction by N-sodium chloride

(7) Available phosphate: Molybdate method

4.3 Soil Classification

The Project area is located along the right bank of lower reaches of the Rarem River. It is formed of plateau and many small rivers connecting with the Rarem or the Terusan River, where the elevation ranges between 5 and 60 m above sea level.

Half of the lands in the surveyed area lie waste and are still covered with forests, bushes and wild grass. Only 28 % of the lands are being used for dry crop farming and perennial crop cultivation on a small scale. The present status of land use in the surveyed area is as follows.

Item	Area (ha)
Lowland paddy field	100
Upland crop field	15,700
Perennial crop field	1,000
Grassland	17,500
Forest	17,300
Swamp	1,100
Village area	7,300
Total	60,000

4.3.1 Soil classification

In the light of the major profile features and the results of the laboratory tests, the soils in the Project area are broadly classified into three groups, i.e., Ferrallitic soil group, Tropical Podzolic soil group and Tropical Alluvial soil group. For the above soil classification, the criteria* on soils in tropical and subtropical regions prepared by Dr. P. Buringh are fully referred.

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* : Dr. P. Buringh, in his report titled "Introduction to the study of soils in tropical and subtropical regions" and revised in 1970, sets up the soil classification criteria on tropical and subtropical soils on the basis of terminology and concepts explained in the Soil Survey Manual (1951) and the Comprehensive System of Soil Classification (1960 to 1967) both prepared by the United States Department of Agriculture (USDA).

In the surveyed area, Ferrallitic soil group is represented by Lateritic soils. In addition, Tropical Podzolic soil group is subdivided into two soil sub-groups, i.e., Red Podzolic soils and Yellow Podzolic soils, from the viewpoint of geological formation.

These soils are further divided by soil phase of low category, particularly by vegetation (present land use pattern) in view of the agricultural land use. The Lateritic soils have four soil phases. The Red Podzolic and Yellow Podzolic soils have five soil phases, respectively. The Tropical Alluvial soil group has two soil phases. The distribution of these soil phases and their proportional extent are as shown in Table 2.1. Representative soil profile descriptions and all chemical and physical analyses data are presented in Data Book. Distribution of soil groups is drawn on the Soil Map attached to the main report.

4.3.2 Main features of soil group

The main features of the soil groups in the Project area are summarized below.

Lateritic soils

These soils develop over hillside of plateau, facing small rivers and having gentle slope, and also observed in the natural forest existing on some parts of the plateau. The area having these soils covers an area of 19,300 ha corresponding to 32.2 % of the total surveyed area.

The Lateritic soils have very deep layer of weathered red clay appeared throughout soil profile, especially the soils extending over the hillside of plateau usually lack Ai horizon due to erosion by heavy rainfall. The horizon sequence of these soils is A/B/C in general.

The depth of A horizon is about 10 cm and B horizon is 10 to 70 cm in depth. Soil color throughout the soil profile is grayish red to reddish brown.

Soil texture of A and B horizons is clay and C horizon becomes clay loam. Structure is weak blocky in A horizon and massive in Band C horizons.

The pH value of each horizon ranges between 5.0 to 6.0 for H_2O-solution. Cation exchange capacity is very low resulting in low fertilizer holding capacity. Taking into consideration the above chemical properties, soil fertilities of these soils are so poor that proper fertilization is indispensable for intensive farming.

In the light of the soil features, the soils of this group are very suitable for cultivation of upland field crop as well as perennial crops such as coffee, pepper, rubber, etc.

Red Podzolic and Yellow Podzolic soils

Red Podzolic soils originates from weathered volcanic tuff often with quartz and Yellow Podzolic soils from tertiary soils. These soils mainly extend over 39,500 ha, corresponding to 65.8 % of the total surveyed area, of grasslands and upland fields on the plateau.

Red Podzolic and Yellowish Podzolic soils have been strongly weathered and are characterized by high content of quartz sands in the surface horizon. In general, these soils have highly leached brownish gray or grayish brown surface soils over a red or yellowish brown clay accumulation horizon of relatively heavy texture, relatively low permeability and low degree of stable aggregation. The development of the leached surface horizon, however, is not always well expressed. The horizon sequence of these soils is $A_1/A_2/B/C$ in general.

The depth of A_1 horizon is about 10 to 20 cm in general. A_2 horizon has leached horizon with a depth of about 10 to 20 cm. B horizon has developed or weakly developed iron and manganese concretions, the content of which is less than 20 %. Sometimes, the lower part of B horizon is generally mottled by the effect of seasonal fluctuation of groundwater table.

Regarding soil color, A_1 horizon is brownish gray (5YR 4/1) or grayish brown (5YR 4/2). A_2 horizon is yellowish brown or reddish

Table 2-1 Major Soil Groups and their Development in the Project Area

Soil group	Soil subgroup	Soil phase	Area (ha)	Proportional extent (%)
Lateritic soils	-	A (Forest phase)	12,000	20.0
		B (Grass phase)	4,800	8.0
		C (Upland phase)	2,200	3.7
		D (Village phase)	300	0.5
		Sub-total	19,300	32.2
Tropical podzolic soils	Red podzolic soils	E (Forest phase)	1,800	3.0
		F (Grass phase)	5,800	9.7
		G (Upland phase)	4,200	7.0
		H (Perennial phase)	800	1.3
		I (Village area)	2,200	3.7
		Sub-total	14,800	24.7
	Yellow podzolic soils	J (Forest phase)	3,500	5.8
		K (Grass phase)	5,900	9.8
		L (Upland phase)	10,300	17.2
		M (Perennial phase)	200	0.3
		N (Village area)	4,800	8.0
		Sub-total	24,700	41.1
Tropical alluvial soils		O (Lowland phase)	100	0.2
		P (Swamp phase)	1,100	1.8
		Sub-total	1,200	2.0
	Total		60,000	100.0

brown. The color of B horizon varies from brown to red in accordance with the effect of groundwater.

Many of the A_1 or A_2 horizons are sandy clay loam to loam. In most of B horizons, clay accumulates resulting in clayey texture. The clay content of C horizon decreases with depth. Structure is crumby in A_1 or A_2 horizons. B horizon has weak blocky or massive structure. C horizon is massive. Soil consistency becomes firmer as the depth increases.

As far as the chemical properties are concerned, A_1 and A_2 horizons have pH value between 4.5 and 5.5 for H_2O-solution, nd between 3.5 and 4.5 for KCl-solution. The B horizon has pH value of 4.5 to 5.0 for H_2O-solution and 3.3 to 4.3 for KCl-solution. Cation exchange capacity is as low as 5 to 10 me per 100 g of soil in both surface soils and subsoils, which indicates low fertilizer holding capacity. The total carbon content of A_1 horizon is about 4 to 5 %, and that of B horizon is about half. Total nitrogen is less than 0.2 % in general and P_2O_5 is less than 2 mg per 100 g of soils. Taking into consideration the above chemical properties, soil fertilities of these soils are so poor that proper fertilization is a requisite for maintaining the level of optimum yield of crops under irrigation farming.

In the light of the soil features, the soils of this group are suitable for mixed farming of dry farm crops with livestock raising as well as the culture of perennial crops such as rubber, coffee, pepper, and clove, etc. They can also be used for the culture of paddy rice by providing irrigation facility.

Tropical Alluvial soils

These soils are too young deposits observed in low-elevated strips of 1,200 ha along the small river in the Project area. The young soils deposited at the transition from the plateau to a small valley bottom during short periods of heavy discharge by rainfall are almost permanently wet, and the effective soil depth is moderately thick. Since the deposits consist of base-leached materials of fine texture and grayish to gray colour, soil fertility is very poor. Furthermore, the pH values show 4.0 to 5.0 for H_2O-solution.

Under the present conditions, their internal and external drainages are very poor. Providing the drainage facilities are completed, these soils can be used for profitable irrigation farming of paddy rice and other crops by the application of proper fertilizers and adapted farming practices.

4.4 Soil Fertility and Soil Conservation

The results of the chemical analysis conducted make clear that the respective soils in the Project area are very poor in soil fertility. Therefore, these soils, even if proper irrigated, still affect harmfully crop production. The problems are arising from coarse soil texture, strong soil acidity and lack of weatherable minerals. These problems can be ameliorated to a certain degree with the incorporation of organic matter. Thus, improvement of such characteristics of the soils requires the timely application of fresh organic matter.

In general, fresh organic matter can be added by plowing-in cover crops, applying barnyard manure, and growing perennial grasses and legumes in rotation with other crops. In view of soil management, it is recommendable in the Project area that rice straw and stubble to be produced on newly reclaimed irrigated paddy field are applied to the surface soils after harvest and also leguminous and green manure crops, i.e., soybean and crotalaria, are taken up into the crop rotation. Applied method and quantity of organic matter should be determined on the basis of input response test under irrigated condition.

4.5 Land Capability

Classification of land capability is the systematic appraisal of land and the designation by categories of essenti l characteristics in order to illustrate the degree of suitability of the land for irrigation farming.

In general, the "classification of the United States Bureau of Reclamation Manual of Irrigated Land Use" has been used as a criteria for land capability classification of most unreclaimed region so far. But the manual has been prepared for use in the appraisal of undeveloped land in the western states of the United States where arid or semi-arid climate prevails. Therefore it is not always applicable on evaluating the capability of land for specific tropical crops inclusive of paddy rice in tropical monsoon climatic region unless it is subject to some modifications so as to be applied to specific regional solis and crops.

On such account, a modified standard* of the United States Bureau of Reclamation Manual of Irrigated Land Use is provisionally prepared in the light of existing soil study results as shown in Table 2.3. The land capability classification in the Project area based upon the provisional standard is described hereunder.

Based upon the provisionally modified U.S.B.R. standard of land capability classification, the lands in the Project area are classified into four classes such as Class II, III, IV and VI by the degree of limitation of land use for irrigation farming as follows.

Class II: Arable

The lands of this Class are moderately suitable for irrigation farming, being measurably lower than Class I, adapted narrower range of crops, more expensive to prepare irrigation and drainage facilities or more costly to prepare farms. They are of moderately low fertility. They have intermediate payment capacities in common.

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* ; This standard is fully referred to "Provisional land classification criteria for irrigation farming of paddy rice with secondary dry field crops under monsoon tropical climate in Asia", which was made by Nippon Koei Co., Ltd. in 1974 for the Land and Water Resources Development Project in South Eastern Sumatra, Indonesia, requested by FAO.

Class III: Arable

The lands of this Class are suitable for irrigation development but are of more restricted suitability than Class II because of more extreme deficiencies due to soil features or topography. They have slightly lower payment capacities than Class II soils even under proper management.

Class IV: Limited arable

The lands of this Class are marginally suitable for irrigation adapted narrowest range of crops due to steep and badly eroded lands. They have lower payment capacities than Class III soils even under proper management.

Class VI: Non-arable

The lands of this Class do not meet the minimum capability requirements for other Classes and are not suitable for irrigation farming in general, due to poor internal and external drainage problems. The lands of this Class do not have sufficient payment capacity to warrant the contemplation of irrigation farming development.

The areas and proportional extents of land by class are as shown in Table 2-2.

Table 2-2 Area and Proportional Extent of Each Class of Land Capability

Land grade	Area (ha)	Proportional extent (%)
Class I	-	-
Class II	22,000	36.6
Class III	6,000	10.0
Class IV	10,000	16.7
Class VI	14,700	24.5
Right of way	7,300	12.2
Total	60,000	100.0

Table 2-3 Specification for Detailed Land Classification

Land Characteristics	Class I Arable	Class II Arable	Class III Arable	Class IV Limited arable	Class VI Non arable
Soils					
Texture	Loamy to friable (or light) clay	Loamy sand to very permeable clay	Loamy sand to permeable clay	Loamy sand to slowly permeable clay	Sandy, gravelly and stony soils
Soil depth to sand, gravel or cobble, rock and other impermeable layer	60 cm minimum for all textures	40 cm minimum for all textures except coarser textures than loamy sand which must have 60 cm minimum	20 cm minimum for all textures except coarser textures than loamy sand which must have 40 cm minimum	15 cm minimum for all textures except coarser textures than loamy sand which must have 20 cm minimum	Less than 15 cm for all textures
Cation exchange capacity in surface soil Acidity	More than 10 me/100g of soils $pH(H_2O)$ in subsoil more than 5.0	Less than 10 me/100g of soils $pH(H_2O)$ in subsoil 4.5 to 5.0	Less than 10 me/100g of soils $pH(H_2O)$ in subsoil less than 4.5	Less than 10 me/100g of soils $pH(H\ O)_2$in subsoil less than 4.5	Less than 10 me/100g of soils $pH(H_2O)$ in subsoil less than 4.5
Topography	Less than 2 % of the land slope (to be graded into Class I by the U.S.B.R. standard) is recognized all over the area. In this classification, however, roughly undulating and/or rolling topography is graded into VI, even less than 2 % of the land slope, due to being directly affected with heavy erosion under the present large precipitation. The lands, having higher elevation than water level in the canal which will be established with the Project, are also excluded from the arable land classes. In some exceptional cases, those higher elevated lands are partly graded into irrigable land classes, if the lands have any possibilities for establishing enough size of a farm plot and can also apply an additional irrigation system by means of booster pumping, etc.				
Drainage	Well surface drainability but poor to restricted sub-surface drainability is recognized all over the project area.				

PART V. AGRICULTURE

5.1 Present Condition

5.1.1 Farm survey

An agricultural survey was carried out to evaluate the present agronomic and economic conditions, and further to estimate the future agricultural productions.

At the beginning of this survey, general informations concerning the settlement date, population, land use, land holding size, land tenure, agricultural production in the entire surveyed area, data were collected from the special executing offices of Way Abung I and II Transmigration Schemes. As a result, it was cleared that there were some differences between the farming type and cropping area of individual transmigrants in accordance with their settlement histories. The surveyed farm household of 30 in number were selected from the Way Abung I and II Transmigration area on the basis of the said difference as well as the kind of transmigration. In addition, each five farm households were picked up from both a native village and an army settlement.

Data were mostly collected through interviews with farmers. From May to August 1973, the agronomist visited the farmers and made inquiries on the family size, family labor force, land holding size, land tenure, farming practices, cropping pattern, farming equipment, farm inputs, production, livestock, living expense and institutional services.

The survey also covered the agronomic and farm economic conditions in the Central Lampung Prefecture in Lampung Province where irrigated cropping of paddy was widely observed. This area is densely networked by canals which were constructed before Indonesia became independent. The intake facilities for these canals have recently been rehabilitated by the Government for efficient utilization of water supplied from the Sekampung River throughout the year. Inasmuch as the above-mentioned survey covers the condition with irrigation, the high paddy production obtained by irrigator may serve as a basis for appraising the paddy yield accruing after the implementation of the Project.

Reliability of all data collected and results of interviews made were reconfirmed by official statistics and informations provided by the prefectural office of North Lampung and the provincial office of Lampung.

According to the above, the special executing offices of Way Abung I and II Transmigration Schemes have promoted the both schemes since the first settlement in 1965. The Lampung Provincial Transmigration Office have also fully supervised getting the support of foodstuff supply for settlement construction from the World Food Program. Under the control of two executing offices, there are 21 villages of Unit Desa in the surveyed area.

Table 5-1 shows the kind of transmigration, settled households and population as of 1975 at the level of respective villages.

5.1.2 Land use

Out of 83,000 ha mentioned in the original plan of the Government, the Provincial Agrarian Office already endowed two private plantations with land concession of 11,500 ha in total. Besides, there are also 11,500 ha of miscellaneous areas such as residential districts around Kotabumi and along the highway, detached areas due to the existence of the said concession areas, etc. Present condition of land use in the remaining 60,000 ha was investigated, The summary of results are given in Table 5-1.

Each farm family settled in the surveyed area through the Way Abung I and II Transmigration Schemes is allocated 2.0 ha, consisting of 1.0 ha to be irrigated, 0.75 ha of upland and 0.25 ha of garden as well as homesite. For the delay of construction planning concerning irrigation water supply system and also the shortage of family labor force, most transmigrants operate rain-fed farming on half of their farm lands of 1.75 ha and abandon the rest as grass land covered with alang-alang.

5.1.3 Farm type

Typically, the farm lands are cultivated with rain-fed upland paddy in the wet season. Around two months before harvesting upland paddy, cassava is mix-planted on the same field. In addition, combined cropping of maize in the wet season and groundnut as well as green bean in the dry season generally prevails in the surveyed area.

Transmigrants having settlement history of more than five years usually grow coconut, banana, coffee, pepper, clove and other perennial cash crops in their gardens. Table 5-2 shows the present situation of cropping at each village level in the surveyed area. Farming situation of each surveyed farm household is summarized as shown in Table 5-3 taking into consideration history of settlement and kind of transmigration.

5.1.4 Cropping pattern

The special executing offices of Way Abung I and II Transmigration Schemes have encouraged settlers to take up the following three types of cropping pattern due to the delay of construction planning concerning irrigation water supply system.

Type	Crop	Sowing time	Harvesting time	Growing period	Fertilizer input Urea	Fertilizer input TSP
A	Upland paddy	7/Nov.	4/Apr.	151 days	90 kg/ha	45 kg/ha
	Maize	25/Nov.	5/Mar.	100	90	32.5
	Cassava	5/Jan.	5/Aug.	212	-	-
	Maize	15/Mar.	25/Jan.	102	90	45
B	Upland paddy	7/Nov.	7/Apr.	151	90	45
	Maize	25/Nov.	5/Mar.	100	90	32.5
	Cassava	5/Jan.	5/Aug.	212	45	30
	Long pea	15/Mar.	15/May	92	45	30
C	Upland paddy	7/Nov.	7/Apr.	151	90	45
	Maize	25/Nov.	5/Mar.	100	80	32.5
	Cassava	5/Jan.	5/Aug.	212	-	-
	Groundnut	15/Mar.	15/May	92	45	30

From the data given in Tables 5-1 and 5-2, average cropping share of typical pattern actually prevailing in the surveyed area is formed of 0.51 ha for mixed-planting of upland paddy and cassava, 0.11 ha for single cropping of upland paddy, 0.06 ha for maize, 0.03 ha for groundnut and 0.02 ha for green bean.

5.1.5 Farming practices

Farming practice based on mixed-cropping of upland paddy and cassava most commonly used in the Project area is very simple, and most part of farm operation is relying on manual power, and very little animal power is used. Although lowland paddy is being cultivated in swamps of 100 ha only, no irrigation, even well water pumping irrigation, can be observed at all in the entire surveyed area.

Table 5-4 presents the standard cultivation method for the aforesaid cropping pattern encouraged. The farming practice of each crop broadly observed in the surveyed area is summarized in Tables 5.5 to 5.8.

5.1.6 Use of input

Normally both seeds and seedlings required are procured by farmers themselves at the rate of 25 to 30 kg/ha for upland paddy, 20 kg/ha for maize, 60 to 70 kg/ha for groundnut and 20 to 25 kg/ha for green bean, and 6,700 or 10,000 seedlings/ha for cassava. In case of mixed-planting with upland paddy, seed quantities of maize and groundnut decrease to 10 and 20 kg/ha, respectively.

The following local varieties of each crop are prevailing in the surveyed area.

Lowland paddy:	Genbira, Mudjair
Upland paddy:	Turunah, Sigendah Memdari, Padan, Kluna, Merbang, Sigajah
Cassava:	Mentega, Kuning
Maize:	Metro

Applications of chemical fertilizers, lime, manure and agro-chemicals hardly prevail in the surveyed area. In some cases of upland paddy cultivation carried out by settlers having experiences of more than five years after migration, approximately 30 to 40 kg/ha of urea and triple superphosphate in total are used on upland paddy fields.

5.1.7 Livestock

About 400 head of cattle and buffaloes as well as 80,000 ducks and fowls are raised in the surveyed area. The number of cattle has stepwise increased year by year due to prevailing cow subsidy system established by the Government. Livestock products are mostly used for home consumption. Livestock raising in the surveyed area is very primitive. Wild grasses and crop residuals are fed to cattle and buffaloes.

5.1.8 Farm labor requirement

In general, labor requirement for the farming is met by family labor. Labor requirement for farm operation of each crop is given in Tables 5-5 to 5-8. In addition, mutual aid and rural market services require some family laborers. At peak time of farm operation which occurs in September and October as shown in Table 5-9, farmers use their children for harvesting and, if labor force is insufficient, they hire additional laborers from other families within the village paying them in kind as wages. Anyway, the quality of farm operation is largely affected by the shortage of available labor force in the whole surveyed area during the above peak time.

After drying harvested paddy by exposure to the sun, threshing is mainly done by hand beating on a straw mat. Cassava, as an important cash crop in the surveyed area, is collected directly from each farmer by the village farmers' cooperatives or brokers having their bases in Telukbetung, the provincial consuming center. Most of upland paddy, maize, groundnut and green bean produced are consumed by the farmers themselves and some parts are sold on local markets.

5.1.9 Yield and production

Crop yield in the surveyed area mostly depends on the amount and distribution of rainfall during the wet season. Another unfavorable factor is the soil condition. Upland crop cultivation in the surveyed area relies on the poor natural fertility of the virgin soil, and the soil fertility is readily lost by cultivation since no countermeasures whatsoever have been taken for soil conservation. Moreover, strong soil acidity in addition to reduced soil fertility begins to show harmful effect on crop yield, especially maize and then upland paddy, only after a several years from the initial settlement as shown in Table 5-3.

In the light of official data and the results of farm survey, an average yield and total production of upland field crops in the Project area are summarized in the following table.

Crop	Season	Crop area (ha)	Yield (ton/ha)	Production (ton)
Upland paddy	wet	7,800	1.2	9,360
Maize	wet	700	0.4	280
Cassava	dry	6,400	12.8	81,920
Groundnut	dry	400	0.6	240
Green bean	dry	300	0.6	180

Average crop yields in the unit of kg/ha around the surveyed area are also summarized in the following table on the basis of statistic prepared by the prefectural agricultural office.

District		Lowland paddy	Upland paddy	Maize	Cassava	Ground-nut	Green bean
Kotabumi	1973	1,823	1,107	906	13,704	707	650
	1974	3,000	1,511	508	21,460	871	500
Abung	1973	-	1,836	829	19,550	830	684
Timur	1974	2,333	1,395	738	18,437	458	-
Abung	1973	2,000	1,377	612	19,512	976	506
Bart	1974	1,522	1,500	624	19,922	533	-
Abung	1973	2,076	1,492	1,581	10,557	796	852
Selatan	1974	1,546	1,300	1,119	14,663	750	-
Menggala	1973	923	1,442	695	18,594	953	537
	1974	1,500	614	606	18,056	548	533

5.1.10 Production value and farm income

Farm gate prices of farm inputs and outputs have been taken into consideration on the basis of the official data obtained through the farm survey. As of the end of 1974, the price per kg was Rp.55, 40, 5, 230 and 170 for upland paddy, maize, fresh cassava, groundnut and green bean, respectively.

The recent monthly economic statistics published by the Government makes clear that the retail prices of farm products fluctuate accordance with demand and supply situation in each local market. For example, the following table shows the retail prices in Jawa and the Lampung Province in 1974.

	Rice Rp./kg	Maize Rp./kg	Cassava Rp./kg	Groundnut Rp./kg
Jawa	81.7	46.7	13.5	236.3
Lampung Province	112.1	40.3	-	261.2
South Lampung	117.3	39.5	-	260.5
Central Lampung	105.5	33.0	-	271.3
North Lampung	115.0	49.0	3.7	242.5
Kotabumi	118.8	39.9	3.7	251.0

The average annual farm income and outgo per family in the surveyed area estimated from the results of the farm survey and the official information are as shown below. The detailed calculation of farm budget in the surveyed farm households is presented in Table 5-10.

A.	Gross income	116,400
	(Farm income	99,400)
	(Non-farm income	17,000)
B.	Gross outgo	16,500
	(Farm expenses	13,300)
	(Taxes	3,200)
C.	Net farm income (A-B)	99,900
D.	Living expenses	95,900
E.	Net revenue (D-C)	4,000

5.2 Future Development

5.2.1 Selection of crop variety

The irrigated paddy cultivation could be considered as the most appropriate way of promoting agricultural development in the Project area for the purposes of increasing individual farmers' income and production of staple foodstuff for local consumption as well as for domestic supply to Jakarta.

From the viewpoint of agronomy and plant physiology, there is no major constraint on paddy cultivation in the Project area, if irrigated properly. Minor constraint due to the nature of the soil is the very low content of weatherable minerals resulting in strongly acid soil and poor soil fertility. Originally, irrigated paddy has high adaptability to wide range of soil reactions. However, for expecting high paddy yield with less farming cost under the tropic-humid climate characterized by annual precipitation of more than 2,500 mm, such soil management based on cultivation of green manure and leguminous forage crops is indispensable in the Project area.

Tables 5-11 and 5-12 present the results of experimental works at many trial plots throughout the country under the management of the CRIA. In addition, the relationship between soil types and paddy yields at each high-yielding variety is summarized in Tables 5-13 and 5-14 on the basis of experimental results in Bogor. As for soybean, the characteristics of quality verieties and the results of field trial test at five experimental sites are given in Tables 5-15 and 5-16, respectively.

Consequently, taking into consideration the above experimental results as as well as the plant physiological environment and soil condition in the surveyed area, it is proposed that Pelita I/1* and Pelita I/2* as high yielding varieties of irrigated paddy, Sumbing and Shakti varieties of soybean, crotalaria for green manure and forage crops, and Pelembang EK-1 variety of coffee should be taken up into the future cropping pattern.

5.2.2 Farming practices

Standard farming practices for irrigated paddy and soybean as shown in Tables 5-17 and 5-18 are prepared making reference to the results of both CRIA's and other station's experiments.

5.2.3 Farm input requirement

Farm input requirement is decided as follows taking the experimental results referred into account.

The rate of seeding is determined taking into consideration the customary amount broadly applied in the country, i.e., 25 kg/ha for paddy, 30 kg/ha for soybean and 30 kg/ha for crotalaria, annually, and 2,500 seedlings/ha for coffee in the initial stage.

To achieve satisfactory yield at the full development stage of the Project, a suitable timing for application of fertilizers is indispensable. The effect of fertilizer application, particularly for irrigated paddy cropping using high yielding varieties, is significant. The fertilizer requirements estimated are as shown hereinafter.

The application of lime is essential to neutralize strong acid soils extending over the Project area. Therefore, 0.8 ton/ha of lime should be applied every year to maintain optimum pH value for vigorous growth of soybean and green manure crop.

The use of agro-chemicals to control pests and diseases is quite important to avoid the decrease in crop yields. The agro-chemical requirements estimated are as shown in the following table.

Materials	Dry season paddy	Wet season paddy	Soybean	Green manure	Coffee
Fertilizer nutrient (kg/ha)					
N	75	70	9	-	120
P	30	25	20	-	120
K	-	-	-	-	120
Lime (ton/ha)	-	-	0.8	0.8	-
Agro-chemicals (kg/ha)					
Insecticide	20	20	2	-	1
Pesticide	10	10	-	-	2
Rodenticide	1	1	1	-	-

5.2.4 Farm labor requirement

Labor requirement per hectare for proposed crops is shown Table 5.19.

Peak time of labor force requirement for paddy cultivation will occur during the transplanting and harvesting periods. Taking into consideration the available manpower of individual farm families in the Project area, the maximum size of paddy field to be cultivated without any hired labor is estimated at 1.25 ha in net. Transplanting and harvesting on 1.25 ha of paddy field require 45 days, respectively. In case of double cropping, the nursery and land preparatory works for the dry season cropping should be carried out after the harvesting work for the wet season cropping is completed.

Based on the proposed cropping pattern to be described in Section 5.2.5, farm labor requirements per household with 1.75 ha of net farm land are estimated as shown in Table 5-20. Monthly distribution of labor requirements is summarized below.

Month	1st year	2nd year	3rd year	4th year
Jan.	64	64	65	65
Feb.	12	23	30	39
Mar.	8	4	6	7
Apr.	45	41	34	27
May	64	60	64	63
June	62	60	49	56
July	29	21	20	19
Aug.	9	11	11	12
Sep.	18	29	23	25
Oct.	47	29	-	-
Nov.	18	12	4	3
Dec.	56	51	42	32
Total:	432	405	348	348

As shown in the above table, the peak labor requirement occurs in December to January and April to June. It is related to the land preparation as well as transplanting and harvesting of wet season paddy and planting of dry season crops. In these months, the family labor force which is estimated at 65 man-days per month (2.6 laborers/family x 25 workable days/month) on an average will be barely enough. If the shortage of labor force occurs, it will be covered by mutual aid within each village in the Project area.

The raising of livestock, especially draft cattle, is one of the most important works for paddy cultivation as well as the improvement of soil fertility by supplying stable manure. For the rapid increase in number of draft cattle for intensive irrigated farming, Bali cattles are proposed to be introduced into the Project area by fully utilizing the government subsidy system. During the six years throughout the construction period, one pair of cows would be provided to each two households.

5.2.5 Prospective cropping pattern

According to the hydrological study, enough effective rainfall in and around the Project area can be expected from November to the beginning of May and high river flow discharge at the dam site can be expected until the beginning of July. Puddling which requires peak irrigation water requirement should be done during the above period for both the wet and dry season croppings. Harvesting during the period of heavy rainfall from December to March should be avoided as much as possible because such will pose the problem of drying harvested paddy. To minimize the scale of Project facilities for cost saving, the peak irrigation water requirement must be reduced by dividing the whole Project area into several blocks to perform farm operation in turn.

As for soybean and crotalaria, seeding work should be done within June for securing good germination in expectation of the available soil moisture content and harvesting work should be completed at least one month before starting the nursery work for wet season paddy cropping.

Forage crop cultivated during the wet season must be harvested at every 60 days and used for self-supply feed to draft animals. In this case, harvested forage crop should be mixed with wild grasses in the ratio of half to half from the viewpoint of animal dietetics.

The proposed cropping pattern is set up as shown in Fig. 5-1 upon considetation of the aforesaid situation. As for the cropping schedule at the individual farm family level, rotation cropping system is adopted as shown in the following table.

	Season	1st year	2nd year	3rd year	4th year
Paddy	wet	1.25 ha	1.25 ha	1.25 ha	1.25 ha
	dry	0.75	0.50	-	-
Soybean	dry	-	-	1.00	1.00
Green manure	dry	0.50	0.75	0.25	0.25
Forage	yearly	0.25	0.25	0.25	0.25
Coffee	yearly	0.25	0.25	0.25	0.25

5.2.6 Prospective crop yield

For the estimation of prospective yield under the condition of "With Project", the experimental data as shown in Tables 5-11 to 5-16 obtained at the farm survey carried out in the developed paddy cultivation area of the Lampung Provice are fully referred to.

If the proper farming practices accompanied by the proposed farm inputs are performed, the target yield of crops can be expected to attain such a high level at the full development stage as shown in the following table.

Crop	Yield (ton/ha)	Crop	Yield (ton/ha)
Paddy		Green manure crops	20.0
Wet season	4.0	Green manure crops	20.0
Dry seaon	4.4	Forrage crops	20.0
Soybean	1.2	Coffee	0.7

5.2.7 Farm income

According to the farm survey, the farm-gate price of dry paddy in the Project area ranged from Rp.50/kg to Rp.60/kg in 1974. This farm-gate price is much higher than in Jawa, one of the largest producing and consuming centers. For example, in the 1974 crop season, there was a regional difference of approximately Rp.15/kg. The difference was mainly due to the shortage of paddy in the Lampung Province. Around 20,000 tons of rice are transported from Jakarta to the Lampung Province every year for meeting the increased provincial demand due to high annual population growth of approximately 5 %.

In view of such price fluctuation caused by the demand and supply situation of staple foodstuff in the respectively local market in the country, therefore, the economic farm-gate prices of agricultural inputs and outputs are set as shown below for the sake of economic evaluation of the Project. In the above, the international market prices worked out on the basis of the 1973/1974 trend and the transportation cost as well as various intermediary expenses have been taken into primary consideration. To estimate the farm budgets under the condition of "Without Project" and With Project", the financial prices are also set as shown in the following table, taking the results of the farm survey into account.

Farm inputs	Economic price	Financial price	Farm outputs	Economic price	Financial price
Urea	Rp.38/kg	Rp.60/kg	Dry paddy	Rp.75/kg	Rp.52/kg
TSP	17	60	Soybean	69	88
DAP	54	60	Coffee	200	200
			Cassava	6	5
			Maize	32	43
			Groundnut	235	240

Using the proposed quantity of each farm input and the economic farm gate prices set, the farm production cost is calculated. Unit crop production cost per hectare and each crop production cost per cropped area in the respective crop rotations proposed are given in Table 5-21. The estimation of crop production value is also based on the anticipated yield and the economic farm-gate price. The results obtained are presented in Table 5-22.

The net farm income estimated for "With Project" and "Without Project" at the full development stage is shown as below.

As given in the following table, the difference in the net production value could be regarded as the benefit attributable to the Project.

Crop	Production value (Rp./ha)	Production cost (Rp./ha)	Net value (Rp./ha)	Total crop area (ha)	Total net value (million Rp.)
"With Project"					
Lowland paddy					
Wet season	300,000	68,000	232,000	20,000	4,640
Dry season	330,000	70,000	260,000	5,000	1,300
Soybean	82,800	35,800	47,000	8,000	376
Coffee	140,000	60,000	80,000	4,000	320
Green manure & forage crop	-	8,000	-8,000	11,000	-88
Total				48,000	6,548
"Without Project"					
Upland paddy	105,000	15,000	90,000	13,600	1,224
Cassava	84,000	6,000	78,000	11,200	873.6
Maize	16,000	2,500	13,500	800	10.8
Groundnut	117,500	18,000	99,500	800	79.6
Total				26,400	2,188

"Annual incremental net production value"

Total (1) - Total (2) = Rp.6,548 million - Rp.2,188 million

= Rp.4,360 million (US$10,506,000)

5.2.8 Farm budget

On the basis of the financial cost set up from the results of the farm survey conducted in the surveyed area, the farm budget of a farm household under the future conditions of "With Project" and "Without Project" is estimated taking the average harvested area at 3.0 ha in case of "With Project" and 1.65 ha in case of "Without Project", respectively, as the most typical size of a farm household. The results of calculation are summarized in the following table and the details in Table 5-23.

Item	Without Project (Rp.)	With Project (Rp.)
(1) Farm Income		
Crop income	106,600	416,000
Other income	23,400	4,000
Gross Farm Income	130,000	420,000
(2) Production Cost		
Crop production cost	17,600	151,000
Other expenses	400	4,000
Gross Production Cost	18,000	155,000
(3) Net Farm Income (1) - (2)	112,000	265,000
(4) Living Expenses		
Food consumption	76,000	95,000
Other living expenses	28,700	36,200
Total Living Expenses	104,700	13 ,200
(5) Taxes	2,300	6,800
(6) Gross Outgo (4) + (5)	125,000	293,000
(7) Capacity to Pay (3) - (6)	5,000	127,000

Table 5-1 Present Situation in Surveyed Area

	Total farms	G.T*1	S.T*2	Popu-lation	Farm*3 land	Home*3 yard
Way Abung I Transmigration Area						
Bagunsari	228	200	28	1,119	399ha	57ha
Tatakarya	543	42	501	2,483	963	137
Purbasakti	767	-	767	3,459	1,342	192
Sidomukti	485	-	485	2,561	849	121
Bumi Restu	706	-	706	3,130	1,236	176
Bumi Raharja	395	-	395	1,365	687	101
Sub-total	3,124	242	2,882	14,117	5,476	784
Way Abung II Transmigration Area						
Dayasakti	534	308	226	2,812	912	135
Makarti	713	-	713	3,151	1,248	178
Margomulyo	751	500	251	3,437	563	188
Dayamurni	834	432	402	4,254	512	208
Mulyoasri	839	525	314	4,091	700	189
Candra Kencana	589	31	558	2,894	589	197
Pulung Kencana	587	445	142	2,580	574	144
Margo Kencana	510	-	510	2,403	393	127
Mulyo Kencana	746	5	741	3,449	758	190
Kagungan Ratu	616	70	546	2,848	616	154
Tirta Kencana	794	20	774	3,639	794	199
Karta Raharja	782	-	782	3,518	1,173	198
Karta Sari	216	-	216	872	378	54
Panaragan Jaya	669	330	339	3,118	668	167
Peraduan Waras	299	-	-	1,208	500	125
Sub-total	9,479	2,665	6,814	44,274	10,378	2,453
Total	12,603	2,907	9,696	58,391	15,854	3,237

*1: Governmental transmigrants
*2: Spotaneous transmigrants
*3: Actual area registered is shown.
In addition, public yards total 10,567ha
Source: Prefectural and local transmigration office

Table 5-2 Cropping Condition in Surveyed Area

(unit: ha)

	Low/and paddy	Upland paddy	Moize	Cassava	Soy-bean	Ground puts	Other beans
Way Abung I Transmigration area							
Bayunsari	3	115	5	175	-	-	-
Tatakarya	-	407	10	540	5	6	6
Purbasakti	-	560	7	700	-	7	20
Sidomukti	-	364	-	363	-	-	-
Bumi Restu	-	385	31	175	-	-	160
Bumi Rakarija	-	125	5	150	-	2	9
Sub-total	3	1,956	57	2,104	5	15	195
Way Abung II Transmigration area							
Dayasakti	-	405	-	534	-	-	16
Makarti	-	635	350	700	-	-	12
Margomulyo	-	515	-	380	-	-	75
Dayamurni	-	612	47	495	-	-	46
Mulyoasri	-	470	29	300	-	22	-
Candra Kencana	-	250	-	250	-	-	-
Pulung Kencana	-	503	134	287	-	-	-
Margo Kencana	-	410	-	250	-	-	-
Mulyo Kencana	-	132	58	89	-	9	-
Kagungan Ratu	-	190	45	70	-	80	-
Tirta Kencana	-	218	-	104	-	10	-
Karta Raharja	-	519	-	400	-	-	-
Karta Sari	-	135	-	175	-	-	-
Panaragan Jaya	-	517	-	85	-	243	-
Peraduan Waras	-	375	-	125	-	-	-
Sub-total	-	5,886	663	4,244	-	364	149
Total	3	7,842	720	6,348	5	379	344

Table 5-3 Farming Condition of Surveyed Farms

	Transmigrants						Army farms	Native farms
	Governmental			Spontaneous				
1) Settled year	1967	1970	1972	1966	1972	1973		
2) Surveyed number	3	9	6	3	4	5	5	5
3) Family member								
- Total person	6.7	8.0	6.5	6.3	5.3	4.6	3.2	8.2
- Workable person	2.1	2.7	1.9	2.2	1.7	1.9	1.7	3.3
4) Land use								
- Lowland paddy	0.17	0.14	-	1.0	-	-	0.05	-
- Upland paddy	1.17	0.72	0.50	0.92	0.47	0.45	0.85	0.95
- Perrenial crop	-	0.08	-	-	-	-	-	2.30
- Non-cultivated	0.50	0.86	1.25	-	1.44	1.30	0.85	2.50
- Home yard	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.33
5) Livestock								
- Cow & bullafo	0.7	0.9	-	1.7	-	-	0.4	-
- Goat & sheep	-	0.3	0.5	2.7	-	0.6	0.2	-
6) Gross cropped area								
- Lowland paddy	0.34	0.03	-	1.17	-	-	0.05	-
- Upland paddy	0.42	0.66	0.50	0.58	0.44	0.50	0.85	0.2
- Cassava	0.75	0.63	0.50	0.92	0.31	0.27	0.56	0.24
- Maize & bean	0.75	0.01	0.14	0.33	0.07	0.10	-	0.20
- Other	-	-	0.04	-	-	0.02	0.06	-
- Coffee	-	-	-	-	-	-	-	1.20
- Pepper	-	-	-	-	-	-	-	0.50
- Rubber	-	-	-	-	-	-	0.14	1.30

Table 5-4 Standard Cultivation Method of Mixed-cropping

Date	Farming practice
15/Oct.	Field selection
20/Oct.	Plowing and harrowing
25/Oct.	Seed preparation
2/Nov.	Basal fertilization for upland paddy
5/Nov.	Seeding of upland paddy
20/Nov.	Weeding on upland paddy field
25/Nov.	Seeding of and fertilizing for maize
30/Nov.	Plant protecting for upland paddy and maize
5/Dec.	Additional fertilizing for upland paddy
20/Dec.	Weeding on upland and maize fields
25/Dec.	Additional fertilizing for maize
5/Jan.	Planting of cassava seedling
10/Jan.	Additional fertilizing for upland paddy
15/Jan.	Plant protecting for upland paddy
20/Jan.	Weeding on maize field
25/Jan.	Additional fertilizing for maize
30/Jan.	Plant protecting for maize
5/Mar.	Harvesting of maize
10/Mar.	Land preparation and peeling of maize
21/Mar.	Seeding of maize and long bean
5/Apr.	Harvesting of upland paddy
20/May	Harvesting of long bean
31/May	Harvesting of maize
5/Aug.	Harvesting of cassava

Table 5-5 Prevailing Farming Practice of Upland Paddy

Working item	Working period	Working method	Labor input
Land preparation	end Aug. to beg. Oct.	By hoe	80 M-D/ha
Sowing	mid Sep. to mid Oct.	By hand	20
Weeding 1st	end Sep. to end Oct.	By hoe	30
2nd	end Nov. to beg. Dec.	By hoe	20
Harvesting	beg. Feb. to beg. Mar.	By ani-ani	30
Drying	mid Feb. to mid Mar.	By natural	10
Threshing	end Feb. to end Mar.	By hand	5
Total			215

Table 5-6 Prevailing Farming Practice of Cassave

Working item	Working period	Working method	Labor input
Land preparation (not necessary because of mixed-planting)			
Planting	beg. Nov. to mid Dec.	By hoe	20 M-D/ha
Weeding	mid Nov. to mid Dec.	By hoe	30
Harvesting	mid Aug. to beg. Sep.	By hand	50
Carrying	mid Aug. to beg. Sep.	By hired ox-cart	
Cutting & drying	beg. Sep. to mid Sep	By hand	50
Total			150

Table 5-7 Prevailing Farming Practice of Maize

Working item	Working period	Working method	Labor input
Land preparation	mid Sep. to end Sep.	By hoe	80 M-D/ha
Sowing	mid Oct.	By stick	10
Weeding 1st	beg. Nov.	By hoe	30
2nd	beg. Dec.	By hoe	30
Harvesting	end Jan.	By hand	30
Drying	mid Feb.	By hand	5
Threshing	mid Feb. to end Feb.	By hand	5
Total			190

Table 5-8 Prevailing Farming Practice of Groundnut

Working item	Working period	Working method	Labor input
Land preparation	beg. Mar. to mid Mar.	By hoe	70
Sowing	beg. Apr.	By stick	30
Weeding 1st	end Apr.	By hoe	20
2nd	mid May	By hoe	20
Harvesting	mid June	By hand	10
Drying	mid July	By hand	10
Threashing	mid July to end July	By hand	10
Total			210

Table 5-9 Monthly Distribution of Labour Requirement

(Unit: Man-day)

Month	Upland paddy (0.62 ha)*	Cassava (0.51 ha)	Maize (0.06 ha)	Legumes (0.05 ha)	Aid and service	Total
Jan.	-	-	2	-	6	8
Feb.	24	-	1	-	6	31
Mar.	4	-	-	4	6	14
Apr.	-	-	-	1	6	7
May	-	-	-	1	6	7
June	-	-	-	3	6	9
July	-	-	-	1	6	7
Aug.	25	8	-	-	6	39
Sep.	37	16	5	-	6	65
Oct.	19	33	1	-	6	59
Nov.	6	21	2	-	6	35
Dec.	6	19	2	-	6	33

*: Figures in parentheses show the average cropped area.

Table 5-10 Typical Farm Budget of Surveyed Farms

	Governmental			Spontaneous			
(1) Settled year	1967	1971	1972	1965	1972	1973	1973
(2) Surveyed farms	3	4	6	3	4	5	5
(3) Gross income (Rp.)							
- Farm income	151,840	143,680	106,370	206,970	69,760	77,360	79,090
- Subsidy	4,260	2,610	5,780	2,220	7,830	3,500	2,510
- Side job	23,300	330	22,370	24,500	16,950	9,800	23,560
- Miscellaneous	-	4,380	1,250	-	880	-	-
Total	179,400	151,000	135,770	233,690	95,420	90,660	105,160
(4) Gross outgo (Rp.)							
- Farming cost	39,300	35,430	23,490	84,290	9,590	8,920	17,950
- Tax	14,150	1,420	-	15,900	-	-	-
- Living cost	117,380	114,630	105,875	131,780	81,950	80,490	83,840
- (Self food supply)	91,770	86,400	80,650	86,800	66,700	53,400	58,030
Total	170,830	151,480	129,365	231,970	91,540	89,410	101,790
(5) Net farm income	112,540	108,250	182,880	122,680	60,170	68,440	61,140
(6) Net revenue	8,570	480	6,405	1,720	3,880	1,250	3,370

Table 5-11 Average Yield of selected Varieties of Paddy Through 62 Experiments Over four Seasons, 1968/61 - 70

(t/ha)

Variety	Wet season 1968/69	Dry season 1969	Wet season 1969/70	Dry season 1970
PB-5	4.8	6.2	5.0	6.2
-8	4.4	5.7	4.9	4.2
C4-63	4.1	5.5	4.5	5.7
IR 20	-	5.7	4.7	5.9
Dewi Ratih	4.2	5.5	4.6	6.1
Pelita I/1	-	-	-	6.8
" I/2	-	-	-	6.6

Sources: CRIA Report on Plant Breeding

Note: Uniform fertilizer application
120 N, 60P_2O_5,, 30 K_2O (kg/ha)

Table 5-12 Grain Yield and Other Characteristics of Major Improved Varieties in Indonesia (wet season in 1970 - 71)

Variety	Average yield (t/ha)	Range at 14 location (t/ha)	Maturity (days)	plant hight (cm)	Quality (by Indonesian standard)
IR-5	6.53	3.3-9.2	135	113	Poorto Medium
-20	6.04	3.8-8.3	124	98	"
-22	4.9	1.821-7.0	121	89	"
Pelita I/1	7.1	3.8-10.9	137	126	Good
" I/2	7.1	3.7-10-6	138	114	"

Sources: Breeding rice Varieties for Indonesia (1971)
Department of Agriculture Central Research Institute for Agriculture, Bogor.

21 Crop suffered bird damage

Table 5-13 Paddy Yield by Varieties & Soil Type (1) 1972/1973

Variety	(Pusanan) Alluvial (t/ha)	Sumatra-Barat (Pd. Pariaman) Latosol (t/ha)	(Sawahlunto) Podozol (t/ha)	Drystalk Paddy (t/ha)
IR 20	3.06	5.15	4.65	6.01
22	2.88	4.51	4.66	6.01
24	2.45	5.25	3.68	4.84
B9c/Md/3/3	2.00	3.46	2.74	3.60
B57c/Md/10/1	3.13	5.49	3.76	4.94
" /2	3.19	5.63	5.50	7.23
B58b/Mr/105/2	-	6.01	5.40	7.01
B60b/Tk/242/5	2.34	4.96	4.88	6.42
" /10	-	4.23	4.64	6.01
529c/Md/10/3/6	2.57	5.15	3.65	4.80
" /2	2.75	5.88	2.55	3.35
419f/Pn/1	3.65	5.66	3.43	4.50

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Table 5-14 Paddy Yield by Varieties & Soil Types (2)

	Sumatra-Barat		Sumatra-Sel	Lampung
	(50 Kota) Andosol (t/ha)	(Pesisir Selatan) Latosol (t/ha)	(Musi-Rawa) Regosol (t/ha)	(Lampung-Sel) Alluvial (t/ha)
Pelita I/1	7.32	5.13	6.94	5.84
" I/2	7.03	5.06	6.59	5.97
531b/Tk/49/20/Pn/7	7.04	5.00	6.58	6.41
531b/Tk/3/Pn/8	6.55	4.56	6.61	5.81
531b/Tk/8/16/Pn/3	6.47	5.25	5.99	5.38
446b/89/1/3/2/2/1	6.61	4.67	6.08	5.09
446f/89/1/3	6.05	5.13	6.20	5.31
446f/Dg/29/1	7.35	4.94	6.84	6.03
529f/Dg/70/3	7.10	4.81	6.11	5.94
529f/Dg/71/2	6.37	4.19	6.46	5.84
B149b/106/2/1	6.88	4.94	6.36	5.22
B149b/106/5/2	6.60	4.56	6.83	5.31

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Table 5-15 The Characteristics of Quality Varieties of Soybeans

Variety	Days to Maturity	Color of Seed Cost	1,000 Seed Weight (g)	Average Yield (100kg/ha)
No. 16	90 - 100	Black	70 - 80	10 - 15
No. 29	90 - 100	Yellow	70	10 - 15
Ringgit (317)	85 - 95	Yellow	80	10 - 15
Sumbing (452)	75 - 80	Yellow	80	10 - 15
Shakti	80 - 85	Yellow	120 - 160	10 - 15
Economic garden (1289)	90 - 95	Yellow	120	13 - 16
Clark 63 (1293)	90 - 95	Yellow	145	12 - 15

Data Source: The Central Research Institute for Agriculture in Bogor

Table 5-16 Yields of Soybeans at 5 Location in Dry Season (Unit: kg/ha)

Variety	Location					
	1	2	3	4	5	Mean
No. 452 Sumbing	1120	1521	935	1601	1670	1327
871X4179/181/1/0	1198	1032	1247	1579	2123	1436
868X4179/15/1/0	1491	1347	1063	1518	2082	1470
868X4179/177/1/0	1223	1362	924	1437	1660	1321
868X4179/54/1/0	1418	1482	985	1375	1845	1422
871X4179/151/1/0	1192	1412	1067	1526	1661	1372
871X4179/30/1/0	1519	1702	999	1663	1852	1547
871X4179/183/1/0	1577	1487	1259	1665	2145	1627
871X4179/1/1/0	1037	1607	830	1591	1586	1339
871X4179/185/1/0	2217	2216	2201	1899	2196	2146

Sources: Staff Meeting, 1 - 2 April, 1971
C.R. I for Agriculture, Bogor

Notes: 1. Tjikeumeuh 3. Djambegede.
2. Modjosari 4. Muneng
5. Genteng.

Table 5-17 Standard Cultivation Method for Lowland Rice

Days	Management	Amount of implements
	Preparation of norsery	
3	Seed selection	Salt solution for seed selection 10 ℓ of water + 2 kg of Nacl
3	Seed disinfection	Benlate-T(200-400x, 6-12 hours) Hemai (200-400x, 6-12 hours)
2	Seed soaking	24 hours
2	Hastening of germination	36 hours
1	Application fertilizer	Urea 1.5 kg/300m^2, TSP 1.0 kg/300m^2
0	Sowing	Acreage 300m^2/ha, seed 25 kg/300m^2/ha
15	Control of disease and insect damage	Diazinon 30-50 cc in 1,000 ℓ 300-500 ℓ/300m^2
After transplanting		
	Preparation of paddy field	
	Basalt manuring	Urea 40 kg/ha, TSP 70 kg/ha
0	Transplanting	Spacing 20-25 cm x 20 cm 3-7 seedling/hill, 25 days seedling
10	Weeding (1st)	Hand weeding
15	Application of fertilizer	Urea 50 kg/ha
30	Weeding (2nd)	Hand weeding
45	Control of disease and insect damage	Sumithion 1 ℓ/ha Rabcide 1 ℓ/ha
60	(Panicle initiation period)	
63	Application of fertilizer (2nd)	Urea 60 kg/ha
70	(Booting period)	
73	Control of disease and insect	Diazinon 1 ℓ/ha Rabcide 1 ℓ/ha
80	(Heading period)	
110	Harvesting	

Note:	Maturity days	Plant height	Amilosa content	Yield (t/ha)	Remarks
Variety IR 20	122	99.2 cm	27	4.6*	(Sumatora)
Pelita I/1	133	117.3	22	5.8	(Lampung)
Pelita I/2	132	114.2	22	5.5	(Lampung)
531 b/Tk/49 20/Pn/7	132	109.5	21.5	6.4	(Lampung)

Nursery period 25 days

Data source: Central Research Institute of Bogor (1974)

*: Another data.

Table 5-18 Standard Cultivation Method for Soybeans

Days	Management	Amount of Implements
	Preparation of field	Lime 300 kg/ha
0	Sowing	Seed 30 kg/ha, Spacing 60 x 30 cm
15	Application of fertilizer (1st)	Urea 10 kg/ha, TSP 50 kg/ha, (Potassium Cloride) 30 kg/ha
17	Intertillage and weeding (1st)	by hand
25	Control of insect damage (1st)	Spray of sumithion (12/ha)
40	Application of fertilizer (2nd)	Urea 10 kg/ha, (Potassium Cloride 20 kg/ha)
45	Intertillage and weeding (2nd)	by hand
50	Control of insect damage (2nd)	Spray of sumithion 1 ℓ/ha
90	Harvesting	
95	Drying	
100	Cleaning	

		Maturity	Color of seed	Yield
Variety:	Ringgit	85-90 days	Yellow	1.5 t/ha
	Shakti	80-85	"	"
	No. 1243	80-85	"	"
	No. 5029	90-100	"	"

Data source: Agricultural tropical Research Center in Japan, May, 1974

Note: Potassium is now used only by plantation and it will be long before peasant farmer come to use it. Hence it is excluded from production cost estimate.

Table 5-19 Future Labour Requirement per Hectare for Main Crops

(Unit: Man-day)

Farming practice	Paddy		Soybean	Green manure	Perennial crops
	Wet season	Dry season			
Nursery	10	10	-	-	-
Land preparation					
Clearing fields	5	5	-	-	-
Plowing	10	13	7	-	-
1st harrowing	7	7	10	-	-
2nd " (paddling)	5	5	-	-	-
3rd harrowing	3	3	4	-	-
Sowing or Transplanting	35	35	8	8	-
Manuring	3	3	2	1	2
Plant protection	5	5	3	-	2
Water management	5	6	1	1	-
Weeding	20	20	15	-	40
Harvesting	40	43	10	10	40
Drying and clearing	20	22	3	-	11
Transportation	5	5	1	10	-
Others	2	2	1	-	15
Total:	175	185	65	30	110

Table 5-20 Monthly Distribution of Labour Requirement

(Unit: Man-day)

Block	Crop	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
I	Paddy wet	55	12	4	44	37	6	-	-	-	-	6	56	200
	Paddy dry	-	-	-	-	6	51	17	4	2	45	7	-	132
	Green manure crop	-	-	-	-	14	-	-	4	16	-	-	-	34
	Forrage crop	4	-	4	-	4	-	4	-	-	2	4	-	22
	Coffee	5	-	-	1	3	5	8	1	-	-	1	-	24
	Total:	64	12	8	45	64	62	29	9	18	47	18	56	432
II	Paddy wet	64	14	4	36	43	9	-	-	-	-	3	47	220
	Paddy dry	-	-	-	-	2	33	13	3	2	29	6	-	88
	Green manure crop	-	-	-	-	12	9	-	3	27	-	-	-	51
	Forrage crop	-	4	-	4	-	4	-	4	-	-	2	4	22
	Coffee	-	5	-	1	3	5	8	1	-	-	1	-	24
	Total:	64	23	4	41	60	60	21	11	29	29	12	51	405
III	Paddy wet	65	21	6	29	48	11	1	-	-	-	1	38	220
	Soybean	-	-	-	-	11	24	11	6	13	-	-	-	65
	Green manure	-	-	-	-	2	5	-	-	10	-	-	-	17
	Forrage crop	-	4	-	4	-	4	-	4	-	-	2	4	22
	Coffee	-	5	-	1	3	5	8	1	-	-	1	-	24
	Total:	65	30	6	34	64	49	20	11	23	0	4	42	348
IV	Paddy wet	65	30	7	22	52	15	1	-	-	-	-	28	220
	Soybean	-	-	-	-	6	27	10	7	15	-	-	-	65
	Green manure	-	-	-	-	2	5	-	-	10	-	-	-	17
	Forrage crop	-	4	-	4	-	4	-	4	-	-	2	4	22
	Coffee	-	5	-	1	3	5	8	1	-	-	1	-	24
	Total:	65	39	7	29	63	56	19	12	25	0	3	32	348

Table 5-21 Unit Production Cost and Total Farming Cost

Crop	Seed	Ferti-lizer	Agro-chemicals	Draft animal cost	Others	Total	With Project Rotation block			Without project
							I	II	III & IV	
Without Project										
Upland paddy	1,800	2,600	1,000	-	9,600	15,000	-	-	-	12,750
Cassava	-	-	-	-	6,000	6,000	-	-	-	4,200
Maize	2,400	-	-	-	100	2,500	-	-	-	125
Groundnut	5,350	5,600	4,100	-	2,950	18,000	-	-	-	900
With Project										
Lowland paddy										
Wet season	1,000	6,860	5,900	29,500	24,740	68,000	85,000	85,000	85,000	-
Dry season	1,500	7,630	5,900	29,500	25,470	70,000	52,500	35,000	-	-
Soybean	2,750	11,700	4,100	14,750	2,500	35,800	-	-	35,800	-
Green manure	2,000	5,000	-	-	1,000	8,000	4,000	6,000	2,000	-
Forrage crop	2,000	5,000	-	-	1,000	8,000	2,000	2,000	2,000	-
Coffee	9,100	43,200	2,700	-	5,000	60,000	15,000	15,000	15,000	-

Note: Unit for production cost is Rp./ha and for farming cost Rp./household.
Costs of others include cost for materials, tools, threshing etc.
Draft animal cost consists of depreciation and interest.

Table 5-22 Crop Production Value

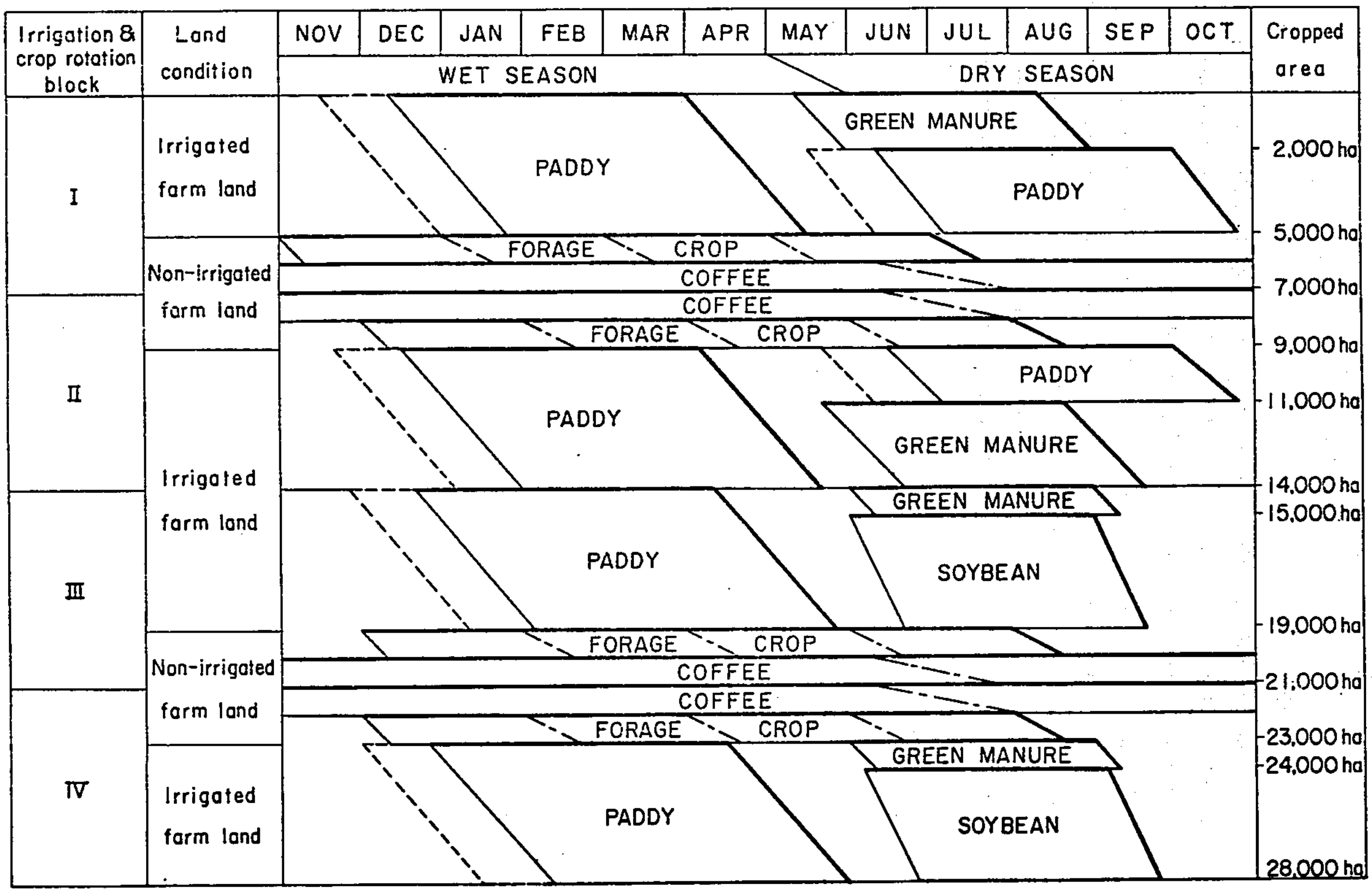
	Block	Unit yield (ton/ha)	Cropped area (ha)	Total yield (tons)	Gross value (Rp.)
Without Project					
Upland paddy	-	1.4	0.85	1.19	89,250
Cassava	-	14.0	0.70	9.80	58,800
Maize	-	0.5	0.05	0.025	800
Groundnut	-	0.5	0.05	0.025	5,875
With Project					
Lowland paddy					
Wet season	Whole	4.0	1.25	5.00	375,000
Dry season	I	4.4	0.75	3.30	247,500
	II	4.4	0.50	2.20	165,000
Soybean	III & IV	1.2	1.00	1.20	82,800
Coffee	Whole	0.7	0.25	0.175	35,000

Table 5-23 Average Farm Budget in Future Condition

	Without Project	With Project
(1) Farm Income		
Crop income	106,600	416,000
(Paddy)	(53,040)	(331,500)
(Dry field crop)	(53,560)	(49,500)
(Perennial crop)	(-)	(35,000)
Other income	23,400	4,000
Gross Farm Income	130,000	420,000
(2) Production Cost		
Crop production cost	17,600	151,000
Paddy	(12,750)	(107,500)
Dry field crop	(4,850)	(24,500)
Perennial crop	(-)	(19,000)
Other expenses	400	4,000
Gross Production Cost	18,000	155,000
(3) Net Return (1) - (2)	112,000	265,000
(4) Living Expenses		
Food consumption	76,000	95,000
Other living expenses	28,700	36,200
Total Living Expenses	104,700	131,200
(5) Taxes	2,300	6,800
(6) Gross Outgo (2) + (4) + (5)	125,000	293,000
(7) Capacity to Pay (1) - (6)	5,000	127,000

Note: Paddy of "Without Project" is upland paddy.

Fig. 5-1 PROPOSED CROPPING PATTERN



PART VI. IRRIGATION PLANNING

6.1 General

The coverage area of the feasibility study in this time is approximately 55,000 ha and the first priority is given to the governmental trasmigration area where it covers about 45,000 ha.

The water sources for the irrigation to the area could be asked for the Rarem river, the small rivers or the groundwater in the area. Actually, however, the available value of the groundwater is not high and the irrigation plan by the small irrigation tanks in the area is not so effective to cover such a big area as this project area from technical and economical points of view. Therefore, the water source is asked for the Rarem river.

The intake method from the Rarem river is generally divided into two systems, namely, the gravity irrigation by dam facility and the pumping-up irrigation by a large scale pump station. As a result of comparison, however, the former is more economically feasible.

It would not be acceptable to connect the Project with other rivers in the neighbourhood by the basin transfer plans such as from the Way Besai through the Way Abung to the Way Rarem at this stage because these rivers have respectively the irrigation plans.

As a result of study, the dam site was proposed about 460 m in the downstream of the confluence of the Way Rarem and the Way Galing. (Refer to 6.2)

The block system that the irrigable area is divided into four (4) nearly equal parts was adopted in order to decide the diversion requirement of which the detail is discribed in the article, 6.3.

The scale of the project is within the scope of 19,000 ha to 25,000 ha by net irrigation area and the optimum scale was decided to be the net irrigation area of 20,000 ha in accordance with the comparative study of the cases of 20,000 ha with 25,000 ha as described in the main report.

In the article, 6.4, the calculation of the water balance and the fluctuation of water level of the dam, the general irrigation system in the benenfited area and others are shown.

6.2 Selection of Dam Site

The elevation of the nearest place in the objective area of the project to the Way Rarem is about 40 m. Therefore, proposed dam sites which can assure the intake water level of 40 m - 50 m in addition to the conveyance loss to the irrigation area were chosen by the topographic maps in a scale of 1/10,000 and the field survey along the Way Rarem from Kotabumi to Pekurum and one of the best proposed dam sites was selected by the study on the following items.

6.2.1 Topography

The Way Rarem starts from the Tebak mountain (top elevation: 2115 m), flows to the northwest while gathering small rivers and unites the Way Galing which is one of the tributaries near Pekurun. Further, the Way Rarem meanders at the west side of Kotabumi and the objective area of the project, merges in the Way Tulangbawang with the Way Kanan at the middle of Cendungrate and Menggala, flows to the east and reachs to the estuary.

The slope of the river bed is steep, and averagely 1/45 for the Way Rarem and 1/70 for the Way Galing from the upstream to the confluence of the both rivers.

The vicinity of the confluence has undulating plateaus with sparse forest of which the top elevations range 60 m to 65 m and the heights over the river bed are around 20 m - 25 m. Gradually, the either elevation of the both side's hills changes lower to the downstream from the confluence and becomes about 30 m near the just downstream of Ajikagungan.

Therefore, the proposed dam sites are obliged to be selected in the upstream from Ajikagungan from this topographic point of view.

6.2.2 Geology

The Way Rarem is the primitive river meandering amoung the undulating plateaus of which the geology consists of Tertiary sedimentary rock, and alluvial deposit and weathered tuff over the rock.

The alluvial deposit along the Way Rarem consists of alternate layers of clay, sand and gravel, and the depth to the bed rock is mostly 5.0 m to 8.0 m, locally 20.0 m and over. The bed rock of the Way Rarem is the alternate layers of tuff, tuff-breccia, clay stone and pumice-tuff.

The proposed dam site is desirable to be selected at the narrow valley which has the outcrop of rock at the both sides for abutment structure, but the river width is generally wide and the meandering is conspicuous as afore-mentioned because of the primitive river which flows among the undulating plateous.

Therefore, each dam site for comparative study is obliged to be proposed on the allevial deposit, but judging by the field survey and the results of the drilling survey in the vicinity of the confluence of the Way Rarem and the Way Galing, the construction of dam is possible.

6.2.3 Comparative study

The comparative study on the following points was carried out at the three places to decide a proposed site in addition to the above findings.

1. Catchment area: The wide catchment area can supply bigger river discharge, but on the countrary the scale of the dam facilities becomes bigger
2. Reservoir area
3. Scale of facility (height, length and volume)
4. Length of main canal to the benefited area

5. Existense of submerged structures (existing road and bridge)

6. Existense of submerged villages.

7. The respective ratios of the dam body volume and the length of the main canal are set up a standard for the ratio of the construction cost.

The result is shown in Table 6-1. Consequently, the place C, that is, about 450 m in the downstream of the confluence of the Way Rarem and the Way Galing was selected as the proposed dam site from the above view points.

Table 6-1 Result of Comperison

Comparative items	Unit	Dam site			Remarks
		A	B	C	
1) Location		Kp. Ajikagungan	Kp. Kumpai	Kp. Pekurun	
2) Straight distance from KB	Km	11.0	14.0	16.0	KB: Kotabumi
3) Distance along river	"	18.7	24.5	27.2	
4) Catchment area	Km^2	362.0	346.0	328.0	
Catchment ratio	%	111.4	106.5	100.0	
5) Canal length to the area	Km	19.0	24.0	25.7	from railway
6) Elevation of river bed	m	23.0	28.0	33.0	
7) Dam height					(Normal water level
in case of $N.W.L_1$	m	26.5	21.5	16.5	$N.W.L_1$:45.0^m
" $N.W.L_2$	"	-	26.5	21.5	$N.W.L_2$:50.0^m)
8) Dam Length					
in case of $N.W.L_1$	m	1,500	1,000	500	
" $N.W.L_2$	"	-	1,250	800	
9) Volume of dam body					
in case of $N.W.L_1$	m^3	1,400,000	800,000	400,000	
" $N.W.L_2$	"	-	1,300,000	650,000	
10) Reservoir area					
in case of $N.W.L_1$	ha	960	595	270	
" $N.W.L_2$	"	-	980	400	
11) Submerged road					
in case of $N.W.L_1$	m	1,500	150	-	
" $N.W.L_2$	"	2,100	250	-	
12) Submerged bridge					
in case of $N.W.L_1$	place	2	1	-	
" $N.W.L_2$	"	2	1	-	
13) Submerged village					
in case of $N.W.L_1$	place	(Part of Kp. Ajikagungan)	-	-	
" $N.W.L_2$			-	-	
14) Ratio of dam body					
in case of $N.W.L_1$	%	350.0	200.0	100.0	
"	"	-	200.0	100.0	
15) Ratio of canal length	"	73.9	93.4	100.0	
16) Total of ratio					
in case of $N.W.L_1$	%	423.9	293.4	200.0	14) + 15)
" $N.W.L_2$	"	-	293.4	200.0	"

6.3 Diversion Requirement

6.3.1 General

Almost no data are available for the crop water requirement in the Project area and in the neighboring area, therefore the consumptive use within the water requirement for paddy cropping was obtained by usinging the climatological data and other requirement was decided by reference to the observation record and the data which are empirically adopted in Indonesia.

6.3.2 Evaporation index and crop factor

The consumptive use is expressed by the product of evaporation index and crop factor. The evaporation index was obtained by the Modified Penman Equation which is explained to be suitable in the humid area, and with respect to the crop factor the data which is used for the above method in Indonesia was applied.

1. Evaporation index

The Modified Penman Equation is expressed as follows.

$$E_o = \frac{\Delta H_{rd}^{ne} - \gamma E q}{\gamma + \Delta} \quad \text{..............................} \quad (1)$$

$$\Delta H_{ra}^{ne} = (H_{sh}^{ne} - H_{eo}^{ne}) \times \Delta L^{-1} \times 10^{2} \quad \text{................} \quad (2)$$

in which

E_o : the Evaporation Index representing the potential evapotranspiration of short-cut grass (mm per day)

H_{sh}^{ne} : the net short-wave radiation (Langleys per day)

H_{eo}^{ne} : the net long-wave radiation (Langleys per day)

Eq : the evaporation computed from the aerodynamic equation (see below), assuming the surface temperature to be equal to the air temperature (mm per day)

L : the latent heat of vaporization (Langleys per mm)

Δ : the slope of saturated vapour pressure V. temperature of the air (mm Hg per °C)

γ : a factor, called the psychrometer constant, which is defined by Bowen's dimensionless ratio (0.49 mm Hg per °C)

If no radiation data are available, the net short-wave radiation can be calculated by means of the following formula:

$$H^{ne}_{sh} = Ash\ f(r) \times oaHsh \times 10^{-2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$Ash\ f(r) = 0.75\ (0.29 \cos\psi + 0.52\ r \times 10^{-2}) \quad \ldots\ldots\ldots \quad (4)$$

in which

r : the relative duration of bright sunshine

ψ : the latitude (degrees)

asHsh : the theoretical maximum short-wave radiation received if no atmosphere were present (Langleys per day)

The formula for calculating the net long-wave radiation is:

$$H^{ne}_{eo} = f(Tai) \times 10^{-2} \times f(Tdp) \times f(m) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$f(Tai) = 97.0\ \sigma\ Tk^4 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$f(Tdp) = 0.47 - 0.077 \sqrt{P^{wd}_{z}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

$$f(m) = 0.20 + 0.80\ (1 - \gamma) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

in which

σ : the Stefan-Bolznann constant

Tk : the average daily air temperature at 2 meters above ground level (degrees Kelvin)

Pz^{wa} : the average daily staturated vapour pressure at dew-point temperature of the air at 2 m above ground level (mm Hg)

Tai : air temperature (°C)

Eq is calculated by means of the following formula:

$$Eq = (P_z^w]\,sa - P_z^{wa})\ f(U_2) \quad \text{(9)}$$

$$f(U_2) = 0.35\ (0.5 + 0.54\ U_2) \quad \text{(10)}$$

in which

U : wind velocity at 2 m above ground level (m/sec)

$P_z^w]sa - P_z^{wa}$: the average daily water vapour pressure deficit of the air at 2 m above ground level (mm Hg)

In the above calculation, the data required in case of no solar radiation data are as follows.

Tai : air temperature (°C)

$\frac{100Pz^{wa}}{Pz^{wa}]sa}$: relative humidity (%)

U_2 : wind velocity (m/sec)

r : relative duration of sunshine (%)
latitude (°)

The tables shown in the following are prepared for the caculation, $f(Tai) \times 10^{-2}$, $\Delta L^{-2} \times 10^2$, $P_z^{wa}]sa$ and $\gamma + \Delta$ are obtained by using Table 6-4 and air temperature, f(Tdp) is from Table 6-5 and P_z^{wa}, $\gamma f(U_2)$ is from Table 6-6 and wind velocity, $oaHsh \times 10^{-2}$ is from Table 6-7, and Ashf(r) and f(m) are obtained by relative duration of sunshine, table 6-8 and Table 6-9 respectively.

The data required for the calculation and the results are as follows.

(1) *Data required*

Latitude : 5° (south)

Table 6-2 Calculation Data for Evaporation Index

Month	Tai	r	$\frac{100\ P_z^{wa}}{P_z^{wa}]sa}$	U_2
	°C	%	%	m/sec
Jan.	26.6	48	81	0.69
Feb.	26.8	57	82	0.63
Mar.	27.1	53	82	0.59
Apr.	27.7	53	83	0.58
May	27.3	53	82	0.61
Jun.	26.9	54	80	0.65
Jul.	27.1	70	77	0.79
Aug.	27.2	62	78	0.79
Sep.	26.9	53	79	0.77
Oct.	27.4	56	77	0.77
Nov.	27.3	47	79	0.62
Dec.	27.0	39	81	0.60

(2) Calculation results

Table 6-3 Calculation of Evaporation Index

Month	f(Tai)x 10^{-2}	ΔL^{-2}x10^{2}	P_z^{wa}]sa	$\gamma - \Delta$	P_z^{wa}	f(Tdp)	P_z^{wa}]sa-P_z^{wa}
Jan.	9.15	2.64	26.18	2.03	21.21	0.115	4.97
Feb.	9.18	2.67	26.46	2.04	21.70	0.111	4.76
Mar.	9.21	2.71	26.90	2.07	22.06	0.108	4.84
Apr.	9.29	2.81	27.85	2.11	23.16	0.100	4.69
May	9.24	2.74	27.21	2.08	22.31	0.106	4.90
Jun.	9.19	2.69	26.60	2.05	21.28	0.114	5.32
Jul.	9.21	2.71	26.90	2.07	20.71	0.120	6.19
Aug.	9.22	2.73	27.05	2.08	21.10	0.116	5.95
Sep.	9.19	2.69	26.60	2.05	21.01	0.116	5.59
Oct.	9.25	2.76	27.37	2.09	21.07	0.116	6.30
Nov.	9.24	2.74	27.21	2.08	21.50	0.113	5.71
Dec.	9.20	2.70	26.74	2.06	21.66	0.111	5.08

Month	rf(U2)	rEq	oaHsh$_2$ x10^{-2}	Ashxf(r)	H_{sh}^{ne}	m = 8(1-γ)	f(m)
Jan.	0.150	0.75	8.97	0.403	3.61	4.16	0.58
Feb.	0.145	0.69	9.08	0.438	3.98	3.44	0.66
Mar.	0.141	0.68	8.91	0.423	3.77	3.76	0.62
Apr.	0.140	0.66	8.42	0.423	3.56	3.76	0.62
May	0.143	0.70	7.81	0.423	3.30	3.76	0.62
Jun.	0.147	0.78	7.45	0.427	3.18	3.68	0.63
Jul.	0.159	0.98	7.56	0.489	3.70	2.40	0.76
Aug.	0.159	0.95	8.08	0.458	3.70	3.04	0.70
Sep.	0.157	0.88	8.64	0.428	3.70	3.76	0.62
Oct.	0.157	0.99	8.95	0.434	3.88	3.52	0.65
Nov.	0.144	0.82	8.94	0.399	3.57	4.24	0.58
Dec.	0.142	0.72	8.89	0.368	3.27	4.88	0.51

Month	H_{eo}^{ne}	$H_{sh}^{ne}-H_{eo}^{ne}$	ΔH_{ra}^{ne}	$\gamma Eq+ \Delta H_{ra}^{ne}$	Eo	E
					mm/day	mm/month
Jan.	0.61	3.00	7.92	8.67	4.27	132.4
Feb.	0.67	3.31	8.84	9.53	4.67	130.8
Mar.	0.62	3.15	8.54	9.22	4.45	138.0
Apr.	0.58	2.98	8.37	9.03	4.30	129.0
May	0.61	2.69	7.37	8.07	3.88	120.3
Jan.	0.66	2.52	6.78	7.56	3.69	110.7
Jul.	0.84	2.86	7.75	8.73	4.22	130.8
Aug.	0.75	2.95	8.05	9.00	4.33	134.2
Sep.	0.66	3.04	8.18	9.06	4.42	132.6
Oct.	0.70	3.18	8.78	9.77	4.67	144.8
Nov.	0.61	2.96	8.11	8.93	4.29	128.7
Dec.	0.52	2.75	7.43	8.15	3.96	122.8

Table 6-4a Tai for 20°- 24°C

$f(T_{ai}) \times 10^{-2}$

$\Delta L^{-1} \times 10^{2}$

P_z^{wa}] sa

$\gamma + \Delta$

T_{ai}	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
20	8.37	8.38	8.40	8.41	8.42	8.43	8.44	8.46	8.47	8.48
	1.84	1.86	1.87	1.88	1.89	1.90	1.91	1.92	1.93	1.94
	17.53	17.64	17.75	17.86	17.97	18.08	18.20	18.31	18.43	18.54
	1.58	1.58	1.59	1.60	1.60	1.61	1.61	1.62	1.63	1.63
21	8.49	8.50	8.51	8.52	8.53	8.54	8.56	8.57	8.58	8.59
	1.96	1.97	1.98	1.99	2.00	2.01	2.02	2.04	2.05	2.06
	18.65	18.77	18.88	19.00	19.11	19.23	19.35	19.46	19.58	19.70
	1.64	1.65	1.65	1.66	1.66	1.67	1.68	1.68	1.69	1.70
22	8.60	8.61	8.62	8.63	8.64	8.65	8.67	8.68	8.69	8.71
	2.07	2.08	2.09	2.10	2.11	2.12	2.14	2.15	2.16	2.17
	19.82	19.94	20.06	20.19	20.31	20.43	20.58	20.69	20.80	20.93
	1.70	1.71	1.72	1.72	1.73	1.74	1.74	1.75	1.75	1.76
23	8.72	8.73	8.74	8.76	8.77	8.78	8.79	8.81	8.82	8.83
	2.18	2.19	2.21	2.22	2.23	2.24	2.26	2.27	2.28	2.29
	21.05	21.19	21.32	21.45	21.58	21.71	21.84	21.97	22.10	22.23
	1.77	1.78	1.78	1.79	1.80	1.80	1.81	1.82	1.82	1.83
24	8.84	8.85	8.86	8.88	8.89	8.90	8.91	8.93	8.94	8.95
	2.30	2.32	2.33	2.34	2.36	2.37	2.38	2.40	2.41	2.42
	22.37	22.50	22.63	22.76	22.91	23.05	23.19	23.31	23.45	23.60
	1.83	1.84	1.85	1.86	1.87	1.87	1.88	1.89	1.89	1.90

Table 6-4b Tai for 25° - 30°C

$f(T_{ai}) \times 10^{-2}$

$\Delta L^{-1} \times 10^{2}$

P_z^{wa}] sa

$\gamma + \Delta$

T_{ai}	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
25	8.96	8.97	8.98	9.00	9.01	9.02	9.03	9.05	9.06	9.07
	2.43	2.45	2.46	2 47	2.49	2 50	2.51	2.52	2.54	2.55
	23.75	23.90	24.03	24.20	24.35	24.49	24.64	24.79	24.94	25.08
	1.91	1.92	1.92	1.93	1.94	1.95	1.95	1.96	1.97	1.98
26	9.08	9.09	9.10	9.12	9.13	9.14	9.15	9.17	9.18	9.19
	2.56	2.57	2.59	2.60	2.62	2.63	2.64	2.66	2.67	2.69
	25.31	25.45	25.60	25.74	25.89	26.03	26.18	26.32	26.46	26.60
	1.98	1.99	2.00	2.01	2.01	2.02	2.03	2.04	2.04	2.05
27	9.20	9.21	9.22	9.24	9.25	9.26	9.27	9.29	9.30	9.31
	2.70	2.71	2.73	2.74	2.76	2.78	2.79	2.81	2.82	2.84
	26.74	26.90	27.05	27.21	27.37	27.53	27.69	27.85	28.10	28.16
	2.06	2.07	2.08	2.08	2.09	2.09	2.10	2.11	2.12	2.13
28	9.32	9.33	9.35	9.36	9.37	9.39	9.40	9.41	9.43	9.44
	2.86	2.87	2.88	2.90	2.91	2.92	2.94	2.95	2.96	2.98
	28.32	28.49	28.66	28.83	29.00	29.17	29.34	29.51	29.68	29.85
	2.14	2 15	2.16	2.17	2.18	2.18	2.19	2.20	2.21	2.22
29	9.45	9.46	9.47	9.49	9.50	9.51	9.52	9.54	9.55	9.56
	2.99	3.01	3.02	3.04	3.05	3.07	3.08	3.10	3.11	3.13
	30.03	30.20	30.38	30.56	30.74	30.92	31.10	31.28	31.46	31.64
	2.23	2.24	2.25	2.25	2.26	2.27	2.28	2.29	2.30	2.31
30	9.57	9.58	9.60	9.61	9.62	9.64	9.65	9.66	9.68	9.69
	3.14	3.16	3.18	3.19	3.21	3.23	3.24	3.26	3.28	3.29
	31.82	32.00	32.19	32.38	32.57	32.76	32.95	33.14	33.33	33.52
	2.32	2.33	2.34	2.35	2.36	2.37	2.38	2.38	2.39	2.40

Table 6-5 Tdp

$f(T_{dp})$

P_z^{wa} (N.B. : in mm Hg)

T_{dp}	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
15	0.195	0.194	0.194	0.193	0.192	0.191	0.190	0.189	0.188	0.187
	12.78	12.86	12.95	13.03	13.11	13.20	13.28	13.37	13.45	13.54
16	0.186	0.185	0.184	0.183	0.182	0.181	0.180	0.179	0.178	0.177
	13.63	13.71	13.80	13.90	13.99	14.08	14.17	14.26	14.35	14.44
17	0.176	0.175	0.175	0.174	0.173	0.172	0.171	0.170	0.169	0.168
	14.53	14.62	14.71	14.80	14.90	14.99	15.09	15.17	15.27	15.38
18	0.167	0.166	0.165	0.164	0.163	0.162	0.161	0.160	0.159	0.158
	15.46	15.56	15.66	15.76	15.86	15.96	16.06	16.16	16.26	16.36
19	0.157	0.156	0.156	0.155	0.154	0.153	0.152	0.151	0.150	0.149
	16.46	16.57	16.68	16.79	16.90	17.00	17.10	17.21	17.32	17.43
20	0.148	0.147	0.146	0.145	0.144	0.143	0.142	0.141	0.140	0.135
	17.53	17.64	17.75	17.86	17.97	18.08	18.20	18.31	18.43	18.54
21	0.137	0.136	0.135	0.134	0.133	0.132	0.131	0.130	0.129	0.128
	18.65	18.77	18.88	19.00	19.11	19.23	19.35	19.46	19.58	19.70
22	0.127	0.126	0.125	0.124	0.123	0.122	0.121	0.120	0.119	0.117
	19.82	19.94	20.06	20.19	20.31	20.43	20.58	20.69	20.80	20.93
23	0.116	0.115	0.114	0.113	0.112	0.111	0.110	0.109	0.108	0.107
	21.05	21.19	21.32	21.45	21.58	21.71	21.84	21.97	22.10	22.23
24	0.106	0.105	0.104	0.103	0.102	0.101	0.100	0.099	0.097	0.096
	22.37	22.50	22.63	22.76	22.91	23.05	23.19	23.31	23.45	23.60
25	0.095	0.094	0.093	0.092	0.091	0.090	0.089	0.088	0.087	0.086
	23.75	23.90	24.03	24.20	24.35	24.49	24.64	24.79	24.94	25.08

Table 6-6 $\gamma \times f(U_2) = 0{,}49 \times 0{,}35\ (0{,}5 + 0{,}54\ U_2)$

U_2	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0.086	0.095	0.104	0.114	0.123	0.132	0.142	0.151	0.160	0.169
1	0.178	0.187	0.197	0.206	0.215	0.225	0.234	0.244	0.253	0.262
2	0.271	0.280	0.290	0.299	0.308	0.318	0.327	0.337	0.346	0.355
3	0.364	0.373	0.382	0.392	0.401	0.410	0.420	0.429	0.438	0.447
4	0.456	0.465	0.475	0.484	0.493	0.503	0.512	0.522	0.531	0.540
5	0.549	0.558	0.568	0.577	0.586	0.596	0.605	0.614	0.624	0.633
6	0.642	0.651	0.660	0.670	0.679	0.688	0.698	0.707	0.716	0.725
7	0.734	0.743	0.752	0.762	0.771	0.780	0.790	0.799	0.808	0.817
8	0.826	0.835	0.845	0.854	0.863	0.873	0.882	0.891	0.901	0.910
9	0.919	0.928	0.938	0.947	0.956	0.966	0.975	0.984	0.994	1.003
10	1.012	1.021	1.031	1.040	1.049	1.059	1.068	1.077	1.087	1.096

If U_2 , the wind velocity at 2 m, is not known, U_2 can be derived from:

$$U_2 = \left(\frac{2}{z}\right)^{1/f} U_z = f(z) \times U_z$$

z	f (z)
0,5	1,22
1	1,105
2	1,00
3	0,994
4	0,906
5	0,877
6	0,854
7	0,836
8	0,820
9	0,807
10	0,795

Table 6-7. $_{oa}H_{sh} \times 10^{-2}$

S. titude	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0	8.59	8.87	8.93	8.67	8.23	7.95	8.03	8.41	8.77	8.83	8.62	8.46
1	8.66	8.92	8.93	8.62	8.15	7.85	7.94	8.34	8.74	8.85	8.68	8.55
2	8.74	8.96	8.92	8.57	8.06	7.75	7.85	8.27	8.71	8.88	8.75	8.63
3	8.82	9.00	8.92	8.52	7.98	7.65	7.75	8.21	8.69	8.91	8.81	8.72
4	8.89	9.04	8.91	8.47	7.89	7.55	7.66	8.14	8.67	8.93	8.88	8.80
5	8.97	9.08	8.91	8.42	7.81	7.45	7.56	8.08	8.64	8.95	8.94	8,89
6	9.04	9.12	8.91	8.37	7.72	7.35	7.47	8.01	8.62	8.97	9.01	8.97
7	9.12	9.16	8.90	8.32	7.64	7.25	7.37	7.95	8.59	8.99	9.08	9.06
8	9.19	9.20	8.90	8.27	7.55	7.15	7.28	7.88	8.57	9.01	9.14	9.14
9	9.27	9.24	8.90	8.22	7.47	7.05	7.18	7.81	8.54	9.03	9.21	9.23
10	9.35	9.28	8.89	8.17	7.38	6.95	7.09	7.74	8.51	9.06	9.27	9.32

Table 6-8: $a_{sh} \times f(r) = 0,75$ [0,29 cos degrees N or S + 0,52 r x 10^{-2}]

Degrees N or S	r										
	0	10	20	30	40	50	60	70	80	90	100
90	0	0.039	0.078	0.117	0.156	0.195	0.234	0.273	0.312	0.351	0.390
80	0.019	0.058	0.097	0.136	0.175	0.214	0.253	0.292	0.331	0.370	0.409
70	0.074	0.113	0.152	0.191	0.230	0.269	0.308	0.347	0.386	0.425	0.464
60	0.120	0.159	0.198	0.237	0.276	0.315	0.354	0.393	0.432	0.471	0.510
50	0.140	0.179	0.218	0.257	0.296	0.335	0.374	0.413	0.452	0.491	0.530
40	0.167	0.206	0.245	0.284	0.323	0.362	0.401	0.440	0.479	0.518	0.557
30	0.188	0.227	0.266	0.305	0.344	0.383	0.422	0.461	0.500	0.539	0.578
20	0.204	0.243	0.282	0.321	0.360	0.399	0.438	0.477	0.516	0.555	0.594
10	0.214	0.253	0.292	0.331	0.370	0.409	0.448	0.487	0.526	0.565	0.604
6	0.216	0.255	0.294	0.333	0.372	0.411	0.450	0.489	0.528	0.567	0.606
0	0.218	0.257	0.296	0.335	0.374	0.413	0.452	0.491	0.530	0.569	0.608

Table 6-9 $f(m) = 0,20 + 0.80 (1 - r)$

With m in octas	f (m)	With m in tenths	f (m)
0	1	0	1
1	0.9	1	0.92
2	0.8	2	0.84
3	0.7	3	0.76
4	0.6	4	0.68
5	0.5	5	0.60
6	0.4	6	0.52
7	0.3	7	0.44
8	0.2	8	0.36
		9	0.28
		10	0.20

2. Crop factor

The crop factors as recommended are expressed as a percentage of total growing period.

at 10% of the growing season, the crop factor is 1.08

at 20% : 1.18

at 30% : 1.27

at 40% : 1.37

at 50% : 1.40

at 60% : 1.33

at 70% : 1.23

at 80% : 1.13

at 90% : 1.02

at 100% : 0.92

In the about table, during the last two weeks before harvest of the crop, no irrigation water is supplied.

The next figure is applied to a crop with a 135 days growing season.

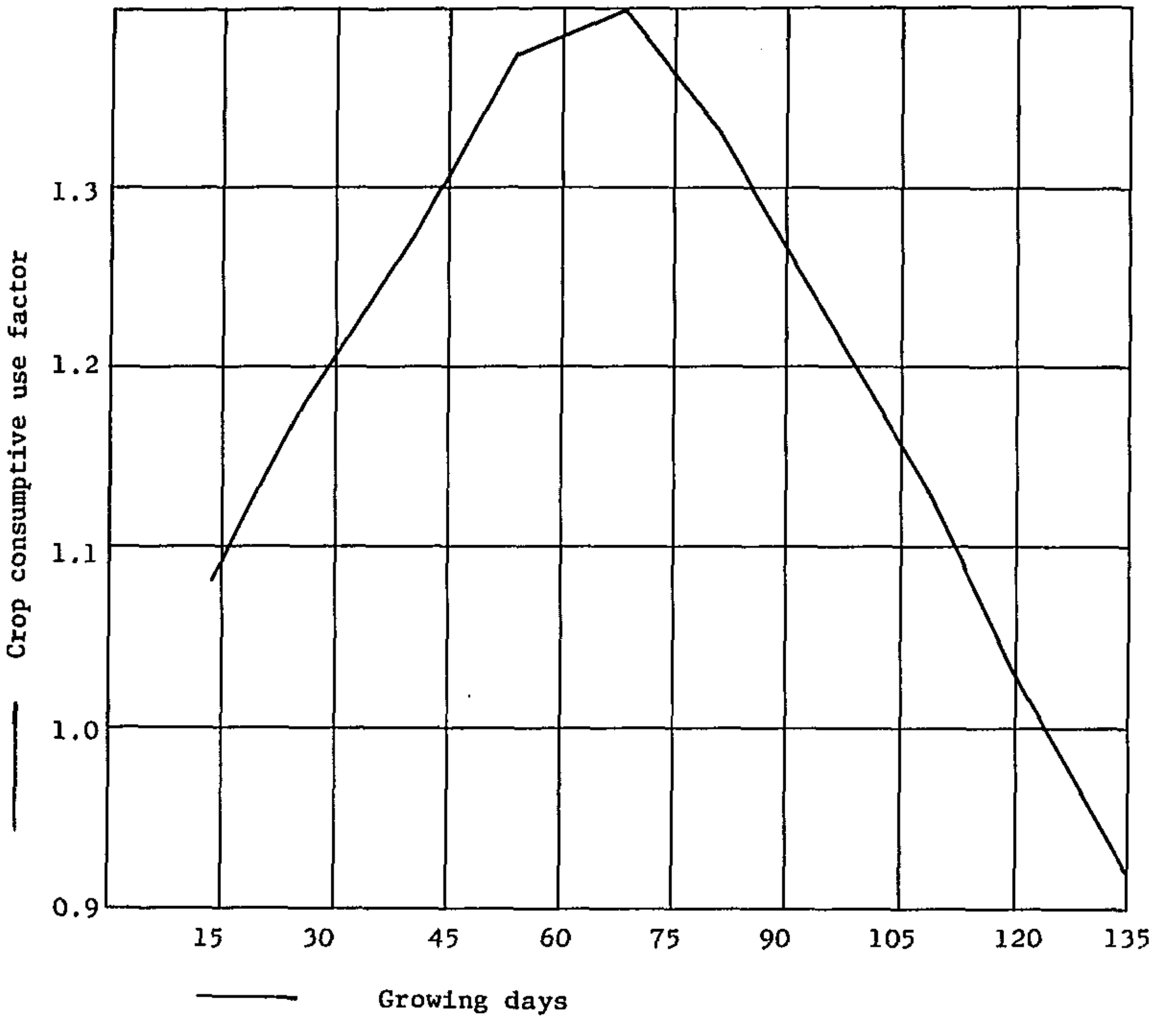


Fig. 6-1

Crop factor curve of the modified penman method for paddy of 135 days growing season.

6.3.3 Effective rainfall

The 1 in 5 year dry monthly rainfall (Rm) was applied to a design rainfall using the monthly rainfall data for 45 to 47 years at Kotabumi.

Effective rainfall (Re) is assumed as the following equation.

$$Re = 0.7 \times Rm \text{ (in mm/month)}$$

The result of calculation is as follows:

Month	Rm	Re
Jan.	252 mm	176.4 mm
Feb.	190	133.0
Mar.	236	165.2
Apr.	156	109.2
May	115	80.5
Jun.	54	37.8
Jul.	42	29.4
Aug.	32	22.4
Sep.	36	25.2
Oct.	69	48.3
Nov.	126	88.2
Dec.	225	157.5
Total	1,533	1,073.1

6.3.4 Percolation, land preparation requirement, puddling requirement and conveyance loss

According to the data obtained and information, the values of the above items are assumed as follows.

1. Percolation

   In wet season : 2.5 mm

   In dry season : 3.0 mm

2. Land preparation requirement : 150 mm/month

   Puddling requirement : 50 mm

3. Coefficient of conveyance loss
   80% for the main canal
   80% for the secondary, tertiary canals and others.
   Total efficiency is assumed to be 0.64.

6.3.5 Cropping pattern

The block system which divides the irrigation area into 4 or 5 was adopted because of the big irrigation area and the rotation system in the dry season, and the comparative study on the various cropping patterns shown in Fig. 6-2, 6-3 and 6-4 was done, considering the growing period of 135 days for paddy, farming practice, labor availability, diversion requirement, river discharge, etc.

These cropping patterns are generally divided into the following three types.

Pattern	Irrigation area per one household	Delay of farming in each block
A	1.00 ha	30 days
B	1.20 ha	40 days
C	1.25 ha	50 days

Fig. 6-2 Cropping Patterns for Comparative Study

Pattern: A

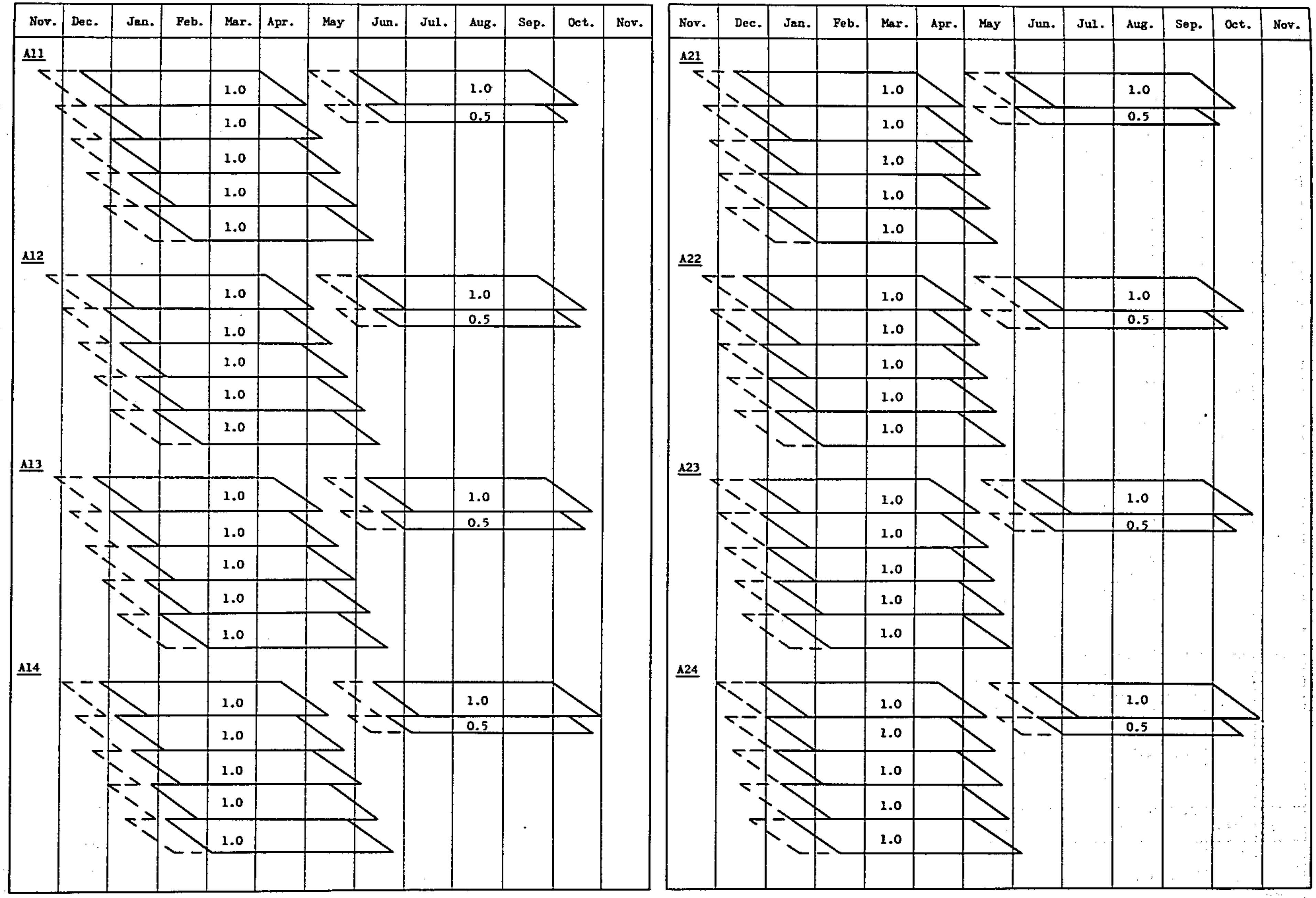


Fig. 6-3 Cropping Pattern for Comparative Study

Pattern: B

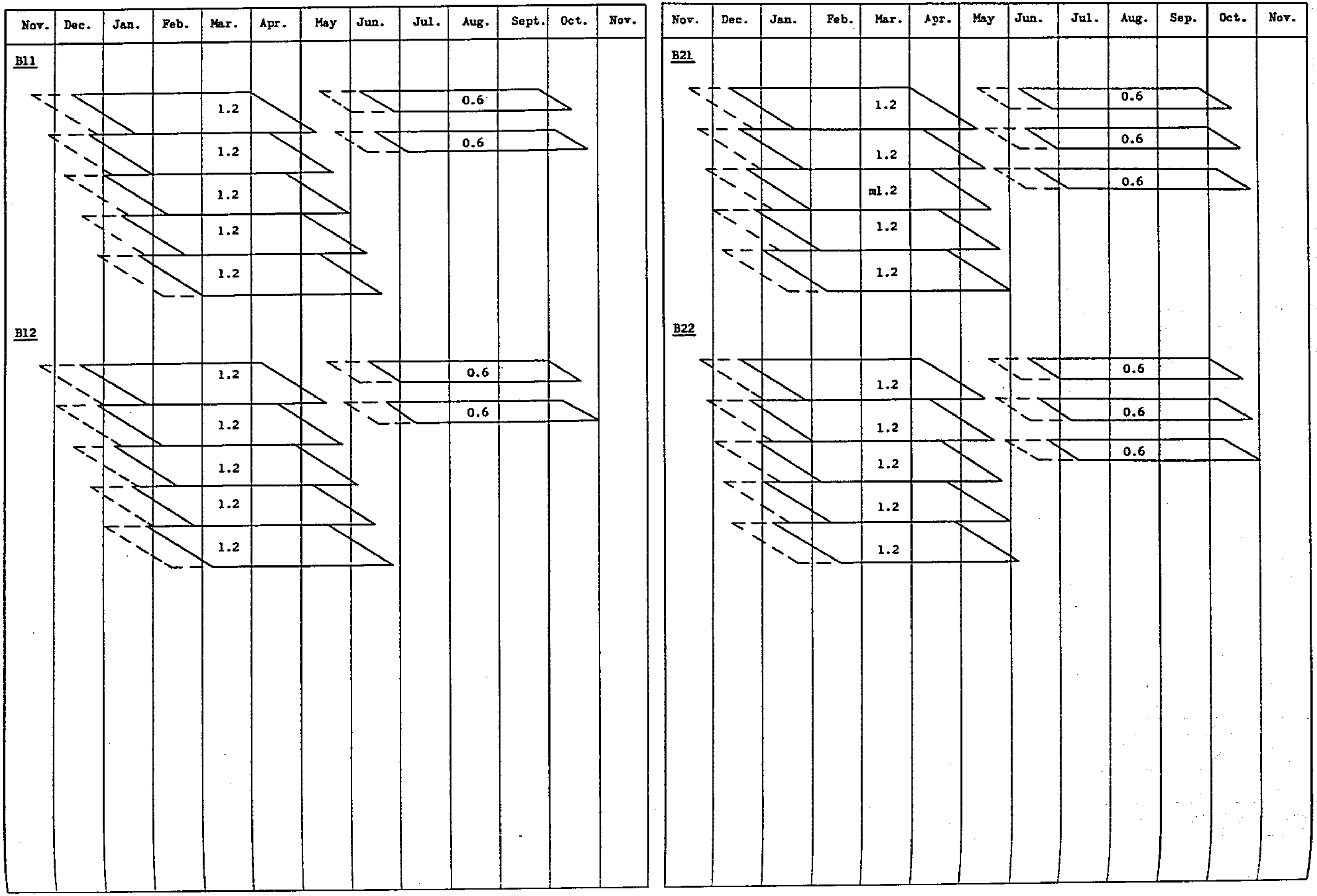
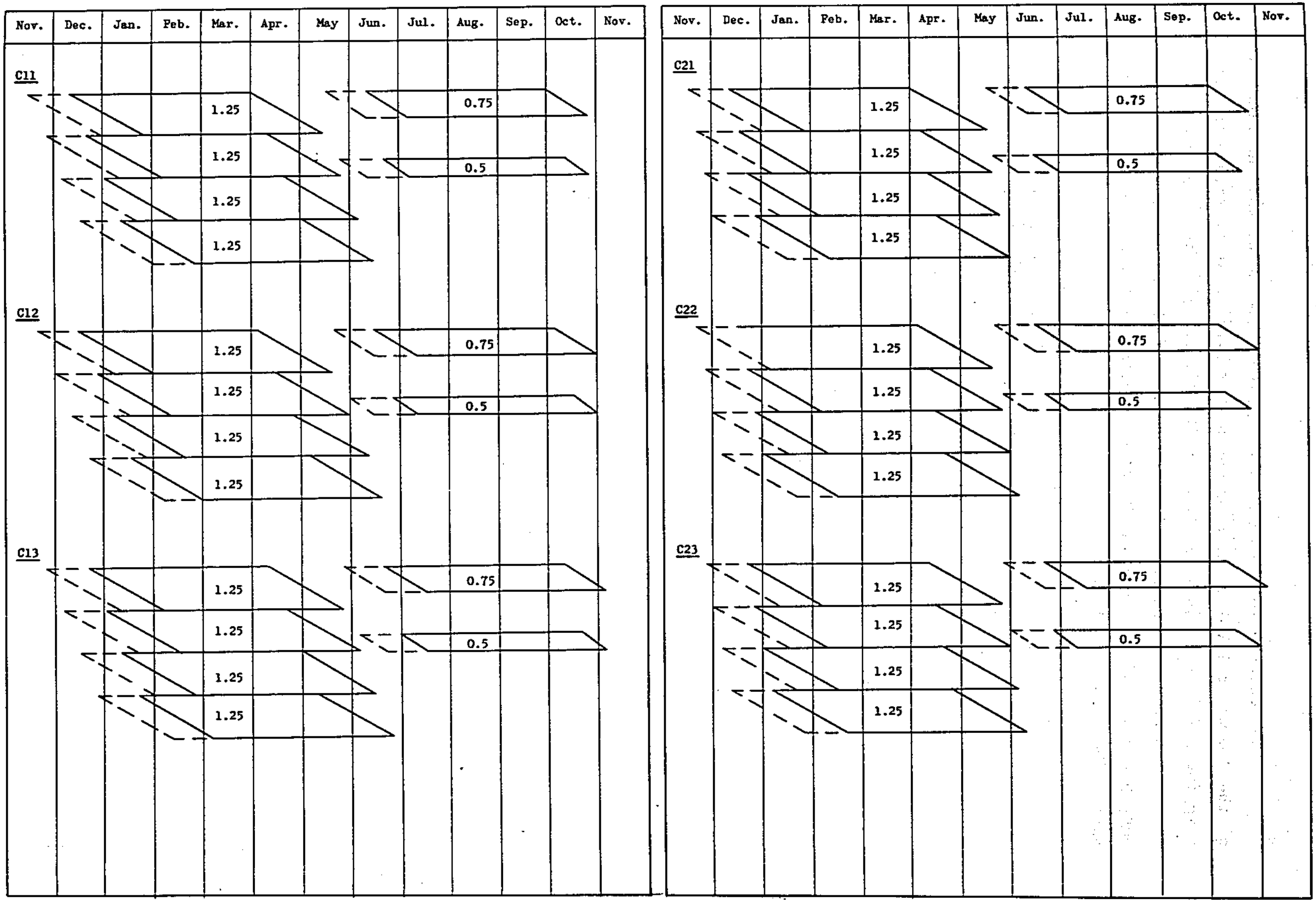


Fig. 6-4 Cropping Pattern for Comparative Study

Pattern: C



The calculation results of diversion requirement and the fluctuation of the dam water level in case of the net irrigation area; 25,000 ha for each cropping pattern are shown in Table 6-10, 11, 12, 13, Fig. 6-5, 6 and 7.

Merely judging from the view points of the total diversion requirement per year and the peak intake discharge, the priority of each cropping pattern becomes as follows.

Priority	Total diversion requirement	Peak intake discharge
1	A21	C11
2	B21	A21
3	A22	A11
4	C22	C23
5	C21	C21
6	A23	B21
7	A24	C22
8	C23	A12
9	B22	A22
10	C11	B11

As for the fluctuation of the dam water level, it can be considered that there is almost no difference.

The above study was merely done from the view points of civil engineering, but finally the proposed cropping pattern was decided to be C11 from the above and agricultural points of view synthetically.

Table 6-10 Average diversion requirement and total diversion discharge per ha.

Month	Cropping pattern							
	A11		A12		A13		A14	
	A ℓ/S/ha	B m^3/ha	A ℓ/S/ha	B m^3/ha	A ℓ/S/ha	B m^3/ha	A ℓ/S/ha	B m^3/ha
Nov.	0.023	59.6	0.008	20.7	0.002	5.2		
Dec.	0.399	1,068.7	0.288	771.4	0.187	500.9	0.111	297.3
Jan.	0.831	2,225.8	0.798	2,137.4	0.758	2,030.2	0.682	1,826.7
Feb.	0.849	2,053.9	0.916	2,216.0	0.990	2,395.0	1.048	2,535.3
Mar.	0.520	1,392.8	0.543	1,454.4	0.558	1,494.5	0.581	1,556.2
Apr.	0.471	1,220.8	0.547	1,417.8	0.605	1,568.2	0.693	1,796.3
May {	0.125	334.8	0.195	552.3	0.259	693.7	0.347	929.4
	0.628	420.5	0.353	236.4	0.185	123.9	0.084	56.2
Jun. {			0.003	7.8	0.011	28.5	0.028	72.6
	1.786	1,157.3	1.937	1,255.2	1.933	1,252.6	1.765	1,143.7
Jul.	1.424	953.5	1.416	948.2	1.433	959.5	1.509	1,010.4
Aug.	1.403	939.4	1.434	960.2	1.463	979.6	1.479	990.3
Sep.	0.890	576.7	1.044	676.5	1.176	762.0	1.271	823.6
Oct.	0.011	7.4	0.052	34.8	0.135	90.4	0.261	174.8
Nov.								
Total		12,411.2		12,689.1		12,884.2		13,212.8
{ Wet season		8,356.4		8,577.8		8,716.2		9,013.8
Dry season		4,054.8		4,111.3		4,168.0		4,199.0

Remarks; (1) The area in dry season : 25%

(2) A : Average diverson requirement per ha.

(3) B : Diversion discharge required per ha.

Table 6-11 Average diversion requirement and total diversion discharge per ha.

Month	Cropping pattern							
	A21		A22		A23		A24	
	A ℓ/S/ha	B m^3/ha	A ℓ/S/ha	B m^3/ha	A ℓ/S/ha	B m^3/ha	A ℓ/S/ha	B m^3/ha
Nov.	0.032	829	0.011	28.5	0.002	5.2		
Dec.	0.650	1,741.0	0.461	1,234.7	0.293	784.8	0.016	42.9
Jan.	0.831	2,225.8	0.933	2,498.9	1.000	2,499.9	1.008	2,699.8
Feb.	0.757	1,831.3	0.768	1,857.9	0.788	1,906.3	0.829	2,005.5
Mar.	0.471	1,261.5	0.505	1,352.6	0.533	1,427.6	0.559	1,497.2
Apr.	0.322	824.6	0.414	1,073.1	0.504	1,306.4	0.583	1,511.1
May {	0.012	32.1	0.031	83.0	0.067	179.5	0.123	329.4
	0.734	491.5	0.439	294.0	0.239	160.0	0.109	73.0
Jun.	1.730	1,121.0	1.885	1,221.5	1.909	1,237.0	1.841	1,193.0
Jul.	1.426	954.8	1.419	950.2	1.443	966.2	1.478	989.7
Aug.	1.395	934.1	1.424	953.5	1.455	974.3	1.473	986.3
Sep.	0.819	530.7	0.976	632.4	1.136	736.1	1.251	810.6
Oct.	0.011	7.4	0.041	27.5	0.104	69.6	0.209	139.9
Nov.								
Total		12,038.7		12,207.8		12,252.9		12,278.4
{ Wet season		7,999.2		8,128.7		8,109.7		8,085.9
Dry season		4,039.5		4,079.1		4,143.2		4,192.5

Remarks, (1) The area in dry season : 25%

(2) A : Average diversion requirement per ha.

(3) B : Diversion discharge required per ha.

Table 6-12 Average diversion requirement and total diversion discharge per ha.

Month	Cropping pattern							
	B11		B12		B21		B22	
	A ℓ/S/hr	B m^3/ha	A ℓ/S/hr	B m^3/ha	A ℓ/S/hr	B m^3/ha	A ℓ/S/hr	B m^3/ha
Nov.	0.017	44.1	0.006	15.6	0.023	59.6	0.008	20.7
Dec.	0.275	736.6	0.147	393.7	0.397	1,063.3	0.256	685.7
Jan.	0.757	2,027.5	0.705	1,888.3	0.893	2,391.8	0.927	2,482.9
Feb.	0.935	2,262.0	0.988	2,390.2	0.792	1,916.0	0.824	1,993.4
Mar.	0.544	1,457.0	0.567	1,518.6	0.503	1,347.2	0.532	1,424.9
Apr.	0.531	1,376.4	0.598	1,550.0	0.398	1,031.6	0.480	1,244.2
May	0.198	530.3	0.287	768.7	0.039	104.5	0.104	278.6
	0.227	152.0	0.101	67.6	0.212	142.0	0.091	60.9
Jun.	0.009	23.3	0.020	51.8				
	1.916	1,241.6	1.814	1,175.5	1.952	1,264.9	1.840	1,192.3
Jul.	1.441	964.9	1.484	993.7	1.425	954.2	1.478	989.7
Aug.	1.454	973.6	1.481	991.7	1.456	974.9	1.479	990.3
Sep.	1.158	750.4	1.271	823.6	1.172	759.5	1.275	826.2
Oct.	0.117	78.3	0.235	157.3	0.109	73.0	0.227	152.0
Nov.								
Total		12,418.0		12,786.3		12,082.5		12,341.8
Wet season		8,257.2		8,576.9		7,914.0		8,130.4
Dry season		4,160.8		4,209.4		4,168.5		4,211.4

Remarks, (1) The area in dry season : 25%

(2) A : Average diversion requirement per ha.

(3) B : Diversion discharge required per ha.

Table 6-13 Average diversion requirement and total diversion discharge per ha.

Month	Cropping pattern					
	C11		C12		C13	
	A ℓ/S/ha	B m3/ha	A ℓ/S/ha	B m3/ha	A ℓ/S/ha	B m3/ha
Nov.	0.018	46.7	0.007	18.1	0.002	5.2
Dec.	0.285	763.3	0.197	527.6	0.125	334.8
Jan.	0.829	2,220.4	0.746	1,998.1	0.705	1,888.3
Feb.	0.796	1,925.7	0.960	2,322.4	0.925	2,237.8
Mar.	0.540	1,446.3	0.560	1,499.9	0.577	1,545.4
Apr.	0.503	1,303.8	0.570	1,477.4	0.631	1,635.6
May	0.157	420.5	0.220	589.2	0.282	755.3
	0.094	62.9	0.034	22.8	0.040	26.8
Jun.	0.002	5.2	0.009	23.3	0.023	59.6
	1.881	1,218.9	1.584	1,026.4	1.209	783.4
Jul.	1.469	983.6	1.582	1,059.3	1.741	1,165.8
Aug.	1.475	987.7	1.494	1,000.4	1.504	1,007.1
Sep.	1.263	818.4	1.325	858.6	1.371	888.4
Oct.	0.214	143.3	0.371	248.4	0.557	373.0
Nov.						
Total		12,346.7		12,671.9		12,706.5
Wet season		8,131.9		8,456.0		8,462.0
Dry season		4,214.8		4,215.9		4,244.5

Remarks, (1) The area in dry season : 25%

(2) A : Average diversion requirement per ha.

(3) B : Diversion discharge required per ha.

Table 6-14 Average diversion requirement and total diversion discharge per ha.

Month	Cropping pattern					
	C21		C22		C23	
	A ℓ/S/hr	B m^3/ha	A ℓ/S/hr	B m^3/hr	A ℓ/S/hr	B m^3/ha
Nov.	0.025	64.8	0.009	23.3	0.002	5.2
Dec.	0.426	1,141.0	0.296	792.8	0.188	503.5
Jan.	0.887	2,375.7	0.909	2,434.7	0.878	2,351.6
Feb.	0.792	1,916.0	0.753	1,821.7	0.786	1,901.5
Mar.	0.503	1,347.2	0.534	1,430.3	0.559	1,497.2
Apr.	0.394	1,021.2	0.471	1,220.8	0.547	1,417.8
May {	0.056	150.0	0.100	267.8	0.147	393.7
	0.125	83.7	0.043	28.8	0.040	26.8
Jun.	1.973	1,278.5	1.753	1,135.9	1.396	904.6
Jul.	1.431	958.2	1.517	1,015.8	1.656	1,108.9
Aug.	1.469	983.6	1.484	993.7	1.508	1,009.8
Sep.	1.242	804.8	1,311	849.5	1.358	880.0
Oct.	0.151	101.1	0.294	196.9	0.475	318.1
Nov.						
Total		12,225.8		12,212.0		12,318.7
{ Wet season		8,015.9		7,991.4		8,070.5
Dry season		4,209.9		4,220.6		4,248.2

Remarks, (1) The area in dry season : 25%

(2) A : Average diversion requirement per ha.

(3) B : Diversion discharge required per ha.

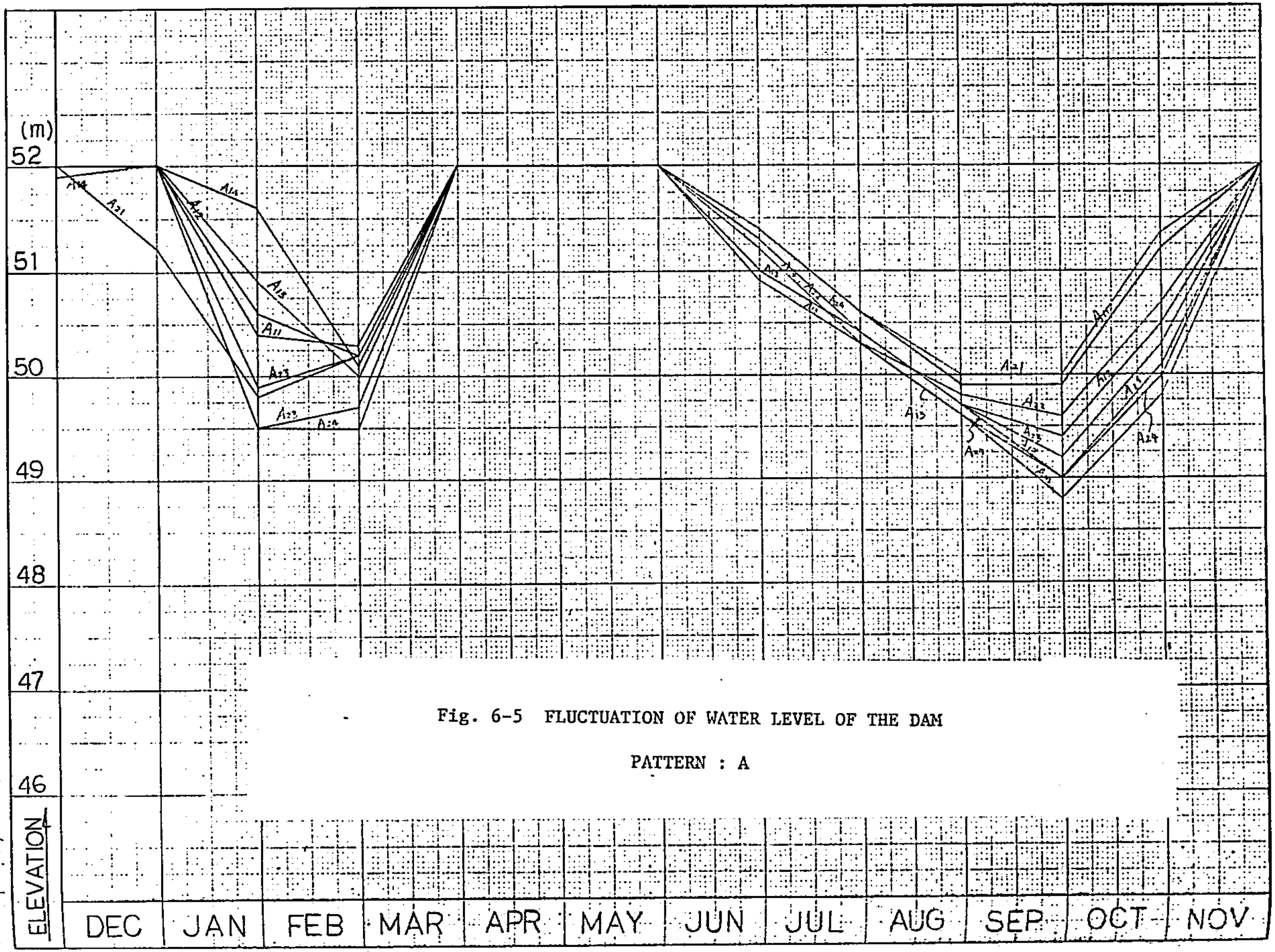


Fig. 6-5 FLUCTUATION OF WATER LEVEL OF THE DAM

PATTERN : A

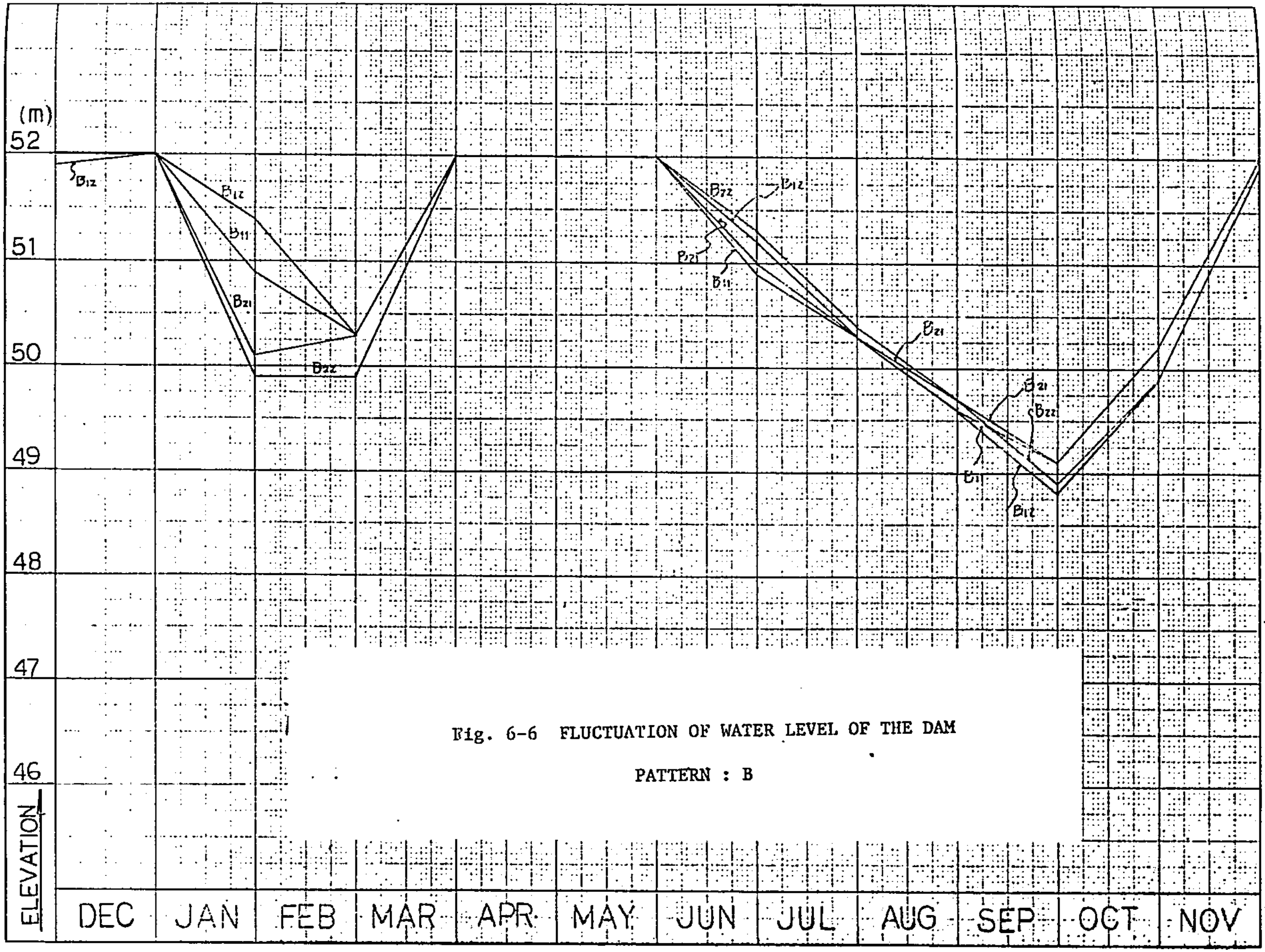


Fig. 6-6 FLUCTUATION OF WATER LEVEL OF THE DAM

PATTERN : B

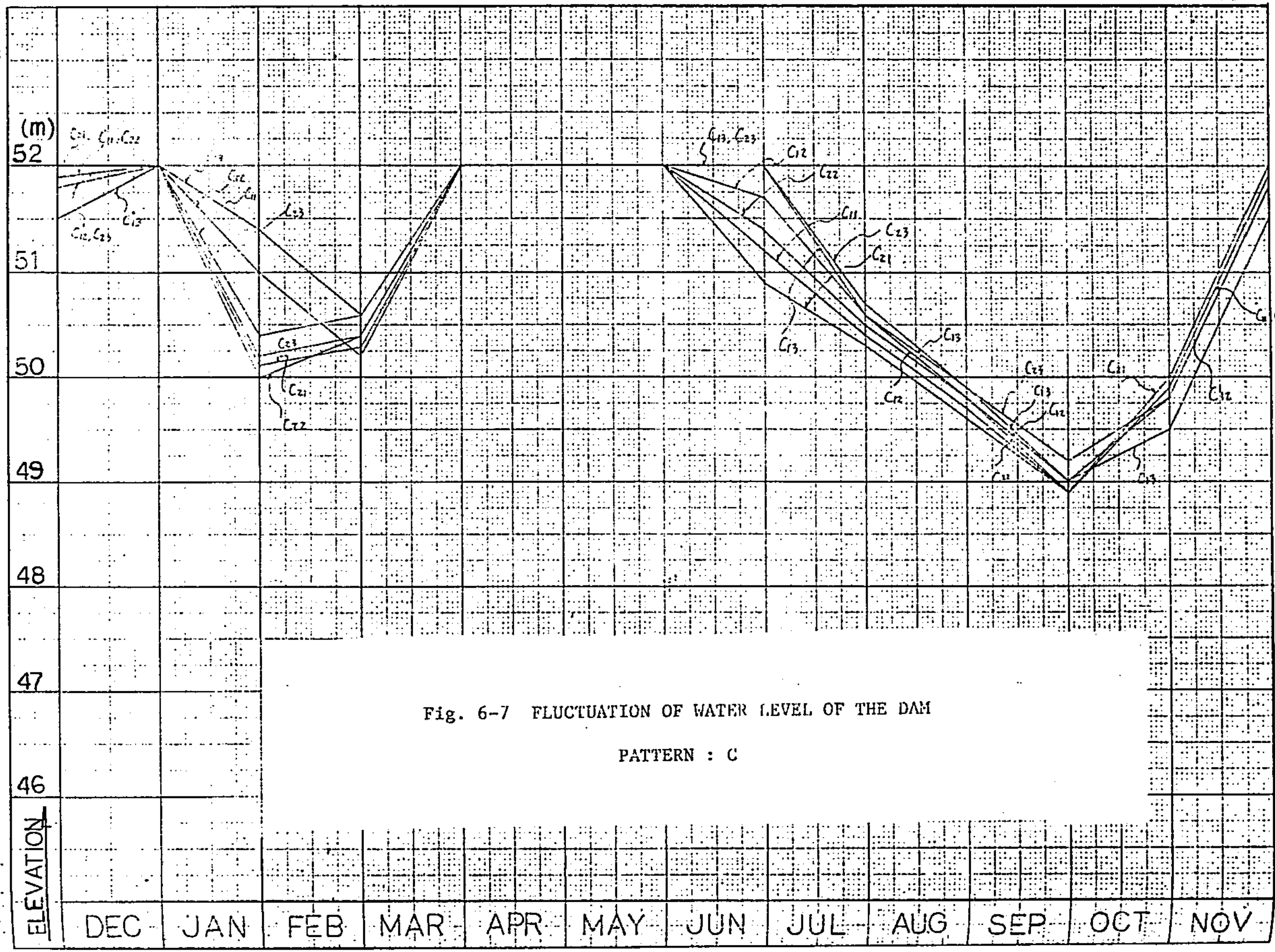


Fig. 6-7 FLUCTUATION OF WATER LEVEL OF THE DAM

PATTERN : C

6.3.6 Diversion requirement

The finally proposed cropping pattern and it's unit diversion requirement is shown in the following table and the calculation results of diversion requirement of each block is shown in Table 6-16, 17, 18 and 19.

Table 6-15 Cropping pattern and unit diversion requirement

Item	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Pattern												
Type 1					1.25					0.75		
2					1.25					0.50		
3					1.25							
4					1.25							
Diversion Requirement												
Type 1	0.067	0.641	0.822	0.775	0.453	0.278	0.152	1.897	1.461	1.469	1.222	0.169
2	0.006	0.350	0.977	0.758	0.519	0.433	0.091	1.856	1.480	1.484	1.325	0.281
3		0.119	0.909	0.520	0.575	0.586	0.185					
4		0.029	0.607	1.129	0.615	0.715	0.366	0.009				
Average	0.018	0.285	0.829	0.796	0.540	0.503	0.094	1.881	1.469	1.475	1.263	0.214

(ℓ/sec/ha)

Table 6-16

Monthly Consumptive Use by Crop and Unit Water Requirement

Type: 1

Item	Unit	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
I. Conditions													
1. Evaporation index	mm	128.7	122.8	132.4	130.8	138.0	129.0	120.3	110.7	130.8	134.2	132.6	144.8
2. Effective rainfall	mm	88.2	157.5	176.4	133.0	165.2	109.2	80.5	37.8	29.4	22.4	25.2	48.3
II. Cropping pattern													
3. Crop factor		1.02	1.08	1.26	1.40	1.22	1.07	1.00 1.02 (1.019)	1.13	1.33	1.35	1.15	1.02
III. Water requirement													
4. Consumptive use(1)x(3)	mm	131.3	132.6	166.8	183.1	168.4	138.0	122.6	125.1	174.0	181.2	152.5	147.7
5. Percolation	mm	75.0	77.5	77.5	70.0	77.5	75.0	93.0	90.0	93.0	93.0	90.0	93.0
6. Water requirement by crop (4)+(5)	mm	206.3	210.1	244.3	253.1	245.9	213.0	215.6	215.1	267.0	274.2	242.5	240.7
7. Puddling water requirement	mm	15.0	112.0	73.0	-	-	-	27.0	160.0	13.0	-	-	-
8. Field delivery requirement(6)+(7)-(2)	mm	133.1	164.6	140.9	120.1	80.7	103.8	162.1	337.3	250.6	251.8	217.3	192.4
-ditto-	ℓ/S/ha	0.513	0.614	0.526	0.496	0.301	0.400	0.605	1.301	0.935	0.940	0.838	0.718
9. Ratio of area		0.083	0.667	1.000	1.000	0.963	0.445	0.009 0.150 (0.159)	0.933	1.000	1.000	0.933	0.150
10. Diversion requirement $\frac{(8)x(9)}{0.64}$	ℓ/S/ha	0.067	0.641	0.822	0.775	0.453	0.278	0.150	1.897	1.461	1.469	1.222	0.169

Table 6-17

Monthly Consumptive Use by Crop And Unit Water Requirement

Type: 2

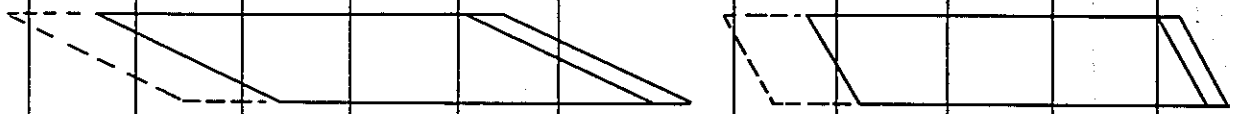
Item	Unit	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
I. Conditions													
1. Evaporation index	mm	128.7	122.8	132.4	130.8	138.0	129.0	120.3	110.7	130.8	134.2	132.6	144.8
2. Effective rainfall	mm	88.2	157.5	176.4	133.0	165.2	109.2	80.5	37.8	29.4	22.4	25.2	48.3
II. Cropping pattern													
3. Crop factor		1.01	1.06	1.20	1.38	1.28	1.10	1.03 1.01 (1.025)	1.09	1.29	1.37	1.17	1.02
III. Water requirement													
4. Consumptive use(1)x(3)	mm	130.0	130.2	158.9	180.5	176.6	141.9	123.3	120.7	168.7	183.9	155.1	147.7
5. Percolation	mm	75.0	77.5	77.5	70.0	77.5	75.0	93.0	90.0	93.0	93.0	90.0	93.0
6. Water requirement by crop (4)+(5)	mm	205.0	207.7	236.4	250.5	254.1	216.9	216.3	210.7	261.7	276.9	245.1	240.7
7. Puddling water requirement	mm	1.5	84.5	114.0	-	-	-	5.0	173.5	21.5	-	-	-
8. Field delivery requirement (6)+(7)-(2)	mm	118.3	134.7	174.0	117.5	88.9	107.7	140.8	346.4	253.8	254.5	219.9	192.4
-ditto-	ℓ/S/ha	0.456	0.503	0.649	0.486	0.332	0.415	0.526	1.336	0.947	0.950	0.848	0.718
9. Ratio of area		0.009	0.445	0.963	1.000	1.000	0.667	0.083 0.028 (0.111)	0.889	1.000	1.000	1.000	0.250
10. Diversion requirement $\frac{(8)x(9)}{0.64}$	ℓ/S/ha	0.006	0.350	0.977	0.758	0.519	0.433	0.091	1.856	1.480	1.484	1.325	0.281

Table 6-18

Monthly Consumptive Use by Crop And Unit Water Requirement

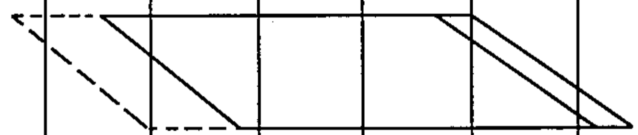
Type: 3

Item	Unit	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
I. Conditions													
1. Evaporation index	mm	122.8	132.4	130.8	138.0	129.0	120.3	110.7	130.8	134.2	132.6	144.8	128.7
2. Effective rainfall	mm	157.5	176.4	133.0	165.2	109.2	80.5	37.8	29.4	22.4	25.2	48.3	88.2
II. Cropping pattern													
3. Crop factor		1.03	1.17	1.33	1.35	1.15	1.04						
III. Water requirement													
4. Consumptive use(1)x(3)	mm	126.5	154.9	174.0	186.3	148.4	125.1						
5. Percolation	mm	77.5	77.5	70.0	77.5	75.0	93.0						
6. Water requirement by crop (4)+(5)	mm	204.0	232.4	244.0	263.8	223.4	218.1						
7. Puddling water requirement	mm	41.5	127.0	31.5	-	-	-						
8. Field delivery requirement(6)+(7)-(2)	mm	88.0	183.0	142.5	98.6	114.2	137.6						
-ditto-	ℓ/S/ha	0.328	0.683	0.589	0.368	0.440	0.514						
9. Ratio of area		0.231	0.852	1.000	1.000	0.852	0.231						
10. Diversion requirement $\frac{(8)x(9)}{0.64}$	ℓ/S/ha	0.119	0.909	0.520	0.575	0.586	0.185						

Table 6-19

Monthly Consumptive Use by Crop And Unit Water Requirement

Type: 4

Item	Unit	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
I. Conditions													
1. Evaporation index	mm	122.8	132.4	130.8	138.0	129.0	120.3	110.7	130.8	134.2	132.6	144.8	128.7
2. Effective rainfall	mm	157.5	176.4	133.0	165.2	109.2	80.5	37.8	29.4	22.4	25.2	48.3	88.2
II. Cropping pattern	-												
3. Crop factor		1.02	1.08	1.26	1.40	1.22	1.07	1.00					
III. Water requirement													
4. Consumptive use(1)x(3)	mm	125.3	143.0	164.8	193.2	157.4	128.7	110.7					
5. Percolation	mm	77.5	77.5	70.0	77.5	75.0	93.0	90.0					
6. Water requirement by crop (4)+(5)	mm	202.8	220.5	234.8	270.7	232.4	221.7	200.7					
7. Puddling water requirement	mm	15.0	112.0	73.0	-	-	-	-					
8. Field delivery requirement(6)+(7)-(2)	mm	60.3	156.1	174.8	105.5	123.2	141.2	162.9					
-ditto-	ℓ/S/ha	0.225	0.583	0.722	0.394	0.475	0.527	0.628					
9. Ratio of area		0.083	0.667	1.000	1.000	0.963	0.445	0.009					
10. Diversion requirement $\frac{(8)x(9)}{0.64}$	ℓ/S/ha	0.029	0.607	1.129	0.615	0.715	0.366	0.009					

6.4 Water Balance of the Dam and Others

The calculation results of water balance of the Rarem dam in both cases of the net irrigation area of 20,000 ha and 25,000 ha are shown in Table 6-20 and 21, and the ralation between elevation of full water surface and net irrigable area is shown in Fig. 6-8.

The peak discharge is not the product of the unit diversion requirement and the covering area because the actual coverage area of each block is not equal. Table 6-22 and Fig. 6-9 show the calculation of peak discharge for main canal in accordance with the proposed block division and the diagram of it's distribution system.

Table 6-20

Water Balance of the Rarem Dam

Net irrigable area

wet season : 20,000 ha.

dry season : 4,700 ha.

Elevation of full water surface: 48.20 m

Planned intake water level : 47.72 m

Bed elevation of canal : 46.00 m

Month	Diversion requirement				River Discharge	Water Loss								B-(A+C)	Storage Capacity	Water level of the Dam
						Evaporation			Leakage		River maintaining flow		EQ			
	qd	q	W.L	A	B	W.A	q1	Q1	q2	Q2	q3	Q3	C			
	ℓ/S/ha	m^3/S	m	10^3m^3/ month	10^3m^3/ month	Km^2	10^3m^3/ month/Km^2	10^3m^3/ month	m^3/day	10^3m^3/ month	m^3/day	10^3m^3/ month	10^3m^3/ month	10^3m^3/ month	10^3m^3	m
Nov.	0.018	0.36	46.18	933	22,810	5.88	154.20	907	11,000	330	17,280	518	1,755	20,122	22,000	48.20
Dec.	0.285	5.70	46.93	15,267	38,837	"	167.40	984	"	341	"	536	1,861	21,709	"	"
Jan.	0.829	16.57	47.72	44,409	44,194	"	149.42	879	"	"	"	536	1,756	- 1,971	20,029	47.50
Feb.	0.796	15.92	47.68	38,514	52,013	5.20	139.44	725	10,015	280	"	484	1,489	12,010	22,000	48.20
Mar.	0.540	10.80	47.35	28,927	66,960	5.88	160.58	944	11,000	341	"	536	1,821	36,212	"	"
Apr.	0.503	10.06	47.30	26,075	54,432	"	156,30	919	"	330	"	518	1,767	26,590	"	"
May	0.157 0.094	3.14 0.44	46.71	8,410 1,178	40,176	"	146.63	862	"	341	"	536	1,739	28,849	"	"
Jun.	0.002 1.881	0.04 8.84	47.20	104 22,913	25,402	"	133.20	783	"	330	"	518	1,631	754	"	"
Jul.	1.469	6.90	47.04	18,481	19,802	"	147.25	866	"	341	"	536	1,743	- 422	21,578	48.00
Aug.	1.475	6.93	47.04	18,561	18,213	5.70	146.63	836	10,789	334	"	536	1,706	- 2,054	19,524	47.40
Sep.	1.263	5.94	46.90	15,396	16,070	5.10	139.80	713	9,762	293	"	518	1,524	- 850	18,674	47.10
Oct.	0.214	1.01	46.33	2,705	15,535	4.86	162.44	789	9,337	289	"	536	1,614	11,216	22,000	48.20

Table 6-21

Water Balance of the Rarem Dam

Net irrigable area

Wet season : 25,000 ha

Dry season : 5,900 ha

Elevation of full water surface: 52.00 m

Planning intake water level :

Bed elevation of canal : 46.00 m

Month	Diversion requirement				River Discharge	Water loss: Evaporation			Water loss: Leakage		Water loss: River Maintaining flow		Water loss: E.Q	Water loss: B-(A+C)	Storage Capacity	Water Level of the Dam
	qd	q	W.L	A	B	W.A	q1	Q1	q2	Q2	q3	Q3	C			
	ℓ/S/ha	m^3/S	m	10^3m^3/month	10^3m^3/month	Km^2	10^3m^3/month/Km^2	10^3m^3/month	m^3/day	10^3m^3/month	m^3/day	10^3m^3/month	10^3m^3/month	10^3m^3/month	10^3m^3	m
Nov.	0.018	0.45		1,166	22,810	7.5	154.20	1,157	18.125	544	17,280	518	2,219	19,425	55,674	51.90
Dec.	0.285	7.13		19,097	38,837	9.1	167.40	1,523	27,873	863	"	536	2,922	16,818	56,700	52.00
Jan.	0.829	20.73		55,523	44,194	9.2	14,942	1,375	28,350	879	"	536	2,790	-14,119	42,581	50.40
Feb.	0.796	19.90		48,142	52,013	7.9	139.44	1,102	21,291	596	"	484	2,182	1,689	44,270	50.60
Mar.	0.540	13.50		36,158	66,960	8.1	160.58	1,301	22,135	686	"	536	2,523	28,279	56,700	52.00
Apr.	0.503	12.58		32,607	54,432	9.2	156.30	1,438	28,350	851	"	518	2,807	19,018	56,700	52.00
May	0.157	3.93		10,526	40,176	9.2	146.63	1,349	"	879	"	536	2,764	25,306	56,700	52.00
	0.094	0.59		1,580												
Jun.	0.002	0.05		130	25,402	9.2	133.20	1,225	"	851	"	518	2,594	- 7,804	48,896	51.20
	1.881	11.76		30,482												
Jul.	1.469	9.18		24,588	19,802	8.5	147.25	1,252	24,448	758	"	536	2,546	- 7,332	41,564	50.40
Aug.	1.475	9.22		24,695	18,213	7.9	146.63	1,158	20,782	644	"	536	2,338	- 8,820	32,744	49.70
Sep.	1.263	7.89		20,451	16,070	7.4	139.80	1,035	16,372	491	"	518	2,044	- 6,425	26,319	48.90
Oct.	0.214	1.34		3,589	15,535	6.6	162.44	1,072	13,160	408	"	536	2,016	9,930	36,249	49.90

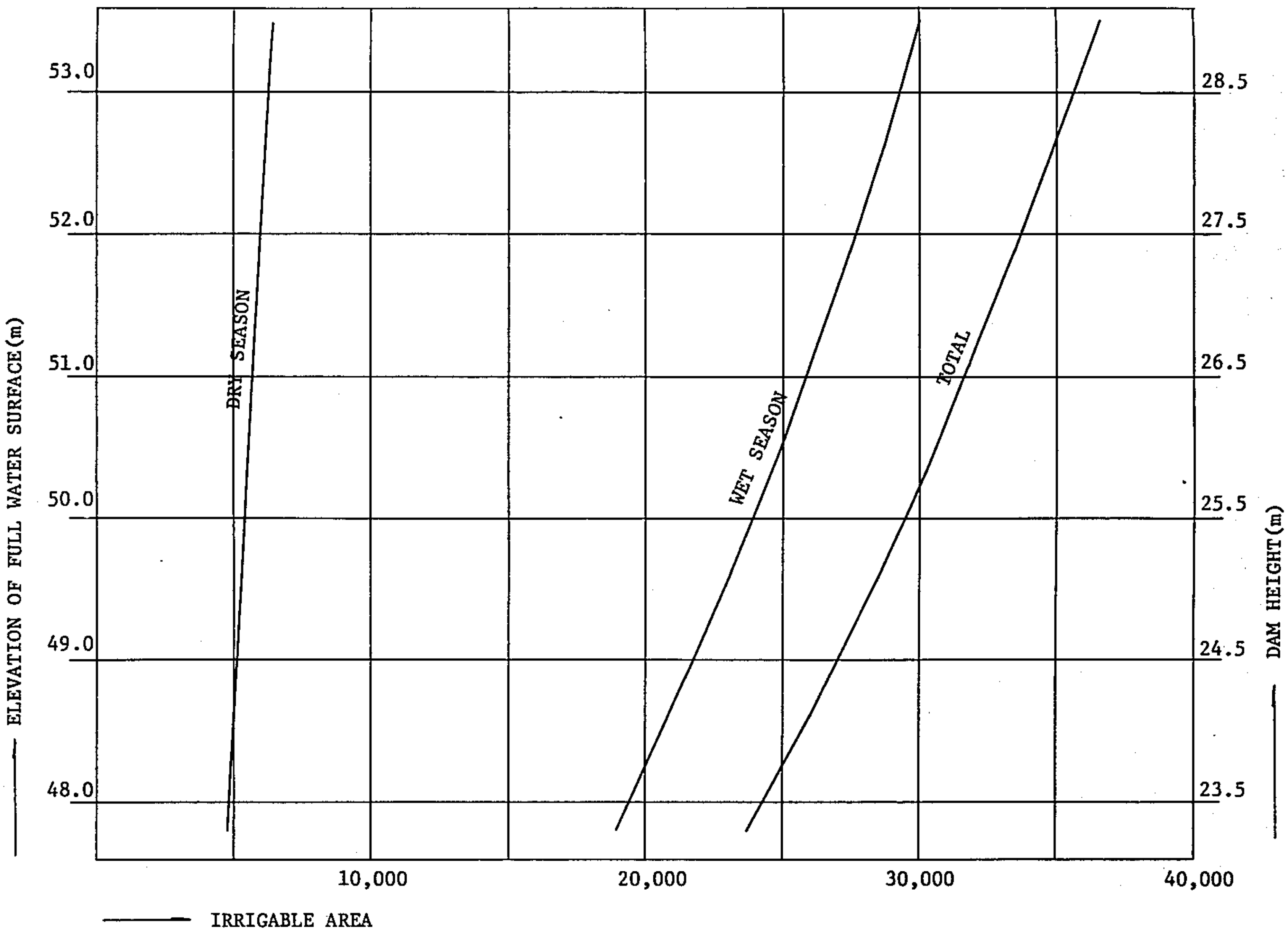


FIG. 6-8 RELATION BETWEEN ELEVATION OF FULL WATER SURFACE AND NET IRRIGABLE AREAR

Fig. 6-9 <u>Diagram of Distribution System</u>

Gross irrigation area 25,000 ha
Net irrigation area 20,000 ha

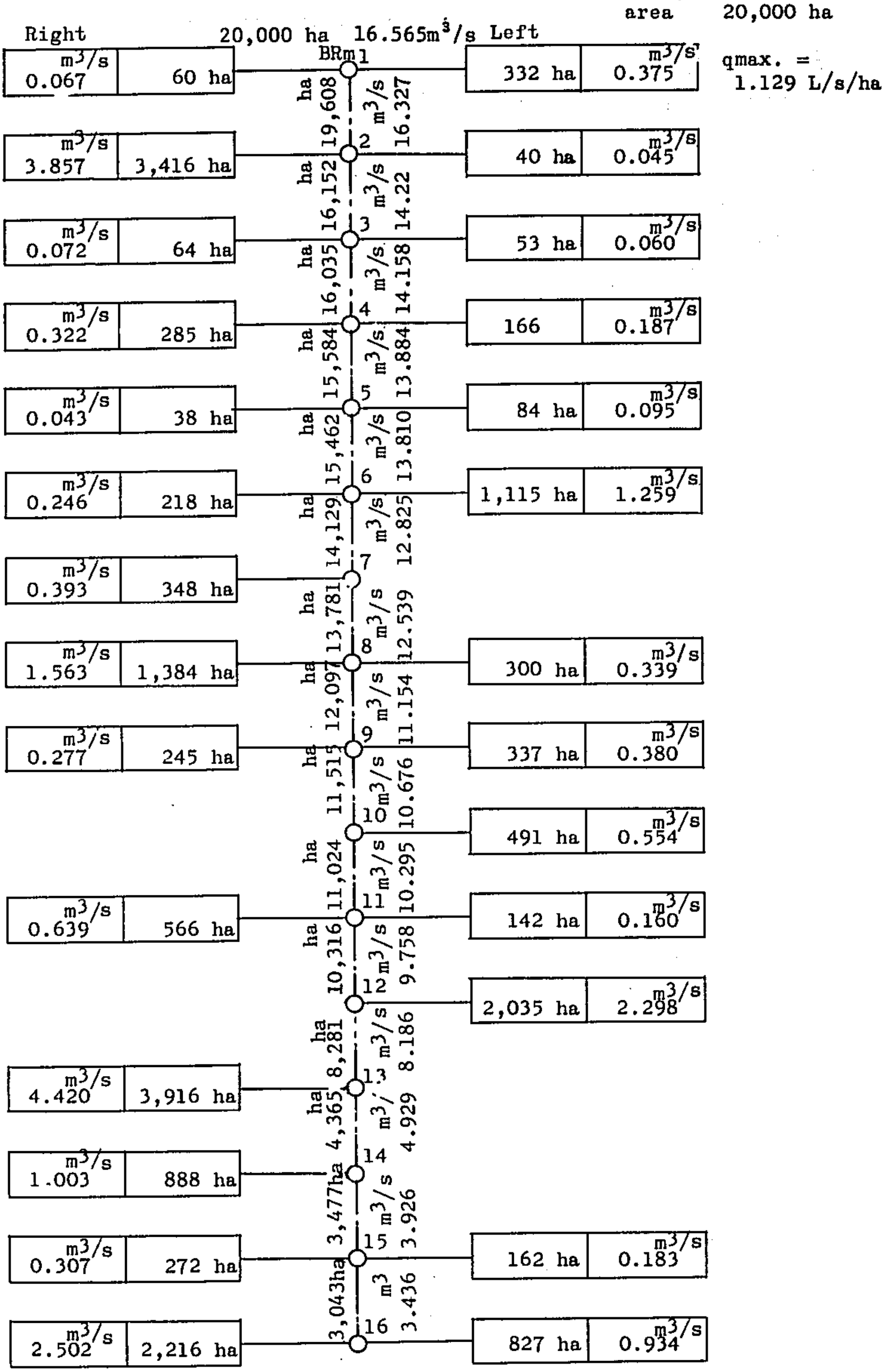


Table 6-22 Calculation of Peak Discharge

Net irrigation area 20,000 ha

No.	Irrigable Area	Require-ment	Diversion Requirement	Canal Discharge	Require-ment	Diversion Requirement	Canal Discharge	Remarks
	ha	ℓ/S/ha	m^3/S	m^3/S	ℓ/S/ha	m^3/S	m^3/S	
B.Rm.1	60	0.520			0.607	0.036	16.565'	. Peak discharge
	332	"			"	0.202		
2	3,416	"			"	2.074	16.327'	
	40	"			"	0.024		
3	64	"			"	0.039	14.229'	
	53	"			"	0.032		
4	285	"			"	0.173	14.158'	
	166	"			"	0.101		
5	38	"			"	0.023	13.884'	
	84	"			"	0.051		
6	218	"			"	0.132	13.810'	
	(288)	"			"	0.175		
	(827)	0.758			0.822	0.678		
7	348	"	0.264	12.648	"	0.286	12.825'	
8	1,384	"	1.049	12.384	"	1.138	12.539'	
	300	"	0.227		"	0.247		
9	245	"	0.186	11.108	"	0.201	11.154'	
	337	"	0.255		"	0.277		
10	491	"	0.372	10.667	"	0.404	10.676'	
11	566	"	0.429	10.295	"	0.465	10.272	
	142	"	0.108		"	0.117		
12	(320)	"	0.243	9.758	"	0.263	9.690	
	(1,715)	0.775	1.329		0.909	1.559		
13	(3,289)	"	2.549	8.186	"	2.990	7.868	
	(627)	1.129	0.708		0.977	0.613		
14	888	"	1.003	4.929	"	0.868		
15	272	"	0.307	3.926	"	0.266		
	162	"	0.183		"	0.158		
16	2,216	"	2.502	3.436	"	2.165		
	827	"	0.934		"	0.808		
Total	20,000 ha							

Table 6-23 Decision of Canal Section

Q peak m^3/s	d=0.775x $Q^{0.284}$ m	d m	V m/s	A m^2	Z	b1 m	S.L m	P m	R m	$R^{2/3}$	K	$I^{1/2}$	1/I	Freeboard
A = 20.000 ha														
16.57	1.720	1.72	0.60	27.62	2.0	12.62	3.85	20.32	1.359	1.227	45.0	0.01087	8,468	0.800
16.33	1.713	1.71	"	27.22	"	12.50	3.82	20.14	1.352	1.223	"	0.01090	8,409	"
14.23	1.647	1.65	0.59	24.12	1.5	12.14	2.97	18.08	1.334	1.212	42.5	0.01146	7,620	"
14.16	1.645	1.65	"	24.00	"	12.07	"	18.01	1.333	1.211	"	0.01146	7,612	"
13.88	1.636	1.64	"	23,53	"	11.89	2.96	17.81	1.321	1.204	"	0.01153	7,521	"
13.81	1.633	1.63	"	23,41	"	11.92	2.94	17.80	1.315	1.200	"	0.01157	7,476	"
12.83	1.600	1.60	0.58	22.12	"	11.43	2.88	17,19	1.287	1.183	"	0.01153	7,516	0.750
12.54	1.589	1.59	"	21.62	"	11.21	2.87	16.95	1.276	1.176	"	0.01160	7,431	"
11.15	1.537	1.54	0.57	19.56	"	10.39	2.78	15.95	1.226	1.145	"	0.01171	7,295	"
10.68	1.519	1.52	0.56	19.07	"	10.27	2.74	15.75	1.211	1.136	"	0.01160	7,435	"
10.30	1.503	1.50	"	18,39	"	10.01	2.70	15.41	1.193	1.125	"	0.01171	7,288	"
9.76	1.480	1.48	0.55	17.75	"	9.77	2.67	15.11	1.175	1.113	"	0.01162	7,403	"
8.19	1,408	1.41	"	14.89	"	8.45	2.54	13.53	1.101	1.066	"	0.01214	6,788	"
4.93	1.219	1.22	0.54	9.13	"	5.65	2.20	10.05	0.908	0.938	40.0	0.01440	4,825	0.600
3.93	1.143	1.14	0.53	7.42	"	4.80	2.06	8.92	0.832	0.885	"	0.01498	4,457	"
3.44	1.101	1.10	"	6.49	"	4.25	1.98	8.21	0.790	0.855	"	0.01550	4,160	"

Design standard

Q	V m³/s	Z m/s	b/d	K	Remarks
0 - 0.15	0.25	1.0	1.0	40.0	
0.15 - 0.30	0.30	"	"	"	
0.30 - 0.40	0.35	"	1.5	"	
0.40 - 0.50	0.40	"	"	"	
0.50 - 0.75	0.45	"	2.0	"	
0.75 - 1.50	0.50	"	"	"	
1.50 - 3.00	"	"	2.5	"	
3.00 - 4.50	"	1.5	3.0	"	
4.50 - 6.00	0.55	"	3.5	"	
6.00 - 7.50	"	"	4.0	"	
7.50 - 9.00	"	"	4.5	42.5	
9.00 -11.00	0.60	"	5.0	"	
11.00 -15.00	"	"	6.0	"	
15.00 -25.00	"	2.0	8.0	45.0	

Table 6-24 Calculation on Bed Elevation of Canal

Name of Canal Work	Discharge m^3/s	Station No.	Distance m	Standard Section	Gradient of Canal	Head Loss m	Water Level m	Water Depth m	Bed Elevation m	Velocity m/s	Remarks
		No. 0					47.720	1.720	46.000		
Intake	16.57		45			0.200					
		No. 0 +45.0					47.520	1.720	45.800		
Earth Canal	16.57		1,485	b=12.62m Z=20	1/8,468	0.175				0.600	
		No.3 +30.0					47.345	1.720	45.625		
1st Siphon	16.57		380	Double box = 2.35m	1/935	0.529				1.513	
		No.2 +410.					46.816	1.720	45.096		
Earth Canal	16.57		1,630	b=12.62m Z=2.0	1/8,468	0.192				0.600	
		No 7 +40					46.624	1.720	44.904		
2nd Siphon	16.57		280	Double Box a= 2.35m	1/935	0.389				1.513	
		No 7 +320					46.235	1.720	44.515		
Earth Canal	16.57		4,490	b=12.62m Z=2.0	1/8,468	0.530				0.600	

Name of Canal Work	Discharge m^3/s	Station No.	Distance	Standard Section	Gradient of Canal	Head Loss	Water Level	Water Depth	Bed Elevation	Velocity m/s	Remarks
		No 16 +310					45.705	1.720	43.985		
3rd Siphon	16.57		340	Double Box a=2.35m	1/935	0.473				1.513	
		No 17 +150					45.232	1.720	43.512		
Earth Canal	16.57		570	b=12.62m Z=2.0	1/8,468	0.067				0.600	
		No 18 +220					45.165	1.720	43.445		
4th Siphon	16.57		350	Double Box	1/935	0.487				1,513	
		No 19 +70					44.678	1.720	42.958		
Earth Canal	16.57		1,270	b=12.62m Z=2.0	1/8,468	0.150				0.600	
		No 21 +340					44.528	1.720	42.808		
5th Siphon	16.57		270	Double box	1/935	0.389				1.513	
		No 22 +100					44.139	1.720	42.419		
Earth Canal	16.57		2,360	b=12.62m Z=2.0	1/8,468	0.279				0.600	
		No 22 +470					43.860	1.720	42.140		
6th Siphon	16.57		250	Double box	1/935	0.348				1.513	
		No 27 +220					43.512	1.720	41.792		

Name of Canal Work	Discharge m^3/s	Station No.	Distance	Standard Section	Gradient of Canal	Head Loss	Water Level	Water Depth	Bed Elevation	Velocity	Remarks
Earth Canal	16.57		11,500	b=12.62m	1/8,468	1.358				0.600	
		No 50 +220					42.154	1.720	40.434		
Culvert	16.57		55	Double box		0.016					
		No 50 +275					42.138	1.720	40.418		
Earth Canal	16.57		350	b=12.62	1/8,468	0.041					
		No 51 +125					42.097	1.720	40.377		
Culvert	16.57		45	Double box		0.013					
		No 51 +170					42.084	1.720	40.364		
Earth Canal	16.57		7,800	b=12.62 Z=2.0	1/8,468	0.921				0.600	
		No 66 +470					41.163	1.720	39.443		BRm1
"	16.33		1,390	b=12.50 Z=2.0	1/8,409	0.465				0.600	
		No 69 +360					40.698	1.710	38.988		BRm2
"	14.23		1,850	b=12.14 Z=1.5	1/7,620	0.543				0.590	
		No 73 +210					40.155	1.650	38.505		BRm3

Name of Canal Work	Discharge m^3/s	Station No.	Distance	Standard Section	Gradient of Canal	Head Loss	Water Level	Water Depth	Bed Elevation	Velocity	Remarks
		No 73 +210					40.155	1.650	38.505		BRm3
Earth Canal	14.16		1,910	b=12.07m Z=1.5	1/7,612	0.251				0.59	
		No 77 +120					39.904	1.650	38.254		
7th Siphon	14.16		480	Double Box		0.832				0.59	
		No 78 +100					39.072	1.650	37.422		
Earth Canal	14.16		1,480	b=12.07mZ = 1.5	1/7,612	0.494				0.59	
		No 81 +80					38.578	1 650	36.928		BRm4
"	13.88		2,030	b=11.89mZ = 1.5	1/7,521	0.270				0.59	
		No 85 +110					38.308	1.640	36.668		BRm5
"	13.81		2,180	b=11.92 Z = 1.5	1/7,476	0.592				0.59	
		No 89 +290					37.716	1.630	36.086		BRm6
"	12.83		1,110	b=11.43 Z = 1.5	1/7,516	0,448				0.58	
		No 91 +400					37.268	1.600	35.668		BRm7

Name of Canal Work	Discharge m^3/s	Station No.	Distance	Standard Section	Gradient of Canal	Head Loss	Water Level	Water Depth	Bed Elavation	Velocity	Remarks
Earth Canal	12.54		3,600	b=11.21 Z=1.5	1/7,431	0.784				0.58	
		No 99					36.484	1.590	34.894		BRm8
"	11.15		2,210	b=10.39 Z=1.5	1/7,295	0.603				0.57	
		No 102 +210					35.881	1.540	34.341		BRm9
"	10.68		2,150	b=10.27 Z=1.5	1/7,435	0,589				0.56	
		No.107 +360					35.292	1.520	33.772		BRm10
"	10.30		1,550	b=10.01 Z=1.5	1/7,288	0.513				0.56	
		No 110 +410					34.779	1.500	33.279		BRm11
Earth Canal	9.76		2,000	b=9.77 Z=1.5	1/7,403	0.570				0.55	
		No 114 +410					34.209	1.480	32.729		BRm12
"	8.19		1,800	b=8.45 Z=1.5	1/6,788	0.565				0.55	
		No 118 +210					33.644	1.410	32.234		BRm13
"	4.93		1,050	b=5.65 Z=1.5	1/4,825	0.518				0.54	
		No 120 +260					33.126	1.220	31.906		BRm14
"	3.93		1,900	b=4.80 Z=1.5	1/4,457	0.726				0.53	
		No 124 +160					32.400	1.140	31.260		BRm15
"	3.44		2,750	b=4.25 Z=1.5	1/4,160	0.661				0.53	
		No 129 +410(EP)					31.739	1.100	30.339		BRm16

PART VII. DESIGN OF THE DAM

7.1 Storage volume

7.1.1 Catchment area

The catchment area of the Rarem dam can be measured from the topographic map in a scale of 1/100,000, and that of the main Rarem river is 195.4 Km^2 and that of the Galing river, a tributary of the Rarem river is 132.6 Km^2, therefore, the total area amounts to 328 Km^2.

7.1.2 Design flood discharge

Design flood discharge is decided from rational formula using the probable daily rainfall of 1/1,000 year frequency.

Design flood discharge: $Q = 1,300\ m^3/sec.$

Specific discharge : $g = 4.0\ m^3/sec/Km^2$

(Refer to PART II, Hydrology)

7.1.3 Water level and storage capacity curve

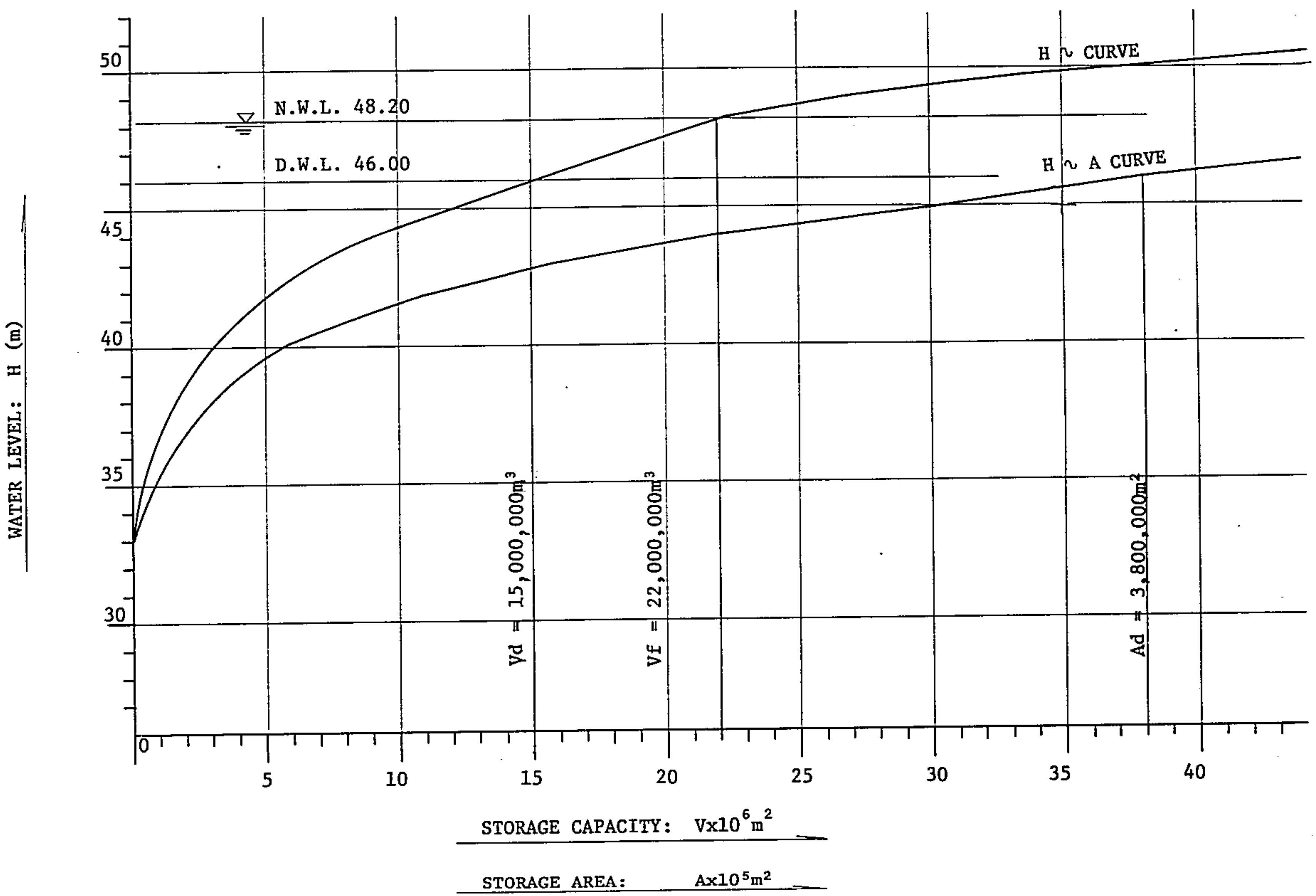
The storage capacity and the surface area are obtained, based on the 5 m interval contour lines in the topographic map of the proposed dam site in a scale of 1/10,000 and this is shown in the following table and figure.

Table 7-1 Calculation of Storage Capacity

Elevation	Difference of height	Area	Average area	Capacity between elevations	Storage capacity
EL(m)	ΔH(m)	A (m^2)	AM (m^2)	ΔV (m^3)	V (m^3)
33					
40	7	890,000	445,000	3,100,000	3,100,000
45	5	2,590,000	1,780,000	8,900,000	12,000,000
50	5	7,570,000	5,080,000	25,400,000	37,400,000
55	5	11,548,000	9,559,000	47,800,000	85,200,000

Fig. 7-1 WATER LEVEL, STORAGE CAPACITY AND SURFACE AREA CURVE

(H ∿ V.A CURVE)



7.1.4 Volume of sedimentation

The volume of sedimentation in the reservoir is affected remarkably by geology of catchment area, topography, phase of forest, condition of meteorology and others.

Accordingly, the exact assumption of the volume is difficult except being based on measurement. The volume of sedimentation is assumed from the topography, the geology and the examples of past design because there is no available data measured about the sedimentation for the project.

(1) Volume of sedimentation per unit area

i) Special feature of topography

a) Erosion of river

The erosion of river side is remarkable, therefore the river has many crooks.

b) Gradient of the river bed

Table 7-2 Gradient of the River Bed

Name of river	Way Rarem	Way Galing
Elevation of river at the most upstream	1,000 m	450 m
Elevation of dam site	33 m	33 m
Difference of height	967 m	417 m
River length	43 Km	29 Km
Mean gradient of river bed	1/45	1/70

c) Undulation of topography

Table 7-3 Undulation of Topography

Name of river	Way Rarem	Way Galing
Highest elevation	1,630 m	700 m
Lowest elevation	33 m	33 m
Difference of height	1,597 m	667 m

d) Other features

Slopes of mountains along the rivers are in about 20 to 40 degrees, and these rivers form V-shape or trapezoidal shape valleys. The river basins consist of thick forest area, sparse forest, grass land, and pepper plantations scattered here and there.

ii) Geological features

As for the geological features in the river basins, the bed rock mainly consist of andesite, tuff, tuff-breceia, clay stone and pumice-tuff. These bed rocks are covered with the wethered tuff.

iii) Determination of Sedimentation volume per unit area

The river basins are considered as volcanic area in the early or late prime geological life period from the viewpoints of item 1) and 2). Consequently, the sedimentation volume per unit area (y) was estimated as follows, by taking into consideration the examples of past design.

$y = 750\ m^3/Km^2/year$

(2) Sedimentation volume (Vd)

Catchment area of the dam: $A = 328\ Km^2$

Sedimentation volume per unit area: $y = 750\ m^3/Km^2/year$

Durable period of the dam : 60 years

Therefore, $Vd = 328 \times 750 \times 60 = 1,500,000\ m^3$

(3) Elevation of sedimentation surface

Sedimentation occured in reservoir depends on gradient of river bed, velocity of runoff inflow to the reservoir and size of sediments in general, and at a early stage, sediments pile up at inflow point then this will be shifted to downstream gradually and the surface of sedimentation form inclined plane, however, the elevation of sedimentation surface will be determined in horizontal plane in this design.

Elevation of sedimentation surface corresponds to sedimentation volume Vd = 15,000,000 m^3 will be EL. 46.00^m, obtained from the H-V curve. Then the dead water level comes to D.W.L. = 46.00^m.
And the sedimentation area corresponds to the dead water level D. D.W.L. = 46.00^m will be obtained to Ad = 3,800,000 m^2 (3.8 Km^2 = 380 ha.) from the H-A curve.

$$Ad = 3.8\ Km^2$$

7.1.5 Full water level

The effective capacity of Rarem reservoir is 7,000,000 m^3 as a result of water balance calculation. On the other hand, the intake level is at EL 46.00, then the water level which holds the effective capacity will be obtained to EL 48.20 m from the H-V curve.

Therefore the available water depth is 2.20 m, between EL 48.20 and EL 46.00. The full water surface area becomes to 5.88 Km^2 (588 ha.) from the H-A curve.

7.2 Scale of the Dam

7.2.1 Designed flood water surface

Designed flood water surface (D.F.S.) will be the water level of reservoir at non-overflow section when the designed flood discharge (Q = 1,300 m^3/sec.) flows over the spillway section, or that will be the water level added the overflow depth to normal water level (N.W.L.=48.20 m, equivalent to the crest level of the spillway).

In this design, it is proposed the shute-typed spillway, and it is considered the most rational overflow depth to H=2.50 m when overflow the designed flood discharge through this spillway. Therefore the designed flood water surface (D.F.S.) is determined as follows.

$$D.F.S. = N.W.L. + H = 48.20 + 2.50 = 50.70\ m$$

7.2.2 Free board

Free board will be determined in the following formula in case of designed flood water surface (D.F.S.) and normal water level (N.W.L.)

(1) Formulae of free board corresponding to respective water level.

Designed flood water surface (D.F.S.)

$$H_{f_1} = hw + \frac{he}{4} + h_i + ha$$

Normal water level (N W.L.)

$$H_{f_2} = hw + \frac{he}{2} + hi + ha$$

where, H_f : Free board

hw : Height of wave due to wind

he : Height of wave due to earthquake

hi : Height of safety depending on dam types

ha : Height of safety depending on spillway types

(2) Height of wave due to wind

Height of wave due to wind will be determined by factors such as distance between both shores, conditions of upstream-side slope, steepness of the slope and wind velocity.

In this design, the following factors are employed. The wind velocity is at 2.0 m m/sec., slope of upstream side of dam body is in 1:2.8 and the surface of the slope consists of rock, then a value corresponding to a rip-rapped slope.

i) Significant height (hw 1/3)

$$hw\ 1/3 = 0.00086\ V^{1.1}\ F^{0.45}$$

where; V : Wind velocity 2.0 m/sec.

F : Distance between both shores 6.0 Km = 6,000 m

$$hw\ 1/3 = 0.00086 \times 2.0^{1.1} \times 6{,}000^{0.45} = 0.092\ m$$

7.2.3 Elevation of the dam base

Elevation of the dam base is defined at the minimum cut off surface. The cut off line of this dam is determined at EL 29.50m, considering permeability and N-value at the foundation of dam.

Elevation of the dam base = EL 29.50 m

7.2.4 Dam height

(1) Determination of elevation of dam crest

Elevation of dam crest = Normal water level + Overflow depth + Freeboard

EL. of dam crest = 49.20 + 2.50 + 2.00 = 52.70m

(2) Determination of dam height (H_D)

Dam height = EL. of dam crest - EL. of dam base.

Where, EL. of dam crest: EL = 52.70m

EL. of dam base : EL = 29.50m

H_D = 52.70 - 29.50 = 23.20 m

(3) Determination of crest width

Generally, crest widths range between 5.0 m and 10.0 m, depending on wave, safety against permeability and connecting road.

Followingly, crest widths will be calculated by empirical formula that was established by relationship between dam heights and crest widths of existing dams.

(i) International commission on large dams

$$b = 3.6\ H^{\frac{1}{3}} - 3.0 = 3.6 \times 23.20^{\frac{1}{3}} - 3.0 = 7.3\ m$$

(ii) U.S.B.R.

$$b = 3.6\ H^{\frac{1}{3}} - 1.5 = 3.6 \times 23.20^{\frac{1}{3}} - 1.5 = 8.5\ m$$

(iii) Merriman

$$b = 0.2\ H + 1.5 = 0.2 \times 23.2 + 1.5 = 6.5\ m$$

ii) Wave length (L)

$$L = 0.011\ V^{0.84}\ F^{0.58}$$

where L : Wave length (m)

V : 2.0 m/sec

F : 6,000 m

$$L = 0.011 \times 2.0^{0.84} \times 6{,}000^{0.58} = 3{,}059\ m$$

iii) Height of wave due to wave (hw)

$$hw^1/_3\ /L = 0.092/3.059 = 0.03$$

$$R/hw^1/_3 = 0.8$$

$$R = 0.8\ hw^1/_3 = 0.8 \times 0.092 = 0.074$$

$$hw = R = 0.074 = 0.08\ m$$

(3) Height of wave due to earthquake (he)

$$he = \frac{Kz}{\pi}\sqrt{g.Hw}$$

Where; K : Seismic factor K = 0.15

Z : Periodic time, 1.0 sec.

g : Acceleration of gravity, 9.8 m/sec^2

Hw: Water depth from the base to designed flood water surface (D F S.)

Hw = D.F.S - G H.

= 50.70 - 29.5 = 21.2 m

$$he = \frac{0.15 \times 1}{3.14}\sqrt{9.8 \times 21.2} = 0.72\ m$$

(i) In case of designed flood water surface (D.F.S.)

he/4 = 0.72/4 = 0.18 m

(ii) In case of normal water level (N.W.L.)

he/2 = 0.72/2 = 0.36 m

(4) Height of safety depending on dam types

In this design, the dam is a fill type one

$hi = 1.0$ m

(5) Height of safety depending on spillway types

The spillway is designed in uncontrollable type here.

$ha = 0.0$ m

(6) Determination of freeboard (H_f)

As results of the above calculation, free-board corresponding to respective water level are shown in the following table.

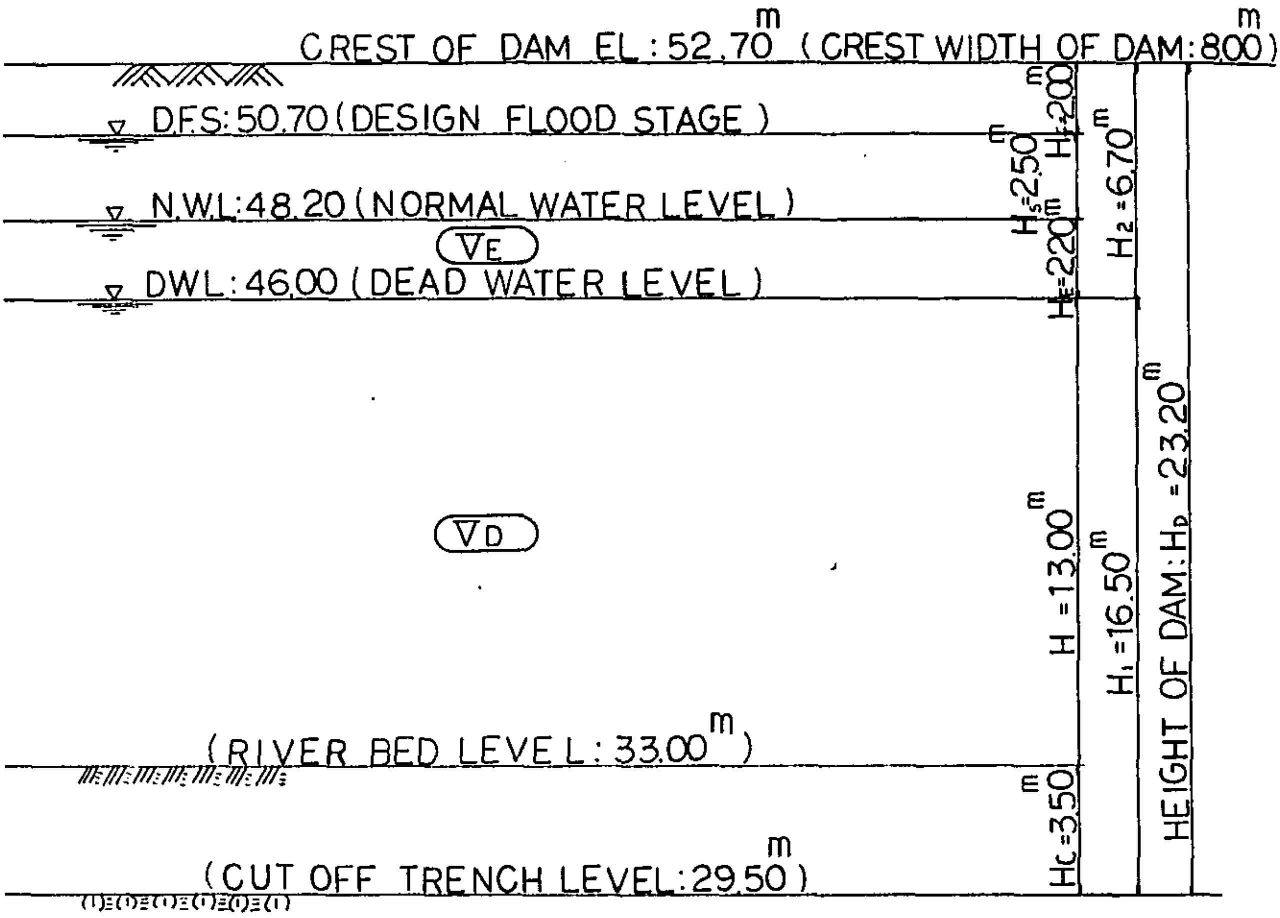
Table 7-4 Calculation of Freeboard

Water level	H. of wave due to wind (m)	H. of wave due to earthquake		H. of safety dam type	H. of safety spillway type	Calculated freeboard	Standard minimum freeboard
		$\frac{he}{4}$	$\frac{he}{2}$	hi(m)	ha(m)	H_f(m)	H_{fa}(m)
Designed flood water surface (D.F.S.)	0.08	0.18		1.00	0	1.26	2.00
Norman water level (N.W.L.)	0.08		0.36	1.00	0	1.44	2.00

Followingly, the calculated freeboard for both water levels does not exceed a standard minimum freeboard (2.0m), then the freeboard is determined to this value.

$H_f = H_{fa} = 2.00$m

DISTRIBUTION OF STORAGE CAPACITY



TOTAL STORAGE CAPACITY

$$\Sigma V = V_E + V_D$$

$$\therefore \Sigma V = 7{,}000{,}000 + 15{,}000{,}000 = 22{,}000{,}000 \ m^3$$

(iv) Traut wins

$$b = 0.6 + 1.1\sqrt{H} = 0.6 + 1.1\sqrt{23.2} = 6.0 \text{ m}$$

(v) Crest widths depend on dam type

Crest widths required for construction vary, depending on heavy machineries to be employed and structural features of dam crests. But it is roughly known as follows for respective dam type.

Homogeneous type dam	:	5 - 8 m
Zone type dam	:	7 - 10 m
Facing type dam	:	5 - 7 m

In this design, dam crest width is determined to 8.00 m, considering dam type, stability of dam, easiness of dam and economy.

$$b = 8.0 \text{ m}$$

7.3 Selection of dam type

7.3.1 Selection of dam type

Most significant factors for selection of dam type are (1) to topographic features of dam site, (2) conditions of dam foundation, (3) embankment materials, etc.

Results of investigation on these factors are shown in the following table.

Table 7-5 Selection of Basic Dam Type

Factor	Selected basic dam type	Ground of selection
Topographic features	Fill type dam	1 Topographic condition factor for proposed dam site. Dam length/dam height = L/H = 650/20 = 325 Then a fill type dam is favorable. Generally; Topographic condition factor for concrete dam LD/HD < 5.0 or so Topographic condition factor for fill type dam LD/HD > 6.0 and more.
Condition of dam foundation	Fill type dam	1 Foundation is semi-previous having a percolation coefficient of $K=10^{-4}$ (cm/sec) or so, and it is possible to cut off the water flow by curtain grouting. 2 Foundation has a unique layer of N = 10 ~ 29 at EL. 20.0 - 24.0 (about 13.0 - 17.0 m beneath the surface). 3 It is unfavorable to construct gravity type dam which has concentrated load on this unique layer from the view-point of non-uniform settlement and stability against slide. 4 In case that a gravity type dam are constructed on the refilled foundation after removal of this unique layer it will require a lot of construction cost accompanied with a increase of embankment volume and foundation strengthening work.

Factor	Selected basic dam type	Ground of selection
		5 Fill type dam has a wide foot and its load is distributed on large area. Therefore, a fill type dam is favorable from the viewpoint of depth, thickness, N-value etc. of the unique layer
Embankment material	Fill type dam (zoned type)	1 About 500,000 m^3 of embankment materials for impervious zone, semi-pervious zone and pervious zone respectively are available. 2 Mechanical character of these materials are satisfactory. 3 However, impervious material for core zone has rather high natural moisture content (about 50-70 %). Therefore, in case that homogenious type dam are constructed, it would be warried about compactibility and stability of dam body due to excess pore pressure. 4 In case the zoned type are employed, clay and rock excavated for cut off and spillway can be transfered and used as embankment material. Therefore, zoned type dam are most favorable in this dam site.

It is clear that the selected basic type is the fill type dam (zoned-type) from the above table.

7.3.2 Determination of dam type

It is clarified that fill type dam is the most suitable basic dam type on this dam site. Fill type dam are generally divided into three types, namely homogeneous type, zoned type and facing type. In this design, zoned type is employed considering character and volume of embankment materials and volume of transferable embankment materials.

There are two sub-type within zoned type dam, namely Center core type and inclined core type. Factors to be considered on selection of these sub-type of dam are (1) dam height, (2) availability of embankment material (3) topographical features of dam site (4) geological character of dam site (5) meteorology (6) construction period (7) purpose of use of reservoir.

As for these factors, investigation of dam type are carried out as shown in the following table.

Table 7-6 Selection of Sub Dam Type

Factor	Selected type	Ground of selection
Dam height	C.C or I.C	1 Zoned type dam has no limit in dam height. Then either type can be constructed.
Available volume and character of embankment material	C.C	1 About 500,000 m^3 of embankment materials for impervious zone, semi-pervious zone and pervious zone respectively are available. 2 Embankment material for impervious zone consists of weathered volcanic clay and has rather high moisture contents. 3 Mechanical characters of the other embankment material are adequately satisfactory.

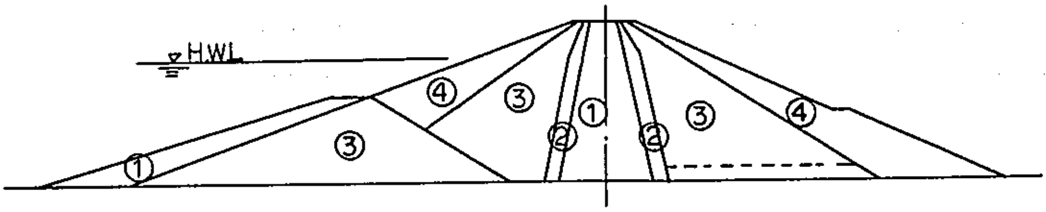
Factor	Selected type	Ground of selection
		4 C.C type is favorable because maximum load exert on the surface where foundation contact with core zone, and this type has much stability against seepage. 5 C.C type is favorable because slope of energy gradient pf seepage line of C.C. type dam is milder than that of I.C. type dam.
Topographical features	C.C.	1 Plain river bed width extend up to 300 m at dam site. 2 Abutment sections of both banks are located at tips thrusted peninsular-like topographically.
Geological character of dam site	C.C	1 Foundation is semi-pervious having a percolation coefficient of $K=10^{-4}$(cm/sec) or so, and it is possible to cut off the water flow by curtain grouting. 2 Foundation has a unique layer of N=10 - 29 at EL 20.0 - EL 24.0 (about 13.0 - 17.0m beneath the surface), then C.C. type dam is favorable because of its adaptability against non-uniform settlement.

Factor	Selected type	Ground of selection
Meteorology	I.C.	1 Precipitational season is clearly defined Rainy season : Nov. - Apr. Dry season : Mar. - Oct. 2 Mean annual precipitation is Rainy season : 2,081 mm Dry season : 781 mm 3 Mean annual number of fine day is 230 day (1951 - 1974) Rainy season : 75 days Dry season : 155 days
Construction period	C.C.	1 Volume of embankment of dam body (except coffer dam) is about 342,000 m^3 and embankment period is 2 years. 2 Impervious embankment material for core zone has rather high moisture contents, therefore a thinner core zoned type is favorable.
Purpose of use of reservoir	C.C.	1 This reservoir is planned for irrigation use, then sudden drawn down of water level is very scarce to happen, however, frequent fluctuation of water level is expected from E 48.20 to 46.00. Accordingly C.C. type dam is favorable.

Note: 1) C.C. : Center core type dam
2) I.C. : Inclined core type dam

As a result of the above investigation, the type of dam is determined to center core zoned rock fill type dam.

Fig. 7-2 Structural Cross Section of Dam



Location	Zone	Materials employed	Role of zone	Remarks
1	Core (Impervious)	Weathered volcanic clay	to cut off water flow	0.6Km upstream from dam site (left bank) 0.6Km down-stream from dam site (right bank)
2	Filter (Semi-pervious)	Sand sedimented at river bed	Not to intrude the seepage line up to downstream slope not to cause erosion of core material and piping.	place adjacent to dam site
3	Transition (Semi-pervious)	Coarse material (gravel, andesite, tuff)	to hold stability of dam body.	Spillway cut off excavation, loose rock at borrow pit.
4	Rock (Pervious)	Andesite	to hold stability (mainly against surface sliding failure). to drain out detained water within the dam body.	5.0Km upstream from dam site.

7.4 Design of Dam Body

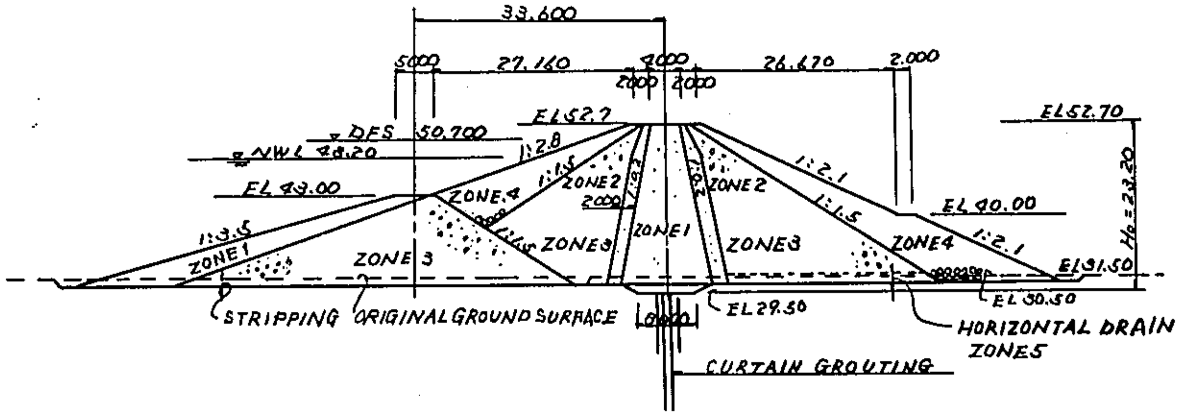
7.4.1 Typical cross section

As mentioned in the above paragraph, a center core type zoned rockfill dam is selected in this design. Zoning of this dam is shown as follows.

Table 7-7 Zoning

Place	Material	Zone	Volume of available material		Volume of dam body		Ratio V_1/V_2
			V_1, Volume (m^3)	%	V_2, Volume (m^3)	%	
Borrow pit (Right upstream, left bank)	Weathered clay	Core	500,000	45.5	108,000	25.1	4.6
(5.0Km upstream)	Andesite	Transition rock	300,000 200,000	27.3 18.2	200,000 90,000	46.6 20.9	1.5 2.2
River bed (right downstream)	Sand Gravel	Filter Drain	45,000 55,000	4.0 5.0	31,000 1,000	7.2 0.2	1.4 55.0
Total			1,100,000	100.0	430,000	100.0	2.6

Fig. 7-3 Basic Cross Section



Note: Zone 1 : Core
" 2 : Filter
" 3 : Transition
" 4 : Rock
" 5 : Drain

Note: Cross section at the lowest ground surface. (river bed).

7.4.2 Investigation on seepage

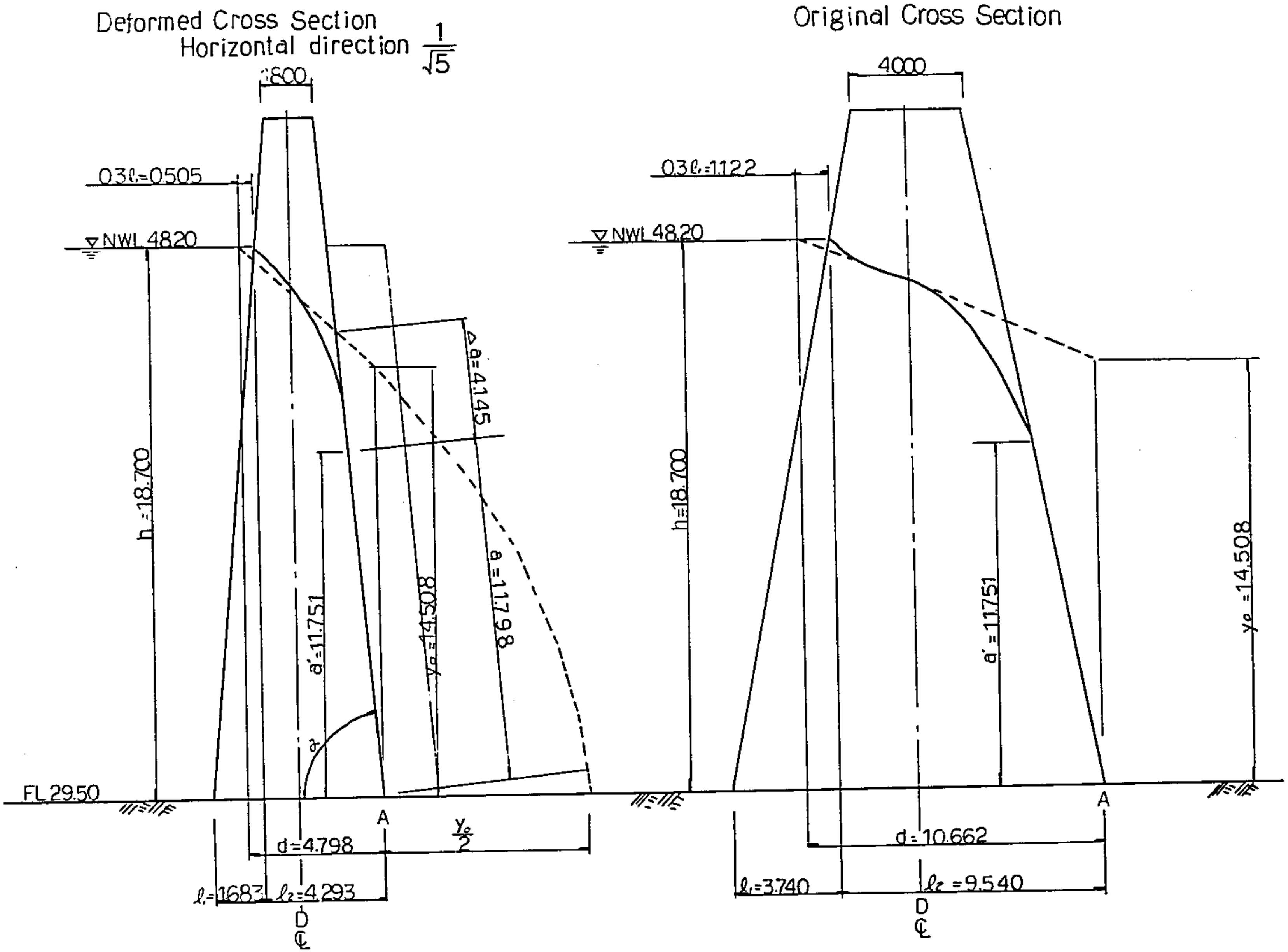
1. Seepage line in the dam body

Embankment material for core zone has different percolation coefficients for vertical (kv) and horizontal (kH) direction, depending on depth of borrow pit, means of excavation, separation caused by transportation and means of dispersion and compaction.

Material for core zone consist of MH mainly, and thickness of layer for embankment is around 20 cm, then a ratio of percolation coefficients (kH/kv = 5) is employed. Followingly, seepage line is drawn by Casagrande's method in case of normal water level N.W.L. = 48.20, then wetted length on the downstream slope of core zone is obtained to a = 11.798 m and its vertical component becomes a' = 11.751 m.

Theoretical and modified seepage lines on deformed and original cross sections are shown in the following figure.

Fig. 7-4 Seepage Line



2. Seepage from dam body

Percolation coefficient of core zone for vertical direction to compaction layer is considered to kv = 5.0×10^{-6} cm/sec., based on the soil mechanical test and designed soil density. On the other hand, the percolation coefficient for horizontal direction (kH) is estimated five times bigger than that for vertical direction, taking into consideration grain distribution and consistency of embankment material and means of compaction, then modified coefficient comes to $k = \sqrt{5}\ kv = \sqrt{5} \times 5.0 \times 10^{-6} = 1.12 \times 10^{-5}$ cm/sec..

Seepage may be obtained as follows, based on the results of seepage line computation.

Seepage per unit width $q_o \fallingdotseq 1.62 \times 10^{-6}$ m^3/sec.
Seepage from dam per second $Q = 7.70 \times 10^{-4}$ m^3/sec.
Total seepage per day $Qd = 66.53$ m^3/day

When the water level stays at normal water level N.W.L. 48.20, the seepage loss is $Qd = 66.53$ m^3/day and this is equivalent to 0.0003 % of total storage capacity.

7.4.3 Investigation on stability

1. Various values for design

Various values to be employed in the design are determined as follows, examining the results of soil mechanical test for core zone material undertaken by the government of Indonesia and mechanical test for rock material carried out by Japanese side.

Table 7-8 Various values for design

Material classification		Core	Transition	Rock
Zone No.		Zone 1	Zone 3	Zone 4
Specific gravity		2.57	2.59	2.59
Unit weight	Dried, rd t/m^3	1.50	1.70	1.80
	Wet, rt "	1.60	1.75	1.85
	Saturated, "	1.92	2.10	2.15
	Submerged, sub "	0.92	1.10	1.15
Shear strength	Cohesion C t/m^2	2.4	-	-
	Internal friction angle ø (degree)	12°-00'	38°-00'	42°-00'

2. Terms for design

Stability against slide on the upstream and downstream slope are investigated under the following terms.

1 Water level stays at N.W.L. 48.20

2 Percolation flow in dam body is under steady flow

3 Horizontal seismic factor $K_H = 0.12$

Under the above terms, stability factor against slide for dam body is obtained by the following formula.

$$S.F = \frac{(\Sigma N - \Sigma U - \Sigma N_E) \tan \phi + CL}{\Sigma T + \Sigma T_E}$$

where S.F. : Safety factor

ΣN : Sum of normal components of force by gravity of embankment materials.

ΣT : Sum of tangent components of force by gravity of embankment materials.

ϕ : Angle of internal friction of embankment materials.

C : Cohesion of embankment materials.

L : Length of slip circle

ΣU : Sum of pore pressure

ΣN_E : Sum of normal components of force by earthquake

ΣT_E : Sum of tangent components of force by earthquake

3. Safety factor

Investigation on stability of dam body is carried out followingly by slip circle method under the above terms, and safety factors are obtained.

1 Safety factor for upstream: S.F. = 1.239

2 Safety factor for downstream: S.F. = 1.250

Both values exceed satisfactory the critical safety factor, however, it is hoped that further tests and investigation will be carried out in the future, then mechanical character of respective embankment materials will be clarified and during under construction period, adequate construction supervision will be given.

Fig. 7-5

RAREM DAM
CRITCAL CIRCLE DIAGRAM

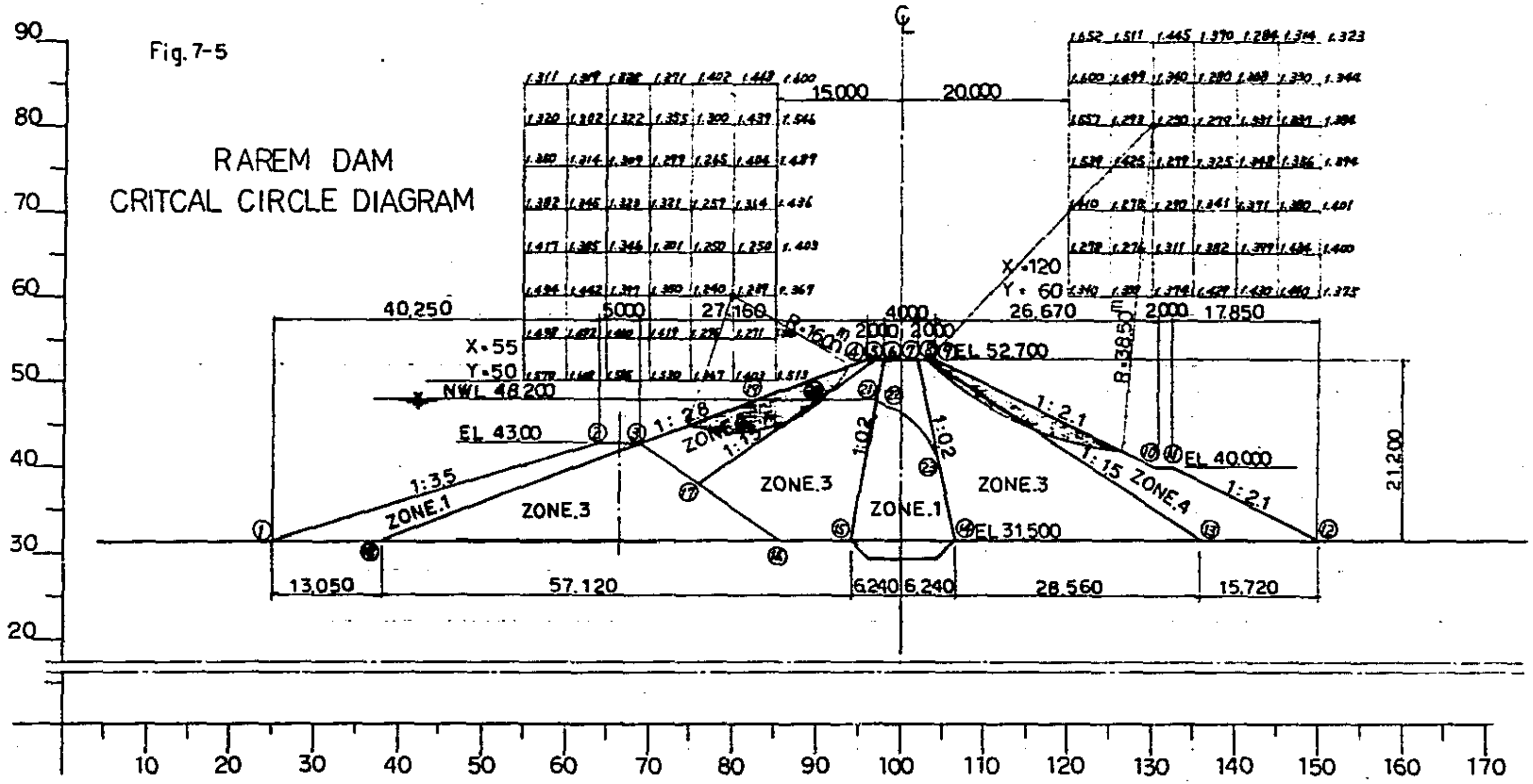


TABLE OF CO-ORDINATES

POINT	X	Y	POINOT	X	Y	POINOT	X	Y
1	23.59	31.50	11	132.67	40.00	21	97.10	48.20
2	63.84	43.00	12	150.52	31.50	22	0.00	47.00
3	68.84	43.00	13	134.80	31.50	23	104.92	41.25
4	96.00	52.70	14	106.24	31.50			
5	97.00	52.70	15	93.76	31.50			
6	98.00	52.70	16	86.09	31.50			
7	102.00	52.70	17	75.65	38.46			
8	103.00	52.70	18	36.64	31.50			
9	104.00	52.70	19	83.40	48.20			
10	130.67	40.00	20	90.25	48.20			

TABLE OF DESIGNED NUMERICAL VALUE

ZONE	UNIT WEIGHT (t/m³)				SHEARING FORCE	
	γ_d	γ_t	γ_{sub}	γ_{sat}	C (t/m²)	ϕ degree
1	1.50	1.60	1.92	0.92	2.4	12°-00
3	1.70	1.75	2.10	1.10	–	38°-00
4	1.80	1.85	2.15	1.15	–	42°-00

PROVISIONS IN THE DESIGN OF DAM

1 Construction of dam was completed.
2 Water level of reservoir is N.W.L, N.W.L =EL 48.200
3 Flow of percolation in dam is steady.
4 Horizontal seismic coefficient, k =0.15

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*   ***** RAREN - DAM (UP-STREAM) *****   *

*****

***** MINIMUM SAFETY FACTOR *****

CIRCLE NO.	CENTER - X -	- Y -	RADIUS (M)	- RM - (T-M)	- SM - (T-M)	SAFETY FACTOR
25	80.00	60.00	16.00	47.64	38.44	1.239

1. RESISTANT FORCE

NW = 92.221 NHW = 3.174 UL = 44.154
CL = 0.000 NE = 3.605

2. SLIDING FORCE

TW = 28.366 THW = 4.874 TE = 14.944

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*                                                            *
*   *****  RAREN - DAM  ( DOWN-STREAM )  *****               *
*                                                            *
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***** MINIMUM SAFETY FACTOR *****

CIRCLE NO.	CENTER - X -	- Y -	RADIUS (M)	- RM - (T-M)	- SM - (T-M)	SAFETY FACTOR
114	130.00	80.00	38.50	62.20	49.74	1.250

1. RESISTANT FORCE

NW	=	66.671	NHW	=	0.000	UL	=	0.000
CL	=	0.000	NE	=	4.473			

2. SLIDING FORCE

TW	=	37.369	THW	=	0.000	TE	=	12.372

7.5 Design of Foundation

Foundation strengthening method will be conducted as follows, taking into consideration results of geological surveys such as core boring, permeability test at field and standard penetration test.

7.5.1 Excavation of river bed

Surface soil and partially existed soft soil will be stripped and removed completely. Depth to be stripped will be 1.0 - 2.0 m.

7.5.2 Cut off excavation

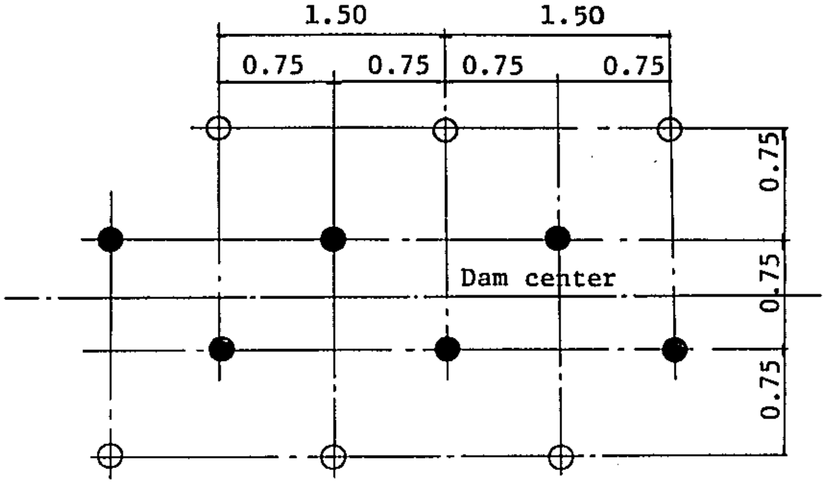
Cut off will be provided along the dam axis. Deposit which consists of clayey soil and gravel at river bed and weathered rock at slope of abutment section along the cut off line will be excavated and removed. This depth to be excavated vary from 0.5m - 6.0m. At river bed section, further depth of about 0.5 m in tuff will be excavated in order to provide cut off.

7.5.3 Waterproof work

A continuous curtain grouting with cement milk will be carried out under the cut off and overflow section of spillway at left bank in order to prevent unreasonable leaking of water through foundation and erosion and failure of foundation due to percolation flow, and decrease uplift effect which would exert toward dam body.

i) Typical disposition of grout

Fig. 7-6 Typical disposition of grout



Note: : curtain grout

: contact grout (supporting curtain)

ii) Depth of grout

Depth of grout is designed as follows in accordance with existing investigation result.

Table 7-9 Depth of grout

Point	Depth of grout (m)	
	Curtain grout	Contact grout
River bed	16.0	8.0
Mountain side	16.0 ∿ 8.0	80 ∿ 5.0
Spillway	8.0	5.0

Besides, grouting test should be carried out before implementation of work. Arrangement of grout hole, density of grout milk and intrusion pressure should be changed after recognizing that percolation coefficient of foundation is improved to be over 5.0×10^{-5} cm/s.

7.6 Related facilities

7.6.1 Temporary diversion channel

(1) Flood discharge for temporary diversion channel

The flood discharge for the temporary diversion channel is decided to depend on the basis of the 1 in 10 years probability, considering also the frequency and scale of flood, and construction period.

Flood discharge for temporary deversion channel; $Qr = 600\ m^3/s$

Specific discharge; $qr = Qr/A = 600/328 = 183\ m^3/s/km$

(See PART II HYDROLOGY)

(2) Selection of temporary diversion channel

The following methods are designed concerning temporary diversion for the flood.

1. Outlet conduit type
2. Tunnel type

However, tunnel type was adopted after due consideration of the following points.

(i) The dam is rock fill type dam such as center core type

(ii) Single layer (N = 25) exists under 14 ∿ 17 m of the dam bed.

(iii) In case the outlet conduit is built in the embankment of the dam, it causes crack of the dam body during earthquake, leakage of the dam during heavy rain, and it forms a remote, cause for the collapse of the dam.

Moreover, in case of the tunnel type, easiness and safety of the dam construction can be expected.

(3) Location

The tunnel route is selected at natural ground of right bank, taking into consideration the following items. (See general map of plane)

(1) Topographically, over covering is large and length of route is short

(2) Stable bed rock exists under the ground.

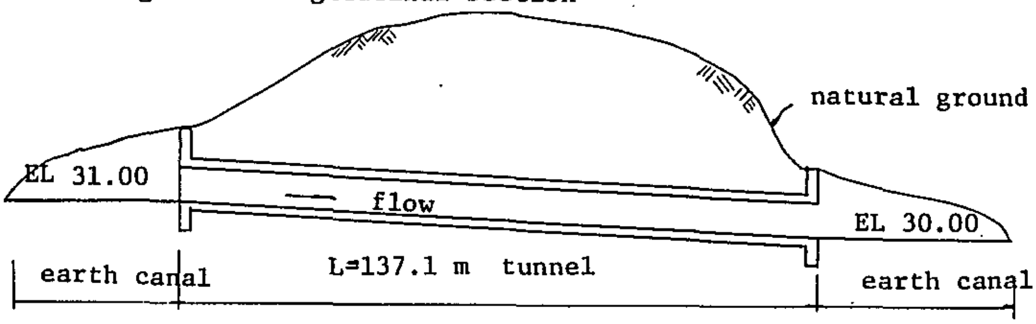
(3) Construction of attached canal between the present river and the tunnel is easy and it's length becomes short.

(4) Decision of tunnel section and height of cofferdam.

i) Design properties

Flood discharge for temporary diversion tunnel;	$Q = 600\ m^3/s$
Sill elevation of tunnel inlet;	EL = 31.00 m
Sill elevation of tunnel outlet;	EL = 30.00 m
Length of tunnel:	L = 137.1 m
Gradient of tunnel;	I = 1/137.1
Typical cross section of tunnel;	Standard horseshoe section 2r type

Fig. 7-7 Longitudinal Section



The flow of the tunnel is assumed to be free - flow hydraulically and the water depth (De) to be 0.8D ∿ 0.85D.

ii) Comparative Studies of Tunnel and Cofferdam.
Comparative studies between one temporary diversion tunnel and the two were carried out. Various hydraulic properties are as follows.

Table 7-10 Comparative hydraulic properties

Item	Mark	Unit	One tunnel	Two tunnels
Flood discharge of temporary diversion channel	Q	m^3/s	600	600/2 = 300
Gradient	I	-	1/137.1	1/137.1
Dc/D	-	-	0.83	0.83
Tunnel Diameter	D	m	9.30	7.00
Critical Depth	Dc	m	7.68	5.82
Cross section area of flow	A	m^2	64.32	36.32
Velocity	v	m/s	9.32	8.26
Velocity head	hv	m	4.43	3.48
Crest Elevation of cofferdam	EL	m	46.40	43.00
Volume of cofferdam	Vc	m^3	145,000,000	87,500,000

note: 1) Crest elevation of cofferdam
= Sill elevation of inlet + water depth + loss head + freeboard

2) Freeboard; H = 1.0 m

iii) Decision of Tunnel Diameter an Crest Elevation of cofferdam

In case of single tunnel, it's diameter is 9.3 m and in case of two tunnels, the diameter is 7.0 m

where;

(1) It is more economical for the cofferdam to be included in the dam.

(2) It structurally hinders stability of the dam to increase the volume of the cofferdam.

(3) Large scale tunnel such as D = 9.3 m becomes uneconomical from view point of over covering of natural ground and geological features.

(4) It is easy to block the tunnel of small diameter.

Considering the above mentioned items, two tunnels type was adopted.

The crest elevation of the cofferdam is EL43.00 m

7.6.2 Design of Spillway

(1) Location and canal route

The two routes are planned on the both side bank of the dam based on the design flood discharge ($Q = 1300\ m^3/s$).

As result of various comparision, the following items are derived.

(1) The straight canal route can be planned extending over the left side bank.

(2) The spillway is attached easily to the downstream of the river on the left side bank.

(3) Bed rock can be seen in a shallow layer on the right side bank.

(4) Total length of the canal of the left side bank is shorter than that of the right side bank.

(5) The approach road for maintenance of the dam is located on the right side bank.

It is necessary to construct a bridge, if the spillway is planned on the right side bank.

The spillway is designed on the left side bank, considering above mentioned matters.
(See General map of plane).

(2) Type

In case of fill type dam, uncontrolled type spillway is desired as a rule.

Side ditch type and chute type are devised as uncontrolled type.

Chute type was selected after considering the following items and characteristics of the side ditch type and the chute type.

(1) The slope of the spillway route is geologically gentle and the overflow part, outlet part, energy dissipator part and approach canal part can be settled in a straight line.

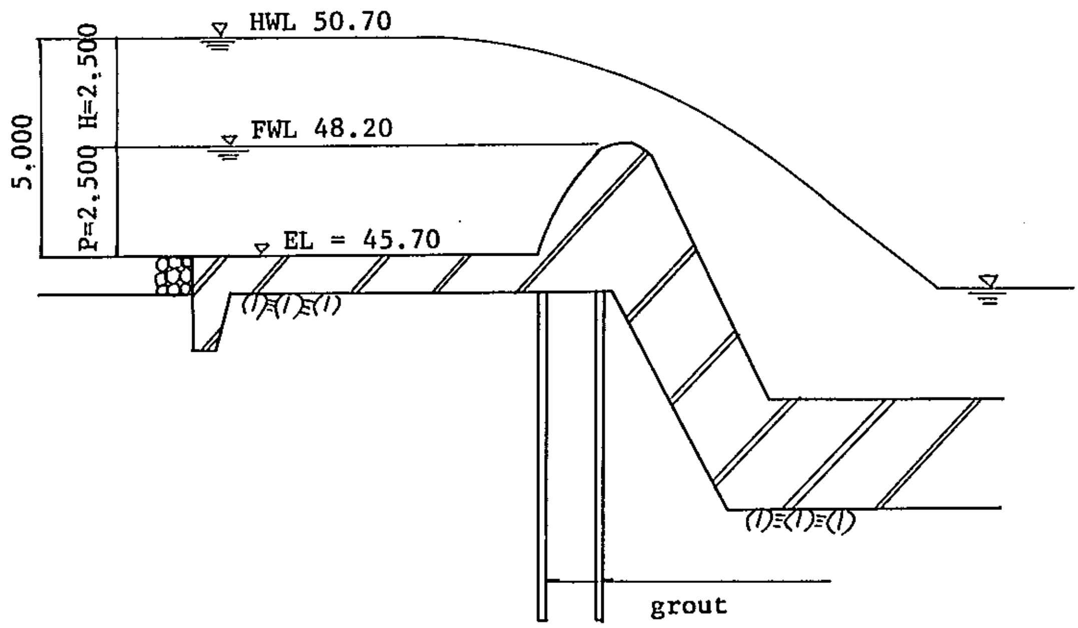
(2) Design flood discharge (Q) is 1,300 m^3/s.

(3) Excavation volume of rock and soil are used for the embankment of the dam body.

(3) Design properties

Design flood discharge:	1,300 m^3/s
Coefficient of roughness: (cast-in-place concrete)	n = 0.015
Overflow depth:	H = 2.50 m
Full water level (F.W.L.):	EL = 48.20 m
High water level (H.W.L.):	EL = 50.70 m
Sill elevation at the beginning of the inlet part:	EL = 48.20 m
Sill elevation of inlet canal:	EL = 45.70 m

Fig. 7-8 Design properties



(4) Hydraulic properties of various parts.

The spillway consists of (1) approach part (2) overflow part (3) transition (4) chute part (5) outlet part (6) energy dissipator part, and they are arranged in a straight line from the upstream side.

Principal hydraulic properties are as follows.

i) Effective length of overflow weir

$$Q = C.L.H^{3/2}$$

where,

Q; Design flood discharge = 1,300 m^3/s

C; Coefficient of overflow = 2.16

for (Upstream slope of the crest against P/H = 1.00m is 2/3.)

L: Effective length of overflow weir

H: Total head over crest = 2.50 m

$$\therefore \quad L = \frac{Q}{CH^{3/2}} = \frac{1{,}300}{2.16 \times 2.5^{3/2}} = 153.0 \text{ m}$$

ii) Hydraulic properties at the end of the transition.

The transition is changed from the width of 15.30 m at the downstream of the wier into that of 100.0 m at the downstream side of the transition, and the length is 180.0 m.

Judging from the place and longitudinal profile of the spillway, control point is appeared at the end of the transition.

Hydraulic properties at this point are as follows.

Critical depth:	dc	= 2.584 m
Cross sectional area of flow:	Ac	= 258.40 m^2
Velocity:	Vc	= 5.031 m/s
Velocity head:	hvc	= 1.291 m
Critical gradient:	Ic	= 1/582

iii) Chute part

Canal width of this part is entirely 100 m because of gentle slope at natural ground.

Hydraulic properties at the end of this part are as follows.

Water depth:	d = 0.817 m
Cross sectional area of flow:	A = 81.70 m^2
Velocity:	V = 15.912 m/s
Velocity head:	hv = 12.918 m
Gradient:	I = 1/7.143

iv) Energy dissipator part

As for energy dissipator part, stilling pool type is adapted because of natural ground, geology and Froude number.

Width of stilling basin pool:	b = 100 m
Unit discharge:	q = 13.0 $m^3/s/m$
Froude number:	F = 5.62
Conjugate depth:	dz = 6.10 m
Length of stilling basin pool:	L = 16.0 m

7.7 Intake facilities

7.7.1 Location and type

The dam is constructed as water source facility for irrigation. Full water surface elevation (N.W.L.) is 48.20 m and sill elevation of intake is 46.00 m.

(1) Location

The elevation of the irrigated area is ranged from EL20.00 m to EL40.00 m, and the distance between the dam and the project area is about 40 km. Therefore, the elevation of the intake is EL46.00 m in order to ensure water head.

Intake point was decided in KP. Pekurun which located in just upstream of the dam site (about 300 m), considering the location of the project area, the route of the main canal, geology and natural feature nearby the dam.

(2) Type

Generally speaking, it is advisable to convert a temporary diversion channel into an intake structure of a dam, but, in this project, it is impossible to convert because it is necessary to ensure water head for the project area.

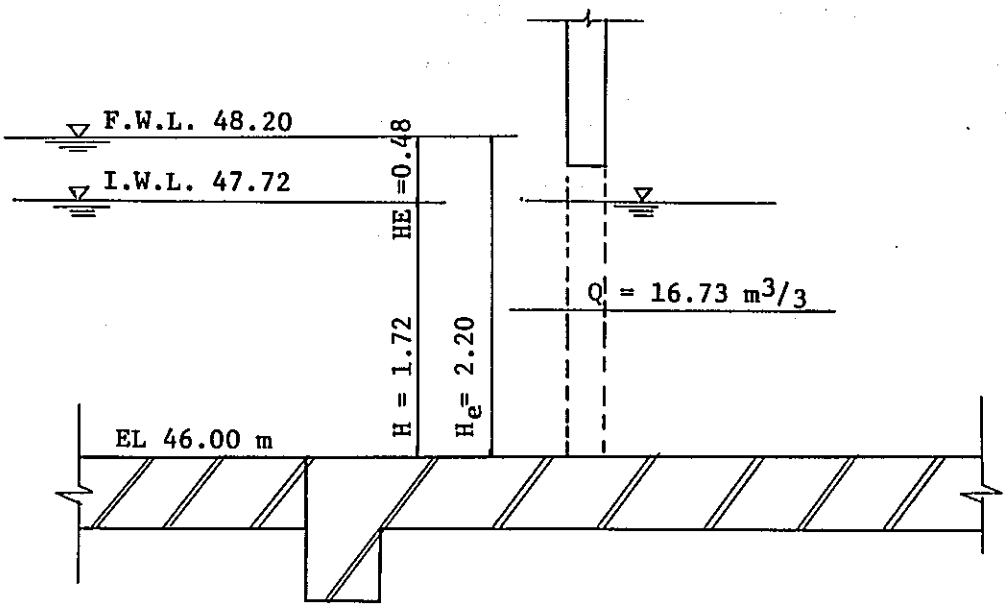
Accordingly, the water gate type was adopted in standpoint of natural feature, geology, economy, operation and maintenance.

7.7.2 Design properties

As a result of the calculation on water balance in the project area, design properties at the intake point are as follows.

Intake discharge:	Q =	16.57 m^3/s
Sill elevation of the intake:	EL =	46.00 m
Water level of the intake:	EL =	47.72 m
Elevation of full water surface:	NWL =	48.20 m
Available water depth:	HE =	2.20 m
Effective water depth:	HE =	0.48 m
Intake water depth:	H =	1.72 m

Fig. 7-9 Design properties at intake point



7.7.3 Design of intake part

The intake structures consist of (1) approach part (2) gate part (3) apron part (4) culvert part (5) approach channel, and they are arranged in a straight line from upstream.

The structure of the intake part were decided in accordance with hydraulic calculation.

Design properties of the intake are as follows.

(1) Gate part

Intake velocity:	V = 1.00 m/s
Effective width of just upstream of pier:	B_1 = 11.20 m
Effective width of pier:	B_2 = 9.20 m
Gate number:	n = 3.20 m /1 span x 3 spans
Screen:	b = 8.8 mm t = 12 mm
Longitudinal length:	L_1 = 5.0 m
Invert elevation:	EL = 46.00 m

(2) Apron part

Effective width: B_3 = 11.20 m

Longitudinal length: L_2 = 9.00 m

Invert elevation: EL 46.00 m

(3) Culvert part (bridge for maintenance)

Effective width: B_4 = 3.20 m/1 span x 3 spans = 9.20 m

Longitudinal length: L_3 = 6.00 m

Invert elevation: EL 46.00 m

(4) Approach channel

The approach channel is gradually widen from the upstream to the downstream at the part which the main canal is connected to.

Effective width at the end of the upstream:

B_5 = 11.20m (oblong section)

Effective width at the end of the downstream:

bed width b = 12.62 m

Invert elevation at the end of the downtream:

EL 45.80 m

Water level at the end of the downstream:

WL 47.52 m

PART VIII. COST ESTIMATES

8.1 Construction Cost and Annual Disbursement

8.1.1 Breakdown of the Cost of Main Civil Work

(Unit: US$)

Item	Unit	Quantity	Domestic		Foreign	
			Unit Cost	Amount	Unit Cost	Amount
1. Preparatory work						
(1) Temporary work						
1) Dam construction						
Improvement of road	Km	2.5	9,000	22,500	-	-
Access road	Km	6.2	20,000	124,000	-	-
Temporary bridge	place	1	8,000	8,000	-	-
Other works	L.S.			7,500		-
(Sub-total)				162,000		-
2) Canal construction						
Improvement of road	Km	30.0	9,000	270,000	-	-
Access road	Km	26.5	20,000	530,000	-	-
Temporary bridge	place	5	8,000	40,000	-	-
Removal of water	day	350	3	1,050	-	-
Coffering	m	350	335	117,250	-	-
Crossed railway work	place	1		5,000	-	-
Other works	L.S.			25,700		-
(Sub-total)				989,000		-
Sub-total				1,151,000		-
(2) Survey cost						
Geological survey	L.S.			100,000		-
Canal survey	L.S.			100,000		-
Other works	L.S.			10,000		-
Sub-total				210,000		-
(3) Overhead and taxes				340,000		-
Total				1,701,000		-

(Unit: US$)

Item	Unit	Quantity	Domestic		Foreign	
			Unit Cost	Amount	Unit Cost	Amount
2. Dam						
(1) Works at borrow pit						
Surface soil removal	m^3	27,000	0.17	4,590	-	-
Excavation (common)	m^3	108,000	0.18	19,440	-	-
Excavation (sand & gravel)	m^3	31,000	0.33	10,230	-	-
Other works	L.S.			740		-
Sub-total				35,000		-
(2) Coffer dam						
Surface soil removal	m^3	19,000	0.17	3,230	-	-
Embankment for core zone	m^3	28,000	0.38	10,640	-	-
Embankment for random zone	m3	60,000	1.59	95,400	0.60	36,000
Other works	L.S.			3,730		1,000
Sub-total				113,000		37,000
(3) Dam body						
Removal of water	day	200	0.68	136	-	-
Surface soil removal	m^3	30,000	0.17	5,100	-	-
Excavation (sand & gravel)						
by manpower	m^3	2,000	1.22	2,440	-	-
by equipment	m^3	21,000	0.33	6,930	-	-
Excavation (rock)	m^3	10,000	0.89	8,900	0.27	2,700
Grout	m	16,600	2.25	37,350	9.65	160,190
Water pressure test	m	180	3.59	646	24.54	4,417
Stripping at quarry site	m^3	3,000	0.21	630	-	-
Embankment for						
core zone	m^3	80,000	0.38	30,400	-	-
filter zone	m^3	31,000	0.13	4,030	-	-
random zone	m^3	140,000	1.59	222,600	0.60	84,000
rock zone	m^3	90,000	1.50	135,000	0.17	15,300

(Unit: US$)

Item	Unit	Quantity	Domestic		Foreign	
			Unit Cost	Amount	Unit Cost	Amount
Crest road	m^3	2,100	1.80	3,780	0.12	252
Horizontal drain	m^3	1,400	0.33	462	1.50	2,100
Disposal of surplus soil	m^3	7,000	0.29	2,030	-	-
Other works	L.S.			15,566		13,041
Sub-total				476,000		282,000
(4) Spillway						
Surface soil removal	m^3	40,000	0.17	6,800	-	-
Excavation (common)						
by manpower	m^3	66,000	0.92	60,720	-	-
by equipment	m^3	265,000	0.18	47,700	-	-
Excavation (rock)	m^3	83,000	0.89	73,870	0.27	22,410
Under drain	m	1,800	2.64	4,752	0.02	36
Invert concrete	m^3	3,750	3.68	13,800	10.23	38,363
Grout	m	2,240	2.25	5,040	9.65	21,615
Metal form	m^2	10,400	0.72	7,488	2.10	21,840
Scaffolding	m^3	4,700	0.24	1,128	0.92	4,324
Round bar	ton	450	17.14	7,713	493.50	222,075
Deformed bar	ton	1,350	18.58	25,083	534.70	721,845
Reinforced concrete	m^3	25,800	3.65	94,170	14.92	384,936
Backfill						
by manpower	m^3	1,000	0.71	710	-	-
by equipment	m^3	66,000	0.13	8,580	-	-
Embankment (common)	m^3	3,000	0.11	330	-	-
Masonry work	m^3	700	30.97	21,679	-	-
Sodding	m^2	4,600	1.08	4,968	-	-
Disposal of surplus soil	m^3	83,000	0.29	24,070	-	-
Other works	L.S.			14,399		71,556
Sub-total				423,000		1,509,000

(Unit: US$)

Item	Unit	Quantity	Domestic		Foreign	
			Unit Cost	Amount	Unit Cost	Amount
(5) Intake						
Surface soil removal	m^3	1,000	0.17	170	-	-
Excavation (common)						
by manpower	m^3	1,000	0.92	920	-	-
by equipment	m^3	4,000	0.18	720	-	-
Excavation (rock)	m^3	1,000	0.89	890	0.27	270
Invert concrete	m^3	50	3.68	184	10.23	512
Grout	m	340	2.25	765	9.65	3,281
Metal form	m^2	800	0.72	576	2.10	1,680
Wooden form	m^2	500	4.37	2,185	-	-
Scaffolding	m^3	1,400	0.24	336	0.92	1,288
Round bar	ton	10	17.14	171	493.50	4,935
Deformed bar	ton	30	18.58	557	534.70	16,041
Reinforced concrete	m^3	450	3.65	1,643	14.92	6,714
Backfill by equipment	m^3	400	0.13	52	-	-
Embankment (common)	m^3	400	0.11	44	-	-
Sodding	m^2	900	1.08	972	-	-
Disposal of surplus soil	m^3	1,000	0.29	290	-	-
Installation of intake gate	set	1		17,000		-
Intake gate	set	1		-		150,000
Steel materials	kg	5,900	1.70	10,030	-	-
Water-level-gauge	place	1		400		200
Rainfall-gauge	place	1		400		200
Discharge gauge	place	1		500		300
Electrical work	L.S.			1,000		-
Other works	L.S.			1,195		8,579
Sub-total				41,000		194,000

(Unit: US$)

	Item	Unit	Quantity	Domestic		Foreign	
				Unit Cost	Amount	Unite Cost	Amount
6)	Diversion channel						
	Surface soil removal	m^3	12,000	0.17	2,040	-	-
	Excavation (common)						
	by manpower	m^3	23,000	0.92	21,160	-	-
	by equipment	m^3	161,000	0.18	28,980	-	-
	Excavation (rock)	m^3	49,000	0.89	43,610	0.27	13,230
	Metal form	m^2	1,800	0.72	1,296	2.10	3,780
	Wooden form	m^2	100	4.37	437	-	-
	Scaffolding	m^3	5,700	0.24	1,368	0.92	5,244
	Round bar	ton	30	17.14	514	493.50	14,805
	Deformed bar	ton	110	18.58	2,043	534.70	58,817
	Reinforced concrete	m^3	1,350	3.65	4,927	14.92	20,142
	Backfill						
	by manpower	m^3	5,000	0.71	3,550	-	-
	by equipment	m^3	45,000	0.13	5,850	-	-
	Disposal of surplus soil	m^3	35,000	0.29	35,000	-	-
	Excavation for tunnel	m^3	22,500	2.12	47,700	0.79	17,775
	Form work for tunnel	m^2	7,300	0.65	4,745	2.10	15,330
	Concrete for tunnel	m^3	7,950	3.70	29,415	13.54	107,643
	Deformed bar for tunnel	ton	400	18.58	7,432	534.70	213,880
	Grout	m^3	1,980	2.33	4,613	15.66	31,006
	Curtain grout	m	110	2.76	303	10.04	1,104
	Shut-off work	place	1		5,000		25,000
	Gate	set	1		25,000		230,000
	Other works	L.S.			8,017		22,244
	Sub-total				283,000		780,000
7)	Overhead and takes				343,000		-
	Total				1,714,000		2,802,000

(Unit: US$)

Item	Unit	Quantity	Domestic		Foreign	
			Unit Cost	Amount	Unit Cost	Amount
3. Main canal						
(1) Main structure						
Surface soil removal	m^3	619,000	0.17	105,230	-	-
Excavation (common)						
by manpower	m^3	321,000	0.92	295,320	-	-
by equipment	m^3	4,546,000	0.18	818,280	-	-
Backfill						
by manpower	m^3	6,000	0.71	4,260	-	-
by equipmnt	m^3	111,000	0.13	14,430	-	-
Embankment						
by manpower	m^3	342,000	0.55	188,100	-	-
common	m^3	2,170,000	0.11	238,700	-	-
from borrow pit	m^3	1,195,000	0.27	322,650	-	-
Disposal of surplus soil	m^3	275,000	0.29	79,750	-	-
Sodding	m^2	850,100	1.08	918,108	-	-
Inspection road	m	62,400	1.80	112,320	0.12	7,488
Metal form	m^2	44,800	0.72	32,256	2.10	94,080
Wooden form	m^2	300	4.37	1,311	-	-
Invert concrete	m^3	1,350	3.68	4,968	10.23	13,811
Reinforced concrete	m^3	15,200	3.65	55,480	14.92	226,784
Round bar	ton	440	17.14	7,542	493.50	217,140
Deformed bar	ton	1,030	18.58	19,137	534.70	550,741
Steel material	kg	6,500	1.70	11,050	-	-
Other works				64,108		21,956
Sub-total				3,293,000		1,132,000
(2) Appurtenant structure						
Cross bridge	place	29		203,000	-	-
Diversion work	place	14		140,000		145,000
Turn out	place	4		20,000		-

(Unit: US$)

Item	Unit	Quantity	Domestic		Foreign	
			Unit Cost	Amount	Unit Cost	Amount
Cross drain	place	40		120,000		-
Spillway & waste way	place	10		50,000		--
Other works				80,000		-
Sub-total				613,000		
(3) Overhead & taxes				977,000		145,000
Total				4,883,000		1,277,000
4. Secondary canal						
(1) Main structure						
Surface soil removal	m^3	946,000	0.17	160,820	-	-
Excavation						
by manpower	m^3	318,000	0.92	292,560	-	-
by equipment	m^3	317,000	0.18	57,060	-	-
Backfill						
by manpower	m^3	57,000	0.71	40,470	-	-
by equipment	m^3	57,000	0.13	7,410	-	-
Embankment						
by manpower	m^3	914,000	0.55	502,700	-	-
common	m^3	914,000	0.11	100,540	-	-
Disposal of surplus soil	m^3	1,000	0.29	290	-	-
Sodding	m^2	623,800	1.08	673,704	-	-
Inspection road	m	152,500	1.80	274,500	0.12	18,300
Wooden form	m^2	68,000	4.37	297,160	-	-
Reinforced concrete	m^3	12,000	32.06	384,720	1.69	20,280
Invert concrete	m^3	2,200	21.95	48,290	1.73	3,806
Round bar	ton	1,080	729.70	788,076	-	-
Steel materials	kg	2,700	1.70	4,590	-	-
Joint filler	m^3	370	219.42	81,185	666.67	246,668
Mortar facing	m^3	80	74.80	5,984	-	-

(Unit: US$)

Item	Unit	Quantity	Domestic		Foreign	
			Unit Cost	Amount	Unit Cost	Amount
Masonry work	m^3	7,400	30.97	229,178	-	-
Other works				78,763		4,946
Sub-total				4,028,000		294,000
(2) Appurtenant structure						
Turn out	place	152		438,000		-
Gate	L.S.			105,000		67,000
Sub-total				543,000		67,000
(3) Overhead and taxes				1,143,000		-
Total				5,714,000		361,000
5. Road rehabilitation						
Surface course	L.S.			200,000	-	-
Overhead and taxes				50,000		-
Total				250,000		-
6. Office and quarters						
(1) Facilities						
Office	m^2	500	26.00	13,000	-	-
Guest house	m^2	120	108.00	12,960	-	-
Staff housing	m^2	350	26.00	9,100	-	-
Dormitory	m^2	1,150	22.00	25,300	-	-
Warehouse & repair shop	m^2	600	16.00	9,600	-	-
Motor-pool	m^2	1,500	12.00	18,000	-	-
Well	place	11	100.00	1,100	-	-
Other works	L.S.			940		-
Sub-total				90,000		-
(2) Overhead and taxes				23,000		-
Total				113,000		-

(Unit: US$)

Item	Unit	Quantity	Domestic		Foreign	
			Unit Cost	Amount	Unit Cost	Amount
7. Land reclamation						
(1) Civil work						
Excavation & embankment						
by Bulldozer	m^3	10,000,000	0.03	300,000	-	-
by Scraper	m^3	30,000,000	0.02	600,000	-	-
Branch road incl. canal	m	1,380,000	0.29	400,200	-	-
Farm road incl. canal	m	700,000	0.20	140,000	-	-
Border	ha	20,000	5.43	108,600	-	-
Other works	L.S.			25,200		-
Sub-total				1,574,000		-
(2) Overhead and taxes				393,000		-
Total				1,967,000		-
8. Pilot form						
Construction cost	ha	80		110,000		-
Overhead and taxes				28,000		-
Total				138,000		-
Grand-total				16,480,000		4,440,000

8.1.2 Units of equipment required

Unit: number

Name of Equipment	Standard	Construction				Total
		Dam	Main Canal	Secondary Canal	Reclamation	
Bulldozer	11 ton	-	4	10	8	22
- ditto -	14 ton	6	23	11	18	58
- ditto -	21 ton	-	-	-	15	15
Tractor shovel	1.4 m^3	-	18	23	-	41
Power shovel	1.2 m^3	5	12	-	-	17
Scraper	9.3 m^3	-	-	-	29	29
Tractor	21 ton	-	-	-	29	29
Dump truck	15 ton	12	56	28	-	96
Tamping roller	6 ton	-	6	4	-	10
- ditto -	10 ton	1	-	-	-	1
Vibrating roller	8 ton	1	-	-	-	1
Sheep's foot roller	10 ton	1	-	-	-	1
Tire roller	10 ton	1	-	-	-	1
Crushing plant	600 x 900	1	-	-	-	1
Batcher plant	0.75m^3 x 2	1	1	-	-	2
Agitator truck	0.8 m^3	2	1	1	-	4
Crawler drill	10 m^3	1	-	-	-	1
Air compressor	4.6 m^3/min	1	-	-	-	1
- ditto -	9.0 m^3/min	2	1	1	-	4
Rammer	80-100 kg	3	3	10	-	16
Sinker	24 kg	15	-	-	-	15
Rake	2.4 ton	1	7	2	-	10
Tamper	120 kg	6	114	31	-	151
Water Tanker	1,750 ℓ	1	-	-	-	1
Conveyor	38 t/h	2	5	2	-	9
Vibrator	ϕ32	3	2	2	-	7
Water pump	ϕ40	1	2	2	-	5
- ditto -	ϕ130	2	2	1	-	5
Concrete pump	ϕ130	1	-	-	-	1

8.1.3 Breakdown of Annual Disbursement

Item	1977		1978		1979		1980		1981		1982		Total		Grand total
	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	
1) Main Civil Work															
a) Preparatory work	588	-	375	-	246	-	246	-	246	-	-	-	1,701	-	1,701
b) Dam	-	-	248	407	410	672	816	1,331	240	392	-	-	1,714	2,802	4,516
c) Main canal	-	-			1,054	276	1,188	311	1,123	294	927	241	4,883	1,277	6,160
d) Secondary canal	-	-	-	-	1,250	79	1,876	118	1,718	108	870	56	5,714	361	6,075
e) Road rehabilitation	-	-	-	-	54	-	98	-	98	-	-	-	250	-	250
f) Office and quarters	57	-	56	-	-	-	-	-	-	-	-	-	113	-	113
g) Land reclamation	-	-	-	-	492	-	492	-	492	-	491	-	1,967	-	1,967
h) Pilot farm	-	-	-	-	-	-	115	-	23	-	-	-	138	-	138
(Sub-total)	(645)	-	(1,270)	562	(3,506)	1,027)	(4,831)	(1,760)	(3,940)	(794)	(2,288)	(297)	(16,480)	(4,440)	(20,920)
2) Land Compensation	60	-	60	-	-	-	-	-	-	-	-	-	120	-	120
3) Construction Equipment and Spare Parts	-	859	-	3,160	-	9,625	-	-	-	-	-	-	-	13,644	13,644
(Depreciation)	-	(859)	-	(3,160)	-	(3,685)	-	(3,251)	-	(2,689)	-	-	-	(13,644)	(13,644)
4) Engineering and Administrative Cost	225	900	75	300	75	300	75	300	75	300	75	300	600	2,400	3,000
Total-1	930	1,759	1,405	4,022	3,581	10,952	4,906	2,060	4,015	1,094	2,363	597	17,200	20,484	37,684
(Total-1)	(930)	(1,759)	(1,405)	(4,022)	(3,581)	(5,012)	(4,906)	(5,311)	(4,015)	(3,783)	(2,363)	(597)	(17,200)	(20,484)	(37,684)
5) Physical Contingency	93	88	140	202	358	548	491	103	402	55	236	30	1,720	1,026	2,746
Total-2	1,023	1,847	1,545	4,224	3,939	11,500	5,397	2,163	4,417	1,149	2,599	627	18,920	21,510	40,430
(Total-2)	1,023	(1,847)	(1,545)	(4,224)	(3,939)	(5,560)	(5,397)	(5,414)	(4,417)	(3,838)	(2,599)	(627)	(18,920)	(21,510)	(40,430)
	(2,870)		(5,769)		(9,499)		(10,811)		(8,255)		(3,226)		(40,430)		
6) Interest during Construction Period	-	558	-	1,039	-	2,219	-	305	-	106	-	28	-	4,255	4,255
7) Price Contingency	119	101	379	477	1,533	2,001	2,967	517	3,219	352	2,413	237	10,630	3,685	14,315
Grand total	1,142	2,506	1,924	5,740	5,472	9,780	8,364	6,236	7,636	4,296	5,012	892	29,550	29,450	59,000
(Grand total)	3,648		7,664		15,252		14,600		11,932		5,904		59,000		

8.2 Construction Cost of Pumping-up Irrigation Plan

(Unit: US$)

Item	Unit	Quantity	Unit cost	Amount
1. Preparatory work				
(1) Temporary work				
1) Pumping station construction				
access road	Km	0.5	20,000	10,000
other works	L.S.			500
2) Pipe line construction				
access road	Km	0.5	20,000	100,000
temporary bridge	place	4	8,000	32,000
other works	L.S.			6,600
3) Farm pond construction				
Improvement road	Km	3.0	9,000	27,000
other works	L.S.			1,300
4) Canal construction				
Improvement road	Km	10.0	9,000	90,000
access road	Km	10.0	20,000	200,000
Temporary bridge	place	2	8,000	16,000
other works	L.S.			15,300
Sub-total:				498,700
(2) Survey cost				
geological survey	L.S.			30,000
canal survey	L.S.			30,000
other works	L.S.			3,000
Sub-total:				63,000
(3) Overhead and taxes				112,300
Total:				674,000

(Unit: US$)

Item	Unit	Quantity	Unit cost	Amount
2. Pumping Station				
(1) Protection of river bed	m^2	1,500		12,000
(2) Intake canal, sand basin and absorption tank	L.S.			234,000
(3) Pump chamber	L.S.			70,000
(4) Houses of pump and generator	m^2	600		60,000
(5) Equipments	L.S.			5,033,000
(6) Installation	L.S.			167,000
(7) Other works	L.S.			279,000
Total:				5,855,000
3. Pipe lines				
(1) Pipe lines	Km	5.0		24,067,000
(2) Outlet tank	m^3	1,200		40,000
(3) Farm pond	$1000m^3$	750		607,000
(4) Other works	L.S.			1,236,000
Total:				25,950,000
4. Main canal	Km	36.5		5,574,000
5. Secondary canal	Km	152.5		6,173,000
6. Road rehabilitation	L.S.			250,000
7. Office and quarters	L.S.			113,000
8. Land reclamation	ha	20,000	323	6,460,000
9. Pilot farm	ha	80		294,000
Grand total:				51,343,000

8.3 Construction Cost Estimate by Contract System

8.3.1 General

The total bidding price is divided into four parts, that is (1) direct construction cost, (2) construction facilities cost, (3) construction machinery cost and (4) general expenses.

8.3.2 Direct construction cost

The direct construction cost consists of such items as:

(1) cost of foreign and domestic technician directly related to construction works, such as foreman, operator, mechanic, carpenter, miner, electrician, and rigger (not engineer and office manager),

(2) cost of domestic labour directly related to the construction work,

(3) cost of domestic or imported materials and spare parts including transportation cost, marine and land, thereof,

(4) cost of maintenance and repair of construction machinery and plants inclusive of the Employer's machinery.

(5) cost of fuel and lubricants for operating machinery and equipment including the Empoyer's machinery to be supplied to the Contractor, and

(6) cost of other miscellaneous services and installations directly related to the construction works, for example, testing equipment and consumables.

8.3.3 Construction facilities cost

The construction facilities cost consists of such items as:

(1) cost of construction or installing and removing construction plants, except the machinery cost stated in Paragraph 8.3.4,

(2) cost of constructing, maintaining and removing the Contractor's power distribution line and lighting installations, and of maintaing the Employer's power distribution line for construction use,

(3) cost of constructing camp housing and its appurtenant facilities, offices, plant shed and other temporary buildings for construction use,

(4) cost of constructing and maintaining temporary roads, bridges and other traffic facilities for construction use,

(5) cost of supplying, installing, maintaining and operating and internal telecommunication system and,

(6) cost of constructing and maintaining other miscellaneous construction facilities.

8.3.4 Construction machinery cost

The construction machinery cost is composed of such items as:

(1) cost of depreciation of construction machinery and plants,
(2) cost of marine transportation thereof, and
(3) cost of inland transportation thereof.

8.3.5 General expenses

The general expenses consists of such items as:

(1) cost of salary, insurance and others for foreign and domestic engineers and managing staff (cost of foreign and domestic technician to be included in the direct construction cost),

(2) Living cost for the above staff at the site,

(3) Travelling expenses of the above staff, air and land,

(4) General expenses at the site including the expenses of domestic staff employed for managing and domestic purposes, clerical works, communication and others,

(5) General expenses, direct and indirect at Tender's offices out the site, and

(6) appropriate profit.

Cost of Main Civil Works by Contract System

Unit: 1,000 US$

Item	Dam			Main Canal			Secondary Canal			Land Reclamation			Total
	Domestic	Foreign	Total	Domestic	Foreign	Total	Domestic	Foreign	Total	Domestic	Foreign	Total	
1. Direct Construction Cost													
1) Labour cost	319	575	894	1,100	19	1,119	1,525	-	1,525	475	-	475	4,013
2) Material cost	872	2,617	3,489	2,662	1,217	3,879	2,968	361	3,329	1,074	-	1,074	11,771
3) Cost maintenance and repair of equipment	-	476	476	-	2,395	2,395	-	519	519	-	1,556	1,556	4,946
Sub-total	1,191	3,668	4,859	3,762	3,631	7,393	4,493	880	5,373	1,549	1,556	3,105	20,730
2. Construction Facilities Cost													
1) Installation work etc	28	125	153	34	60	94	23	-	23	5	-	5	275
2) Power distribution work	10	-	10	10	-	10	5	-	5	10	-	10	35
3) Office and quarters	40	-	40	30	-	30	20	-	20	23	-	23	113
4) Temporary work	162	-	162	500	-	500	489	-	489	-	-	-	1,151
5) Others	22	-	22	100	-	100	50	-	50	10	-	10	182
Sub-total	262	125	387	674	60	734	587	-	587	48	-	48	1,756
3. Construction Machinery Cost													
1) Depreciation cost	-	862	862	-	4,498	4,498	-	966	966	-	2,236	2,236	8,562
2) Transportation cost	-	32	32	-	100	100	-	48	48	-	68	68	248
Sub-total	-	894	894	-	4,598	4,598	-	1,014	1,014	-	2,304	2,304	8,810
4. General expenses													
1) Salary, etc for engineers	240	-	240	180	-	180	90	-	90	90	-	90	600
2) Living cost	30	-	30	18	-	18	9	-	9	9	-	9	66
3) Travelling expenses	10	-	10	6	-	6	1	-	1	3	-	3	20
4) Employee's cost	25	-	25	15	-	15	7	-	7	10	-	10	57
5) General expenses	30	-	30	50	-	50	25	-	25	30	-	30	135
6) Profit	330	-	330	650	-	650	350	-	350	280	-	280	1,610
Sub-total	665	-	665	919	-	919	482	-	482	422	-	422	2,488
Total	2,118	-	6,805	5,355	8,289	13,644	5,562	1,894	7,456	2,019	3,860	5,879	33,784

8.4 Project Cost and Annual Disbursement Program in case that the Net Irrigation Area is 25,000 ha.

8.4.1 Project Cost

(Unit 1,000 US$)

Item	Domestic	Foreign	Total
1. Main Civil Work			
a) Preparatory work	2,042	-	2,042
b) Dam	1,919	2,954	4,873
c) Main canal	6,216	1,612	7,828
d) Secondary canal	7,590	473	8,063
e) Road rehabilitation	300	-	300
f) Office and quarters	136	-	136
g) Land reclamation	2,780	-	2,780
" (upland field)	1,200	-	1,200
h) Pilot farm	138	-	138
(Sub-total)	(22,321)	(5,039)	(27,360)
2. Land Compensation Expenses	130	-	130
3. Construction Equipments and Spare Parts	-	17,705	17,705
4. Engineering and Administrative Cost	750	3,000	3,750
5. Physical Contingency	2,320	1,285	3,605
Total	25,521	27,029	52,550
6. Interest during Construction Period	-	5,950	5,950
7. Price Contingency	14,869	4,631	19,500
Grand total	40,390	37,610	78,000

8.4.2 Annual Disbursement Program

Portion	1977	1978	1979	1980	1981	1982	Total
Domestic	1,309	2,484	7,695	11,016	10,464	7,422	40,390
Foreign	2,770	7,877	19,613	4,197	2,095	1,058	37,610
Total	4,079	10,361	27,308	15,213	12,559	8,480	78,000

8.4.3 Breakdown of Annual Disbursement

	1977		1978		1979		1980		1981		1982		Total		Grand total
	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	
1) Main Civil Work															
a) Preparatory work	706	-	450	-	296	-	295	-	295	-	-	-	2,042	-	2,042
b) Dam	-	-	278	429	458	709	913	1,403	270	413	-	-	1,919	2,954	4,873
c) Main canal	-	-	752	195	1,343	348	1,513	392	1,428	371	1,180	306	6,216	1,612	7,828
d) Secondary canal	-	-	-	-	1,661	104	2,492	155	2,283	142	1,154	72	7,590	473	8,063
e) Road rehabilitation	-	-	-	-	54	-	98	-	98	-	50	-	300	-	300
f) Office and quarters	68	-	68	-	-	-	-	-	-	-	-	-	136	-	136
g) Land reclamation (lowland)	-	-	-	-	695	-	695	-	695	-	695	-	2,780	-	2,780
(upland)	-	-	-	-	300	-	300	-	300	-	300	-	1,200	-	1,200
h) Pilot farm	-	-	-	-	115	-	-	-	23	-	-	-	138	-	138
Sub-total	774	-	1,548	624	4,922	1,161	6,329	1,950	5,369	926	3,379	378	22,321	5,039	27,360
2) Land Compensation	65	-	65	-	-	-	-	-	-	-	-	-	130	-	
3) Construction Equipment and	-	1,043	-	4,116	-	12,546	-	-	-	-	-	-	-	17,705	17,705
Spare Parts (Depreciation)	-	(1,043)	-	(4,116)	-	(4,728)	-	(4,247)	-	(3,571)	-	-	-	(17,705)	(17,705)
4) Engineering and Administrative Cost	225	900	193	780	83	330	83	330	83	330	83	330	750	3,000	3,750
Total-1	1,064	1,943	1,806	5,520	5,005	14,037	6,412	2,280	5,452	1,256	3,462	708	23,201	25,744	48,945
(Total-1)	(1,064)	(1,943)	(1,806)	(5,520)	(5,005)	(6,219)	(6,412)	(6,527)	(5,452)	(4,827)	(3,462)	(708)	(23,201)	(25,744)	(48,945)
5) Physical Contingency	106	97	181	276	501	310	641	326	545	241	346	35	2,320	1,285	3,605
Total-2	1,170	2,040	1,987	5,796	5,506	14,347	7,503	2,606	5,997	1,497	3,808	743	25,521	27,029	52,550
(Total-2)	(1,170)	(2,040)	(1,987)	(5,796)	(5,506)	(6,529)	(7,503)	(6,853)	(5,997)	(5,068)	(3,808)	(743)	(25,521)	(27,029)	(52,550)
	(3,210)		(7,783)		(12,035)		(13,906)		(11,065)		(4,551)		(52,550)		
6) Interest during Construction Period	-	617	-	1,426	-	2,769	-	9 967	-	138	-	33	-	5,950	5,950
7) Price Contingency	139	113	497	655	2,189	2,497	3,963	624	4,467	460	3,614	282	14,869	4,631	19,500
Grand total	1,309	2,770	2,484	7,877	7,695	19,613	11,016	4,197	10,464	2,095	7,422	1,058	40,390	37,610	78,000
	4,079		10,361		27,308		15,213		12,559		8,480		78,000		