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THE REPUBLIC OF INDONESIA

THE FEASIBILITY STUDY ON THE VOLCANIC DEBRIS CONTROL AND WATER CONSERVATION PROJECT IN THE SOUTHEASTERN SLOPE OF MT. SEMERU

SUPPORTING REPORT (4)

WATER CONSERVATION STUDY

DECEMBER, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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CONTENTS

1. INTRODUCTION

This is a final report dealing with the water conservation study which was carried out as first stage using the data collected between March, 1982 and April, 1983 and as second stage using the data collected between May, 1983 and June, 1984.

The study result of the first stage was reported in the interim report of Supporting Report (5) Water Conservation Study, Oct., 1983. The second stage study was executed to make up the first stage study and compiled in Appendix-5 and 6.

We believe that the water resources potential in the area and the preliminary development plan obtained in this study will be a useful informatin for the next stage study and planning.

1.1 OBJECTIVE OF THE STUDY

The objectives of the study are summarized as follows:

① An assessment of the hydrologic situation of the area, in order to estimate the surface base flow of K. Mujur, K. Rejali and K. Glidik at each discharge reference point;

② An assessment of the hydrogeologic situation of the K. Lengkong Fan area, in order to evaluate the groundwater potential;

③ An assessment of the potential of land and water, in order to select the area of land and water use;

④ A preliminary plan for water conservation of the area, in order to pre-estimate the feasibility of the water conservation project.

1.2 STUDY CONTENTS

To accomplish the above mentioned objectives, the followings were investigated and studied:

① Hydrological study;

- Rainfall observation
- Base flow observation
- Base flow analysis

② Hydrogeological study;

- Groundwater observation
- Water quality investigation
- Geological survey
- Soil investigation
- Groundwater analysis

③ Water use potential;

- Land use investigation
- Water use investigation
- Land and water use analysis

Detailed information concerned with the above items is described in SUPPORTING REPORT (5), INVESTIGATION AND ANALYSIS.

④ Preliminary planning for water conservation

- Facility plan
- Water use plan
- Project plan and preliminary evaluation

1.3 STUDY FLOWCHART

The study flowchart is shown in Fig.-1.1.

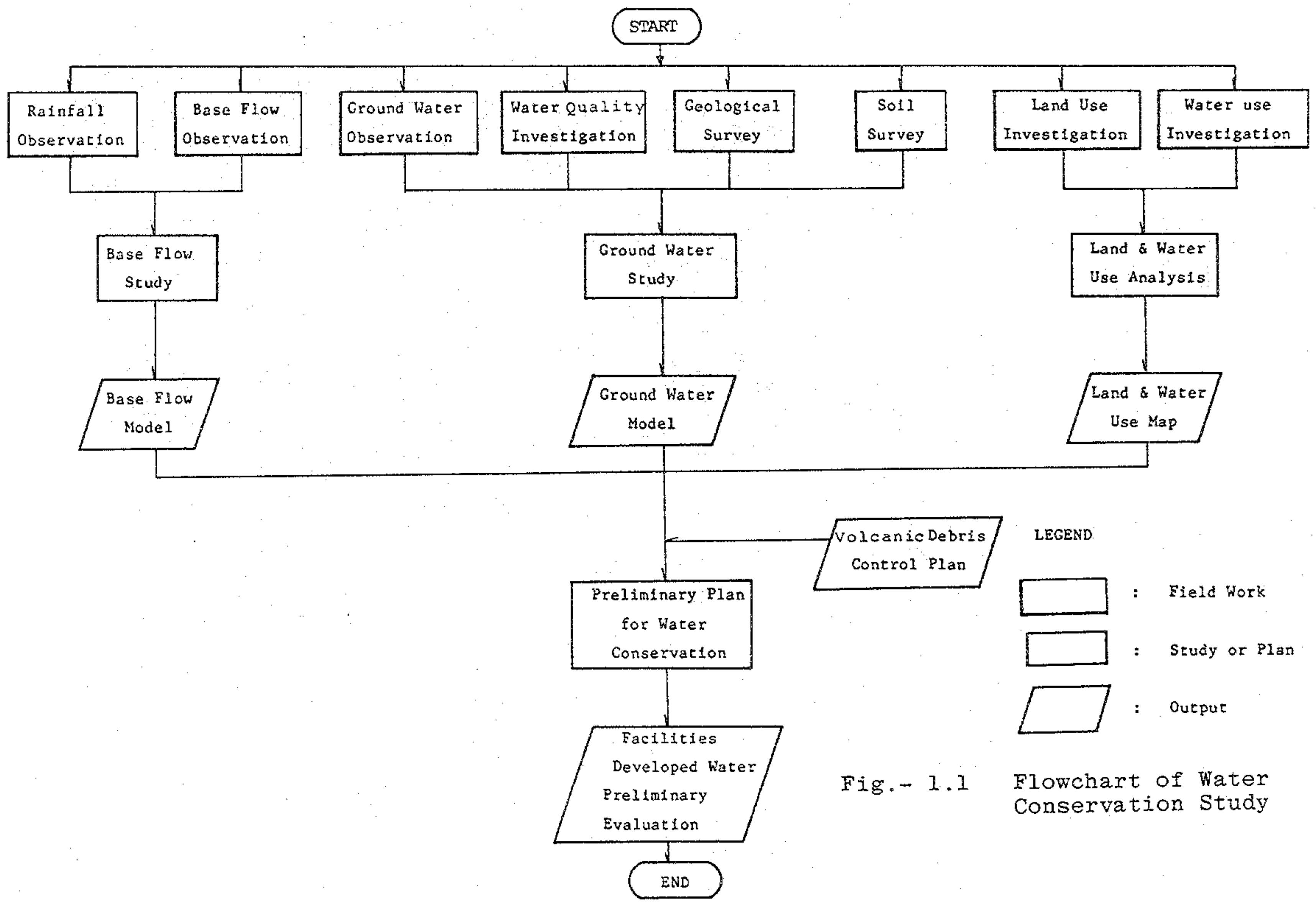


Fig.- 1.1 Flowchart of Water Conservation Study

2. SUMMARY

2.1 WATER RESOURCES POTENTIAL

(1) Surface Base Flow

The base flow of the following points during the last 30 years (1953 to 1983) was obtained by using the base flow model (statistic response computer model which was verified against the rainfall and flow rate data aquired during the investigation).

- The intake Rowojedang of K. Mujur (A = 69.1 km^2)
- The Leprak No. 1 check dam of K. Rejali (A = 27.6 km^2)
- The planned Pronojiwo Dam of K. Glidik (A = 54.3 km^2)

The simulation results are given below. (c.f. Fig.-3.4 to 3.7)

① The monthly mean base flow (Q), the standard deviation (σn), a coefficient of fluctuation (c_f = σn/Q) and specific mean base flow (q = Q/A) at the base points are shown in Table-2.1.

Table-2.1 Simulated Base Flow

Reference Point \ Items	Q (m^3/s)	n (m^3/s)	c_f (N.D.)	q ($m^3/s/km^3$)
(M) Intake Rowojedang of K. Mujur	0.898	0.258	0.287	0.013
(R) Leprak No. 1 Check Dam of K. Rejali	0.992	0.309	0.312	0.036
(G) Planned Pronojwio Dam of K. Glidik	2.468	0.681	0.276	0.045

② Among three points, the highest amounts of mean base flow and specific mean base flow are obtained at the planned Pronojiwo dam site of K. Glidik. The fluctuation coefficient is smallest at the same site. This means that the area upstream of the point possesses a greater natural reservoir being created in Mt. Semeru body than the others.

③ The periodicity of the monthly base flow is noted although the interval is not one but two or three years.

④ The fluctuation of each annual mean monthly base flow is rather level due to the reason stated above in ③.

⑤ The fluctuation of the annual mean base flow for K. Glidik is the smallest.

(2) Groundwater and Water Quality

The hydrogeological structure and the potential groundwater volume of the K. Lengkong Fan, which provides the groundwater basin, are summarized below. Refer to Fig.-3.8 and Fig.-3.9.

① The groundwater basin is formed in the area surrounded by the underground ridge of tuff which runs north to south in the west of the fan and by the Tertiary mountains to the south of Mt. Semeru.

② The Lahar deposits which cover this groundwater basin can become an aquifer. The permeability and the aquiferability of this aquifer is estimated at 10^{-4} cm/s - 10^{2} cm/s in terms of its coefficient of permeability, and its effective percentage of void is about 20%.

③ Main sources of groundwater supply at present are considered to be the infiltration of rain over the basin area, the infiltration of surface water over the upper slope of Mt. Semeru and the inflow of groundwater from Mt. Semeru.

④ The groundwater basin volume can be supposed to be some 100 x $10^6 m^3$ based on the above information, however the developable groundwater will be some 1.0 m^3/s at the maximum judging from the results of the groundwater simulation.

The quality of surface water and the groundwater sampled at 40 points is summarized below.

① Some groundwater is unsuitable drinking but all of it can be used for irrigation.

② The groundwater is vadose water consisting of relatively new precipitation.

2.2 PRELIMINARY PLAN FOR WATER CONSERVATION

(1) Preconditions for Planning

① Prevention of disaster in the area where the developed water has a beneficial effect should be assured as the sediment control works progress to a certain degree.

② The Pronojiwo dam should be constructed according to the diversion plan, which is an integral part of the first priority facility project, to secure safe and easy intake of water at that point.

(2) Water Conservation Plan

The promising water conservation project should include the following facilities:

① Intake Facility

Able to take the base flow discharge of K. Besuk Bang and K. Lengkong and the exploited ground water.

② Ground water Exploitation Facility at K. Lengkong Fan Pumping Well (Well and A pump).

③ Water Conveyance Facility (1)

Tunnel or Open Channel

④ Hydro-electric Power Station

Hydro-electric power generation at the end of the water conveyance facility (1).

⑤ Water Conveyance Facility (2)

Open channel from K. Rejali to the irrigation area.

⑥ Cultivated Paddy Field

To facilitate the land improvement programme for the irrigation area, certain wastelands are reclaimed to be paddy fields in the K. Rejali and K. Semut basins.

Specifications and estimated construction costs of these facilities are shown in Table.

The project will also produce the following effect:

① Irrigation

The devastated area extending from the K. Rejali basin to the K. Pancing basin and not exceeding EL. 500 m where there is no irrigation at present is chosen to be the target area for the irrigation programme. According to the amount of developed water, 3.5 $m^3/s/y$, 4.0 $m^3 s/y$ and 4.5 $m^3 s/y$, areas of 3,500 ha, 4,000 ha and 4,500 ha will be irrigated through the year, respectively, as paddy fields.

② Hydro-electric Power Generation

The electric-power shown in Table-2.3 will be generated.

Table-2.3 Hydro-electric Power Generation

Items / Developed Water	3.5 $m^3/s/y$	4.0 $m^3/s/y$	4.5 $m^3/s/y$
Maximum output (KW)	2,200	2,200	2,200
Annual Output of Electric Energy (10^6 KWH)	16.7	18.5	19.5

(3) Alternatives of Water Conservation Plan

A number of possible water conservation plans can be developed based on a different combination of facilities.

Table-4.7 shows the combination of facilities for each plan and their respective preliminary economic evaluation.

① While I.R.R. of each alternative plan exceeds 7%, the best plan (I.R.R. = 14.3%) would be Alternative 2.

② Among the alternative plans, the plan in which there is the least amount of ground water development with the open channel water conveyance system shows higher I.R.R.

③ However, as the economic evaluation of each plan is carried out on the basis of the mean amount of the developed water, the stable water supply by the ground water development during the dry seasons should be also evaluated reasonably in the next study.

2.3 CONCLUSION AND RECOMMENDATION

Assuming that the precondition of security against volcanic debris disaster in the target area has been guaranteed and further supposing water use of irrigation and production of electric power, I.R.R. of between 8.7% to 16.2% was obtained as a result of the preliminary economic evaluation for the six alternative preliminary plans.

From the standpoint of maintaining the area's basis of livlihood as well as economic considerations, several of the water development plans examined are thought to be promising undertakings. Should it be judged desirable to execute such undertakings, it would be mandatory to confirm their feasibility by carrying out a more advanced study than the present one.

3. WATER RESOURCES POTENTIAL

3.1 BASE FLOW

3.1.1 SIMULATION MODEL

(1) Discharge Reference Point

The discharge reference point for each unit is as follows: Refer to Fig.-3.1.

① Unit M. K. Mujur

Rowojedang Intake
(Catchment area = 69.1 km^2)

② Unit R, K. Rejali

K. Leprak No. 1 Check Dam
(Catchment area = 27.6 km^2)

③ Unit G. K. Glidik

Planned Pronojiwo Dam
(Catchment area = 54.3 km^2)

Upstream from these points there is no intake; therefore, we can obtain an actual amount of monthly base flow discharge from this model.

(2) Basic Equation

The basic equation to obtain a monthly mean base flow discharge (Q) is given below. Rerfer to Fig.-3.2.

$$Q = Ca \sum_{i=1}^{n} (Cm(i) \times Rm(i)) \qquad \text{..... (1)}$$

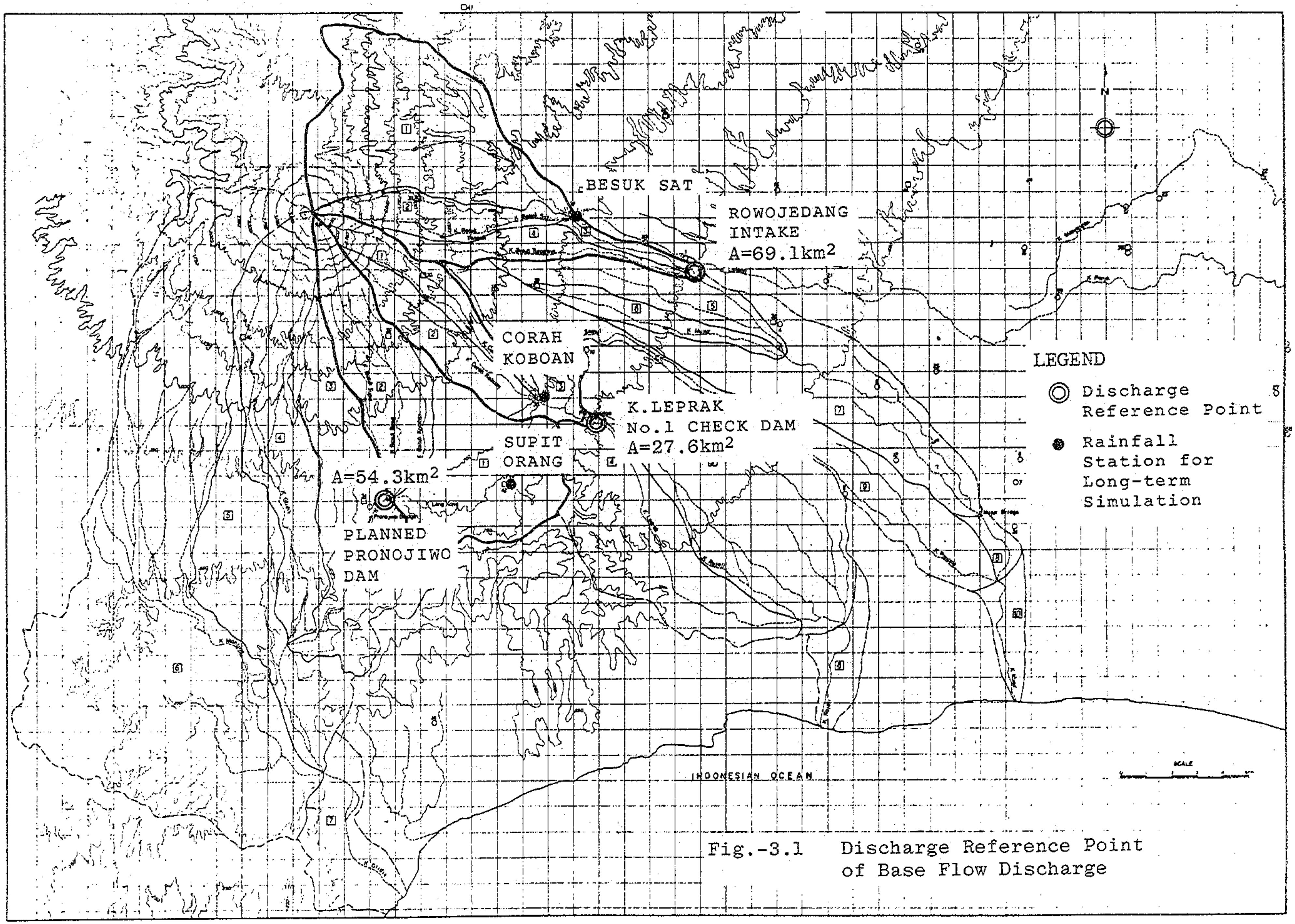


Fig.-3.1 Discharge Reference Point of Base Flow Discharge

Where,

Q: Monthly mean base flow discharge (m^3/day)

Rm(i): Monthly rainfall amount of i-month

Ca: Coefficient of area and discharge rate

cm(i): Coefficient of monthly rainfall contribution

i: Elapsed month from simulation month

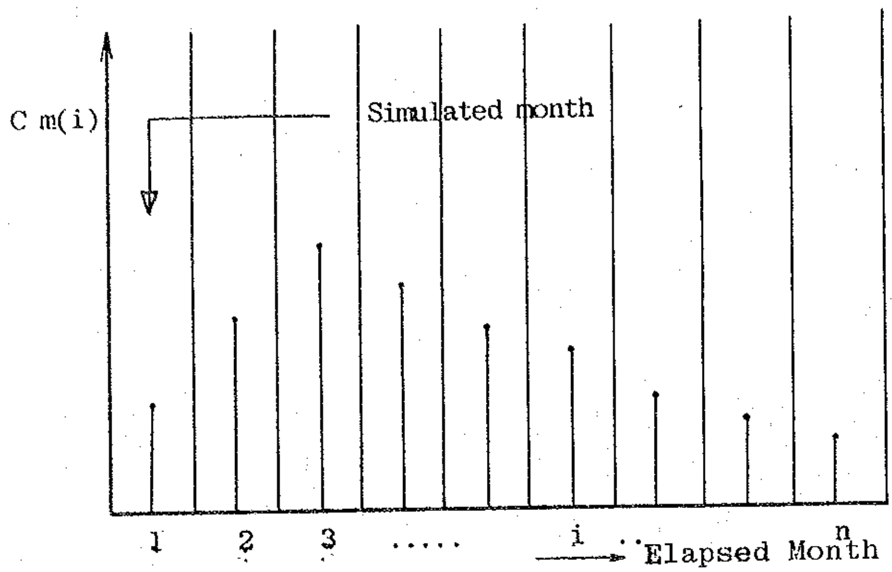


Fig.-3.2 Base Flow Model

The equation (1) means that the monthly mean discharge of an arbitrary month is composed of the elapsed n-months monthly rainfall; however, the contribution rate of i-month rainfall is restricted to Cm(i).

The model mentioned above was verified with such data as the base flow discharge observed at each reference point and the monthly rainfall at Besuksat, Curahkobo'an and Supiturang.

The results of verification and the fixed parameters of the model are shown in Fig.-3.3 and Table-3.1, respectively.

Table-3.1 Parameters for Base Flow Model

Parameter \ Unit		Unit M K. Mujur	Unit R K. Rejali	Unit G K. Glidik
Total Contribution Month n		12	12	12
Coefficient Ca		0.243	0.323	0.723
Coefficient Cm	Cm (1)	0.070	0.210	0.065
	Cm (2)	0.100	0.180	0.100
	Cm (3)	0.135	0.150	0.140
	Cm (4)	0.145	0.120	0.145
	Cm (5)	0.130	0.090	0.130
	Cm (6)	0.110	0.070	0.110
	Cm (7)	0.095	0.055	0.095
	Cm (8)	0.075	0.045	0.075
	Cm (9)	0.060	0.035	0.060
	Cm (10)	0.045	0.025	0.045
	Cm (11)	0.025	0.015	0.025
	Cm (12)	0.010	0.005	0.010

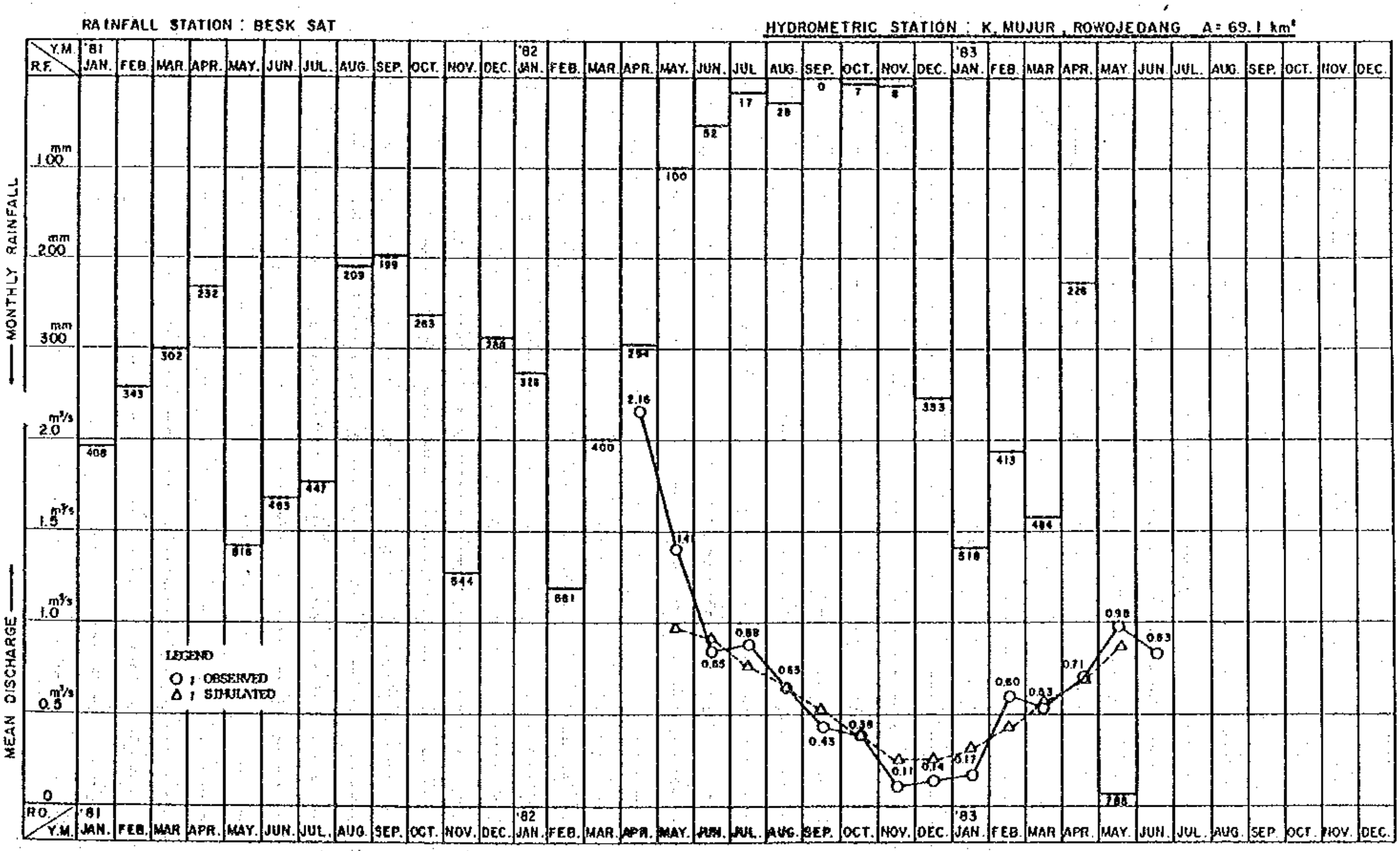


Fig.- 3.3(1) Result of Verification (K.Mujur)

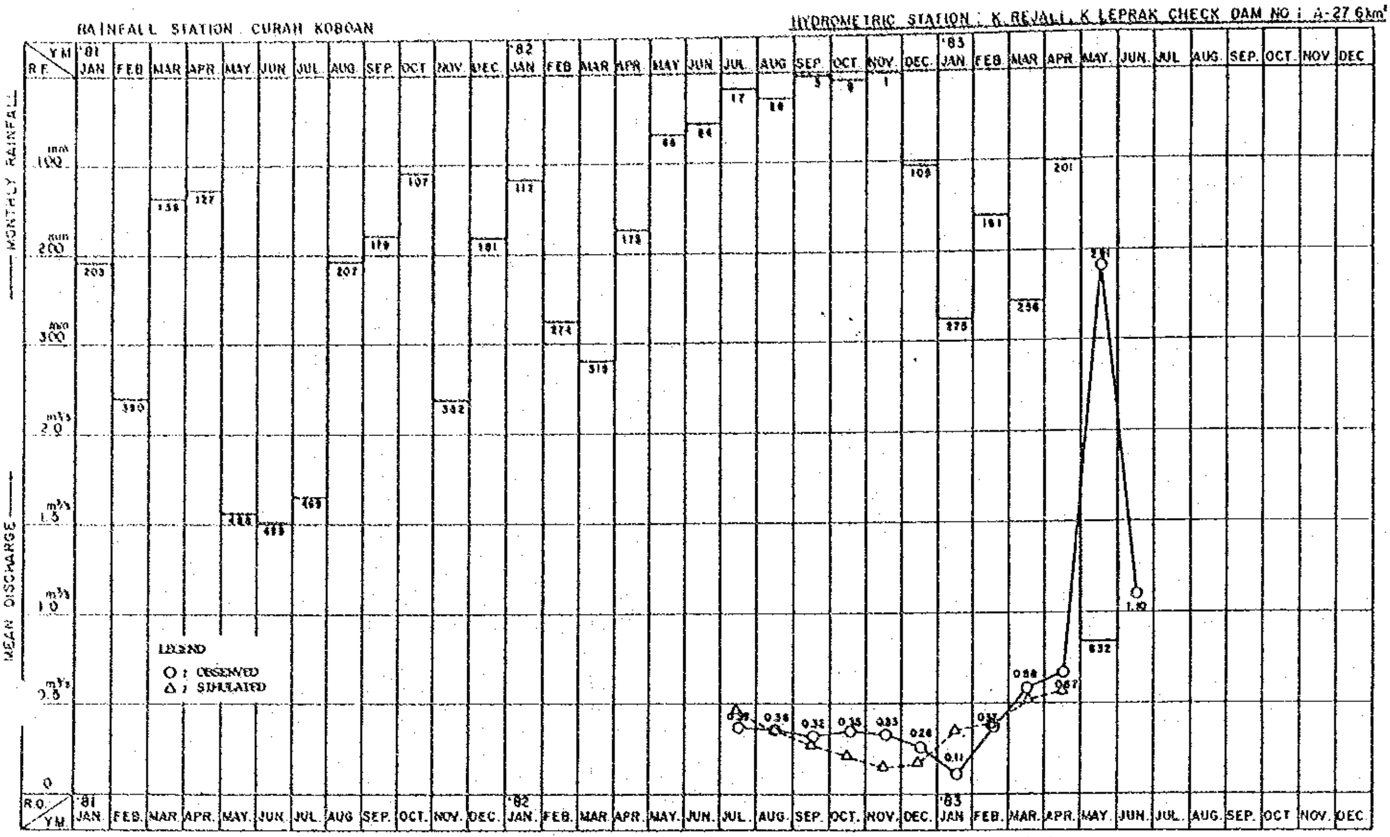


Fig.- 3.3(2) Result of Verification (K.Rejali)

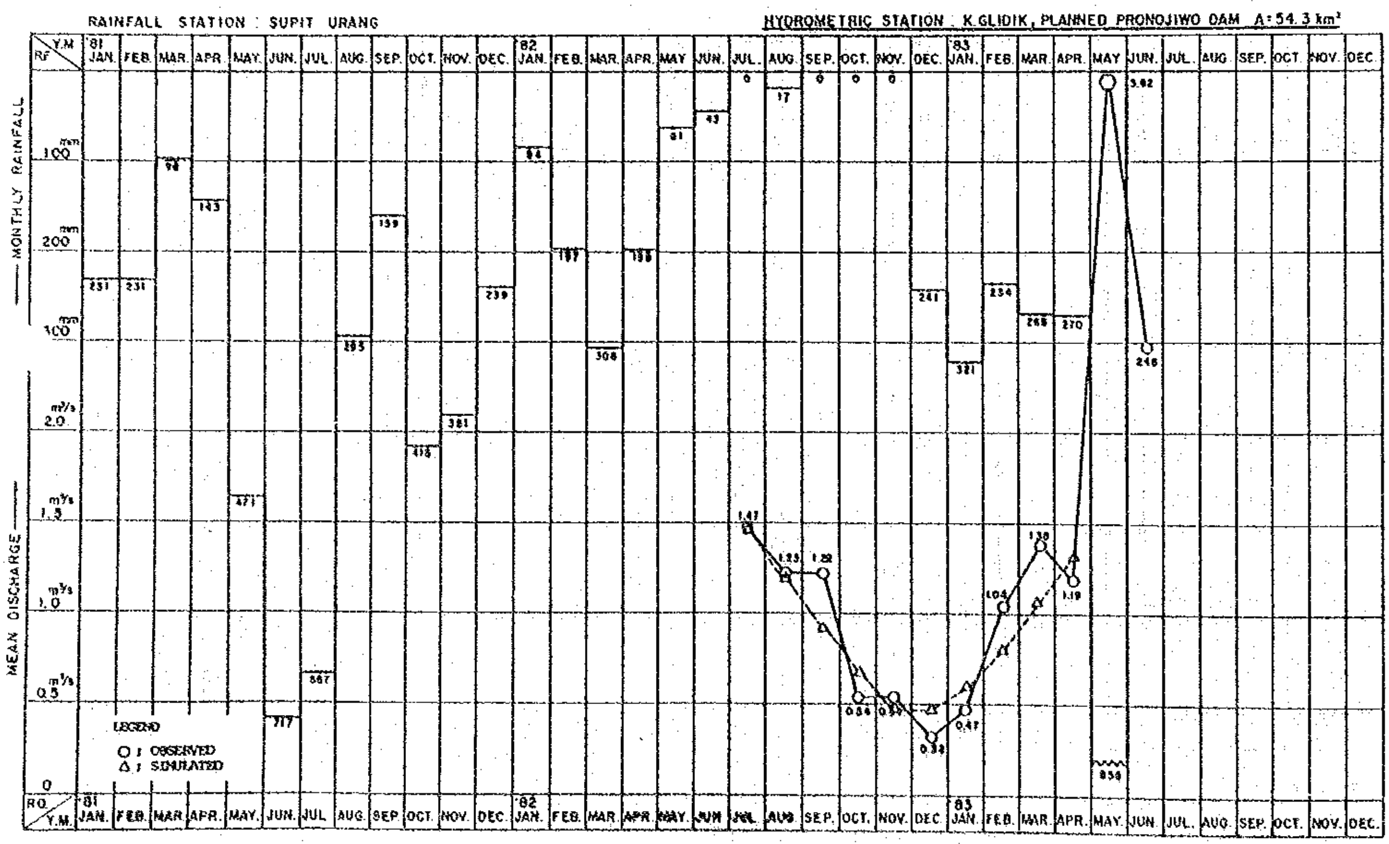


Fig.- 3.3(3) Result of Verification (K.Glidik)

3.1.2 SIMULATION OF LONG-TERM BASE FLOW

(1) Conditions of Simulation

Under the following conditions, the base flow simulation for a long term period was carried out, using the model verified in the above section:

① Discharge reference model;

- Rowojedang Intake for Unit M, K. Mujur
- K. Leprak No. 1 Check Dam for Unit R, K. Rejali
- Planned Pronojiwo Dam for Unit G, K. Glidik

② Simulation period;

30 years, from 1953 to 1982

③ Monthly rainfall data used;

- Besuk Sat for Unit M, K. Mujur from 1952 to 1982
- Curah Kobo'an for Unit R, K. Rejali from 1952 to 1982
- Supit Urang for Unit G, K. Glidik from 1952 to 1982 (Data from 1952 to 1969 is estimated by the correlation to Curah Kobo'an)

(2) Results of Simulation

The simulation results of long term base flow are shown in the following figures and tables.

①	Fig.-3.4	:	Annual Mean Base Flow
②	Fig.-3.5	:	Annual Mean Monthly Base Flow Distribution
③	Fig.-3.6	:	Annual Mean Monthly Base Flow and Rainfll Distribution
④	Fig.-3.7	:	Monthly Distribution of Base Flow
⑤	Table-3.2	:	Characteristics of Simulated Monthly Base Flow
⑥	Table-3.3	:	Computer Output of Long-term Base Flow Simulation

From these figures and tables, the following characteristics of base flow discharge are summarized:

① Among three points, the highest amounts of mean base flow and specific mean base flow are obtained at the planned Pronojiwo Damsite of K. Glidik. The fluctuation coefficient is smallest at the same site. This means that the area upstream of the point possesses a greater natural reservoir in Mt. Semeru than the others;

② The periodicity of the monthly base flow is noted although the interval is not one but two or three years;

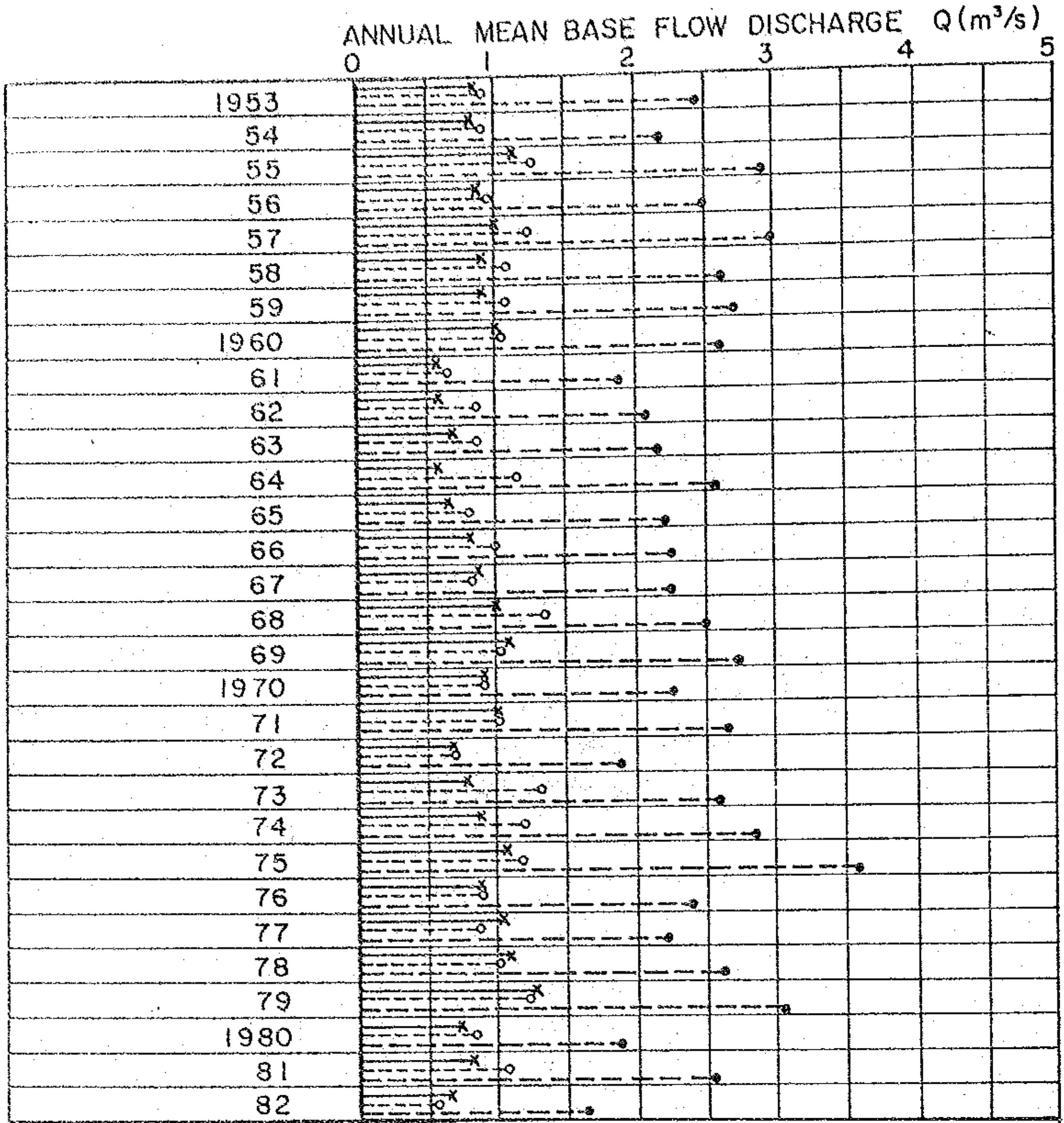
③ The fluctuation of the annual mean monthly base flow is rather level due to the reason stated above in ②;

④ The fluctuation of the annual mean base flow can be said to be small judging from its fluctuation coefficient (slightly lower than 20%).

Table-3.2 Characteristics of Simulated Monthly Base Flow

Reference Point \ Items	Q (m^3/s)	σn (m^3/s)	C_f (N.D.)	q ($m^3/s/km^2$)
(M) Intake Rowojedang of K. Mujur	0.898	0.258	0.287	0.013
(R) Leprak No. 1 Check Dam of K. Rejali	0.992	0.309	0.312	0.036
(G) Planned Pronojiwo Dam of K. Glidik	2.468	0.681	0.276	0.045

Notes: Q = Monthly mean base flow
σn = Standard deviation
c_f = Coefficient of fluctuation ($\sigma n/Q$)
q = Specific mean base flow (Q/area)



① K. MUJUR INTAKE ROWOJEDANG	$\bar{Q}$	——— x 0.898 m³/s
	δ_n	— 0.258 m³/s
	Cf	0.287
② K. REJALI K. LERAK CHD NO.1 SITE	$\bar{Q}$	- - - - - o 0.992 m³/s
	δ_n	— 0.195 m³/s
	Cf	0.196
③ K. GLIDIK PRONOJIWO DAM SITE	$\bar{Q}$	— — — — • 2.468 m³/s
	δ_n	— 0.411 m³/s
	Cf	0.167

Fig.-3.4 : Annual Mean Base Flow

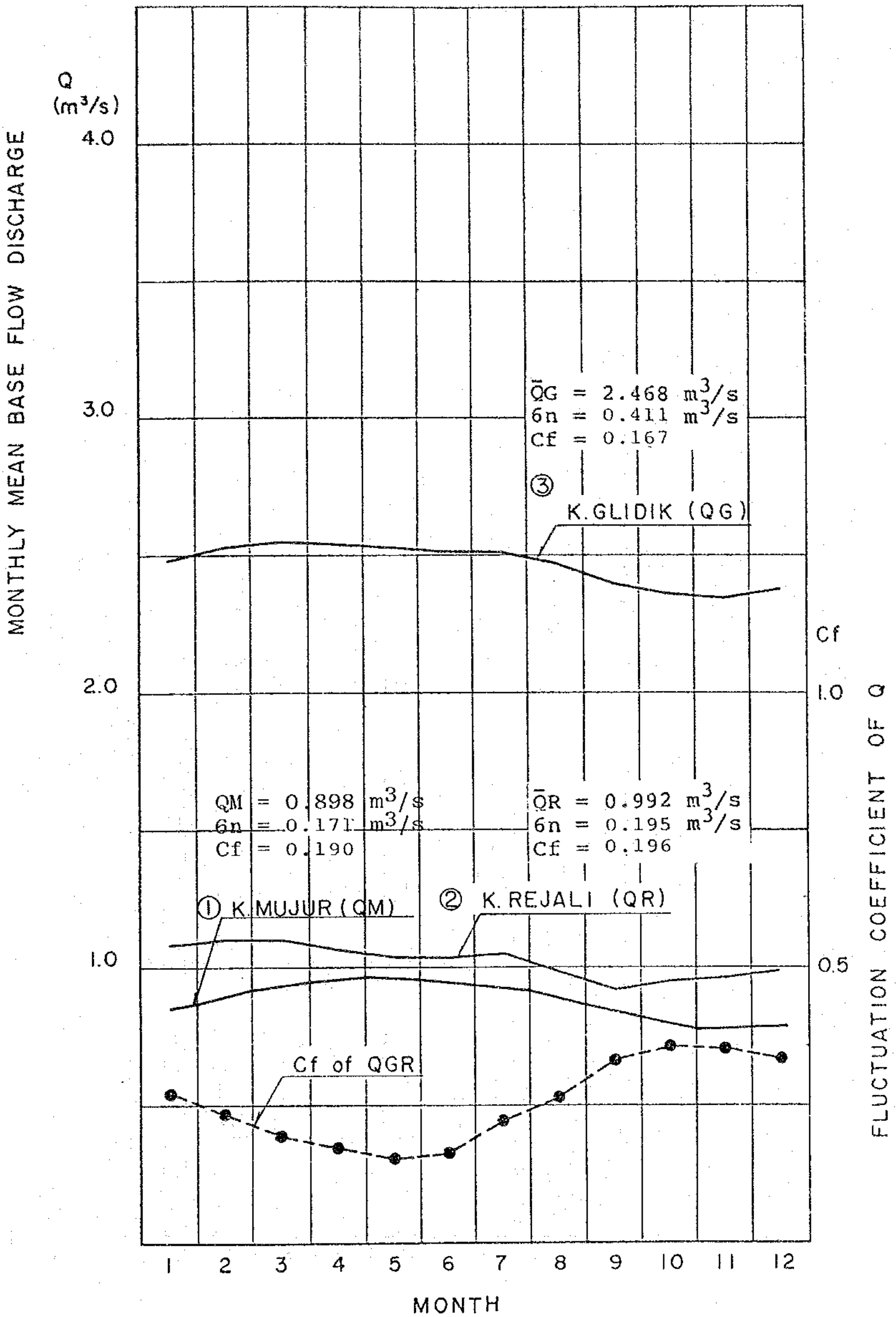


Fig.-3.5 : Annual Mean Monthly Base Flow Distribution

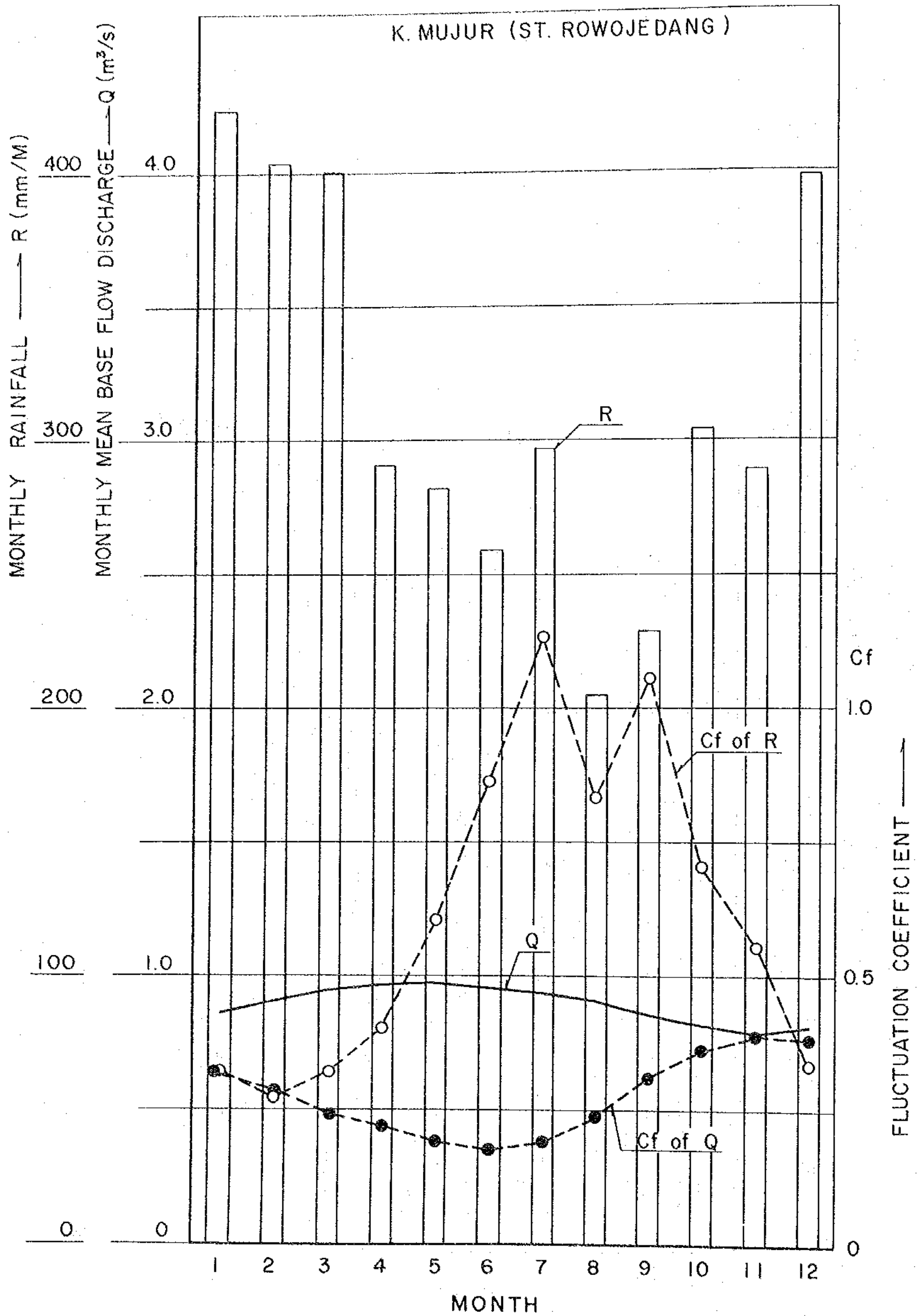


Fig.-3.6 (1) Annual Mean Monthly Base Flow and Rainfll Distribution

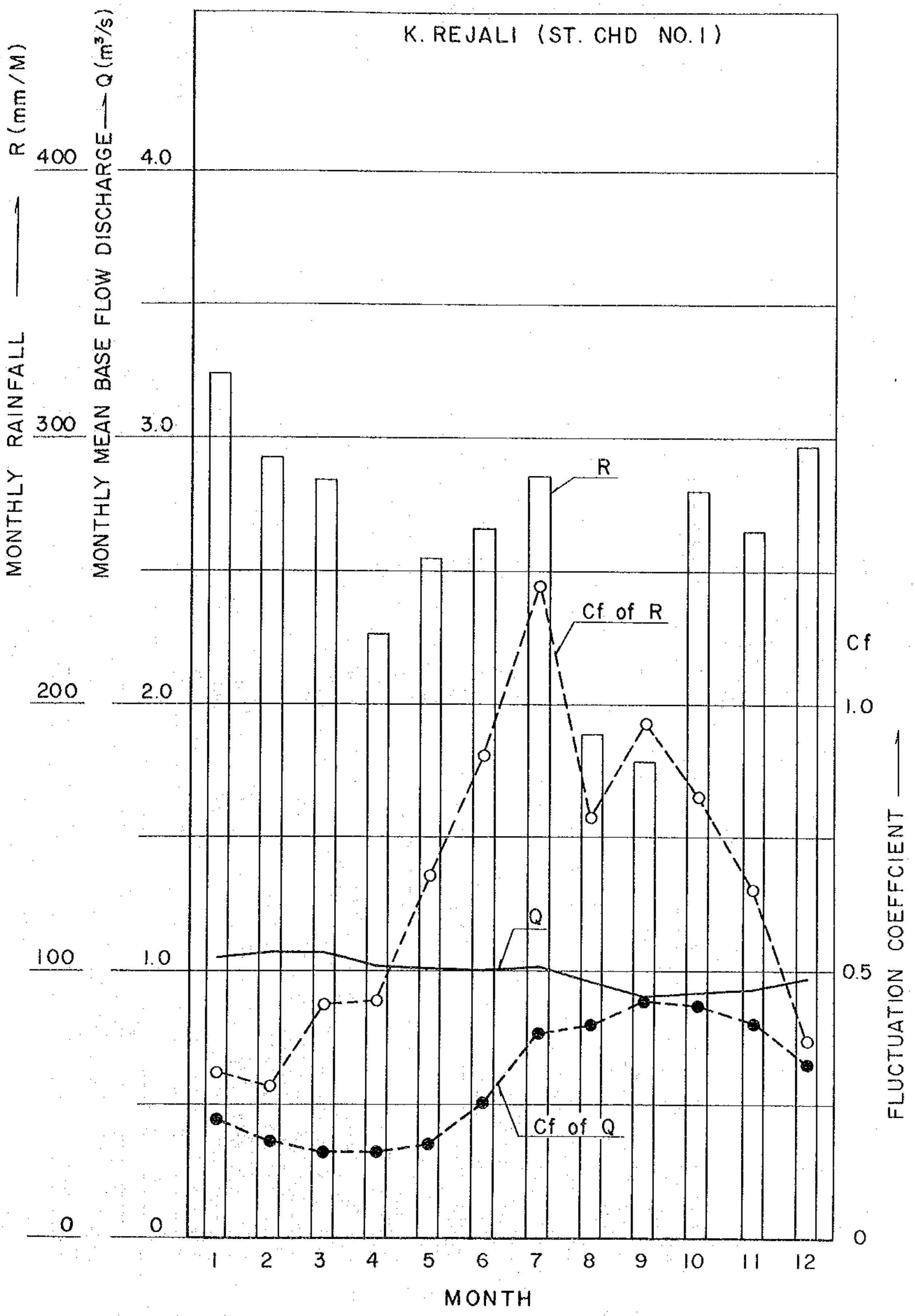


Fig.-3.6 (2) : Annual Mean Monthly Base Flow and Rainfll Distribution

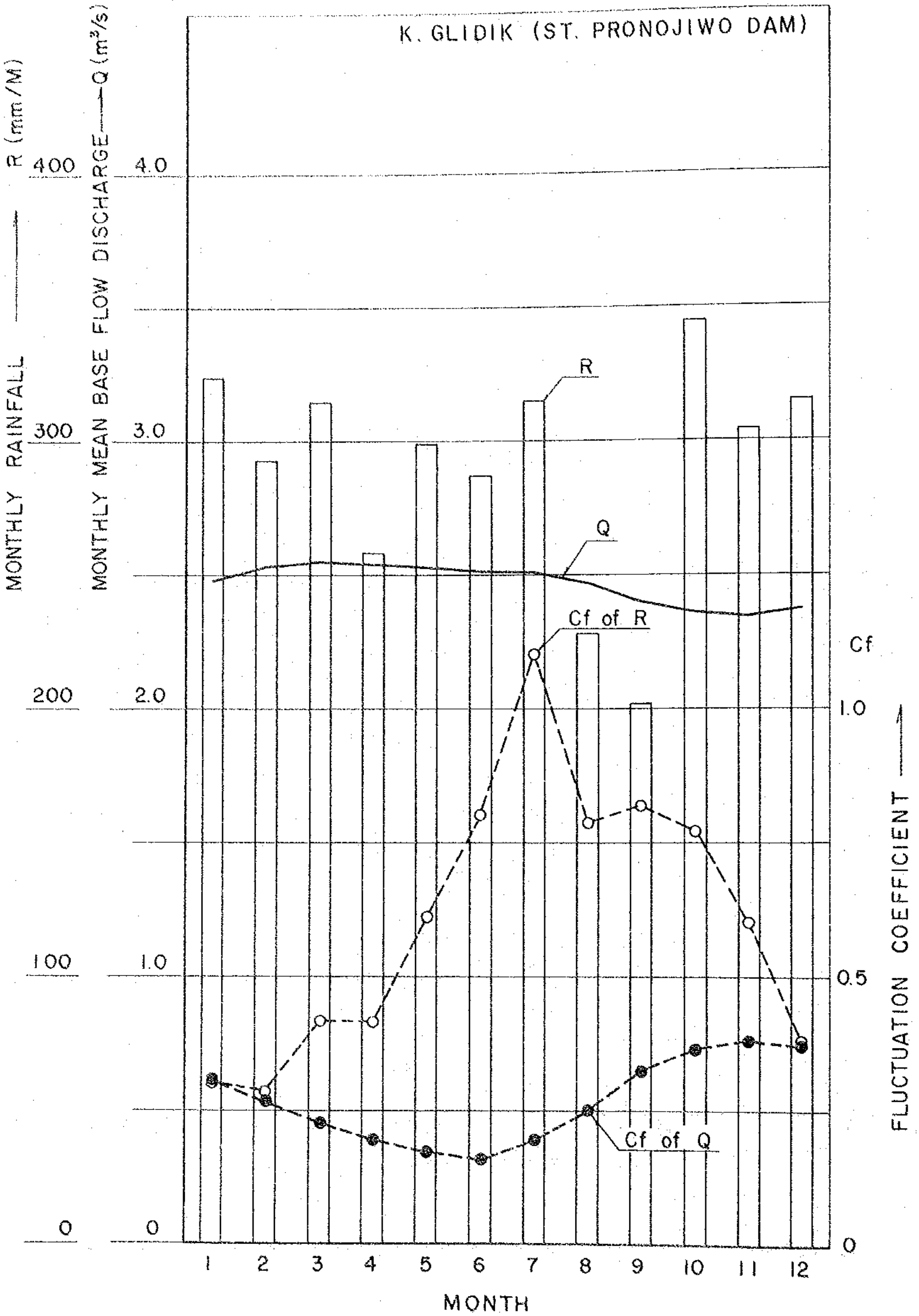
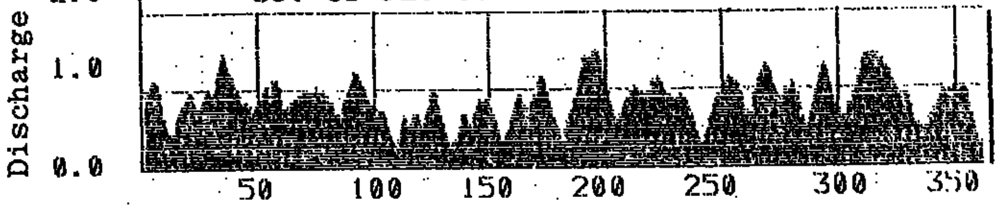


Fig.-3.6 (3) : Annual Mean Monthly Base Flow and Rainfll Distribution

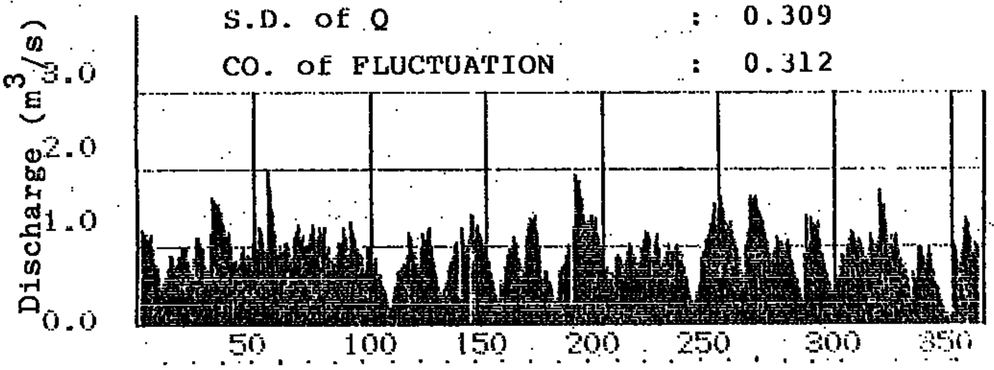
① K.MUJUR

MEAN BASE FLOW Q(m^3/s) : 0.898
S.D. of Q : 0.258
CO. of FLUCTUATION : 0.287



② K.REJALI

MEAN BASE FLOW Q(m^3/s) : 0.992
S.D. of Q : 0.309
CO. of FLUCTUATION : 0.312



③ K.GLIDIK

MEAN BASE FLOW Q(m^3/s) : 2.468
S.D. of Q : 0.681
CO. of FLUCTUATION : 0.276

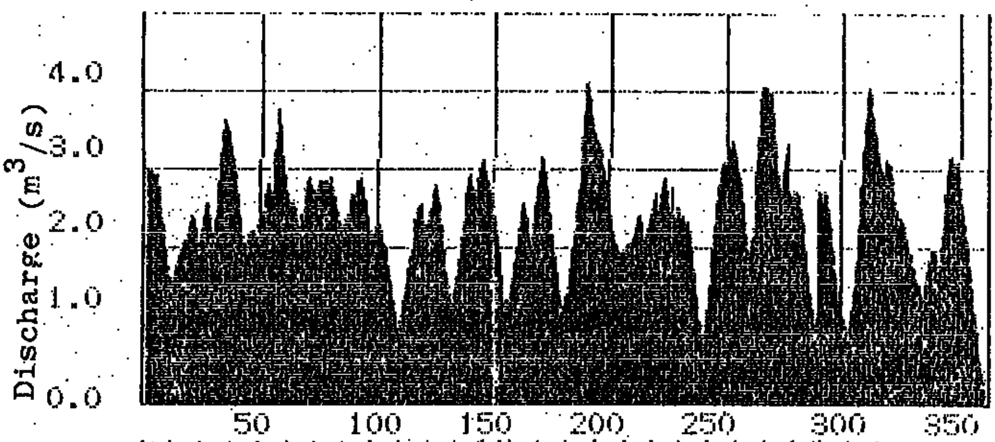


Fig.-3.7 : Monthly Distribution of Base Flow

Table 3(1) Computer Output of I g-term Base Flow Simulation

########## K.MUJUR (ST. ROWOJEDANG) 1953-1982 ########## RUNOFF (m^3/s)

	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	MEAN
1953	1.007	1.046	1.082	1.117	1.137	1.074	0.973	0.834	0.676	0.559	0.490	0.500	10.494	0.874
1954	0.560	0.642	0.719	0.799	0.841	0.916	0.938	0.968	0.918	0.863	0.820	0.801	9.786	0.816
1955	0.856	0.903	0.949	0.945	0.912	0.955	1.159	1.278	1.403	1.473	1.430	1.364	13.625	1.135
1956	1.258	1.183	1.097	0.993	0.930	0.857	0.848	0.849	0.807	0.789	0.754	0.797	11.162	0.930
1957	0.831	0.897	1.005	1.040	1.036	0.984	1.119	1.123	1.136	1.051	0.889	0.803	11.917	0.993
1958	0.787	0.793	0.848	0.890	0.873	0.937	0.938	1.017	1.013	1.005	0.975	0.977	11.053	0.921
1959	0.983	1.021	0.949	0.968	0.952	0.925	0.922	0.867	0.838	0.773	0.730	0.777	10.756	0.896
1960	0.823	0.907	0.986	1.045	1.134	1.222	1.215	1.187	1.113	1.028	0.964	0.900	12.524	1.044
1961	0.861	0.816	0.745	0.761	0.760	0.734	0.715	0.632	0.535	0.438	0.359	0.323	7.701	0.642
1962	0.396	0.501	0.612	0.661	0.650	0.620	0.654	0.671	0.665	0.668	0.637	0.653	7.387	0.616
1963	0.736	0.809	0.928	1.001	0.973	0.911	0.797	0.666	0.541	0.423	0.346	0.325	8.456	0.705
1964	0.331	0.393	0.497	0.577	0.662	0.694	0.679	0.667	0.659	0.724	0.792	0.824	7.498	0.625
1965	0.864	0.846	0.877	0.872	0.855	0.793	0.710	0.590	0.495	0.419	0.425	0.464	8.210	0.684
1966	0.547	0.647	0.763	0.841	0.924	0.917	0.866	0.816	0.782	0.786	0.847	0.905	9.642	0.803
1967	0.997	1.107	1.158	1.170	1.102	0.996	0.895	0.776	0.662	0.569	0.467	0.496	10.396	0.866
1968	0.514	0.584	0.676	0.777	0.876	0.970	1.167	1.255	1.413	1.459	1.448	1.454	12.594	1.050
1969	1.479	1.480	1.520	1.491	1.389	1.249	1.099	0.950	0.828	0.735	0.648	0.664	13.531	1.128
1970	0.682	0.752	0.827	0.890	0.955	1.001	1.038	1.010	1.001	0.956	0.942	0.951	11.006	0.917
1971	1.003	1.068	1.136	1.132	1.142	1.131	1.082	1.007	0.937	0.907	0.880	0.886	12.309	1.026
1972	0.888	0.868	0.907	0.892	0.891	0.851	0.772	0.662	0.543	0.424	0.369	0.368	8.434	0.703
1973	0.428	0.490	0.603	0.694	0.804	0.873	0.928	0.916	1.023	1.077	1.115	1.145	10.097	0.841
1974	1.112	1.108	1.075	1.027	0.966	0.878	0.760	0.774	0.766	0.901	1.018	1.116	11.502	0.959
1975	1.204	1.259	1.304	1.334	1.295	1.197	1.060	0.943	0.909	0.894	0.905	0.946	13.250	1.104
1976	0.983	1.014	1.075	1.075	1.020	0.929	0.798	0.666	0.551	0.595	0.702	0.799	10.207	0.851
1977	0.948	1.062	1.185	1.287	1.322	1.281	1.185	1.033	0.893	0.801	0.712	0.727	12.436	1.036
1978	0.734	0.775	0.819	0.848	0.924	1.030	1.154	1.253	1.383	1.453	1.469	1.452	13.292	1.108
1979	1.479	1.487	1.468	1.454	1.384	1.403	1.340	1.327	1.234	1.122	1.042	0.950	15.691	1.308
1980	0.914	0.927	0.909	0.911	0.873	0.792	0.705	0.644	0.556	0.550	0.533	0.557	8.871	0.739
1981	0.613	0.673	0.732	0.775	0.850	0.919	0.997	1.019	1.006	0.963	0.968	0.951	10.465	0.872
1982	0.961	1.009	1.032	1.041	0.997	0.908	0.788	0.662	0.525	0.403	0.296	0.274	8.896	0.741
TOTAL	25.777	27.066	28.552	29.305	29.431	28.947	28.302	27.063	25.811	24.808	23.973	24.152	323.188	26.933
MEAN	0.859	0.902	0.952	0.977	0.981	0.965	0.943	0.902	0.860	0.827	0.799	0.805	10.773	0.898
S.D.	0.279	0.260	0.236	0.216	0.186	0.173	0.182	0.216	0.269	0.299	0.313	0.309	2.046	0.171
CE	0.325	0.288	0.248	0.220	0.190	0.180	0.193	0.239	0.313	0.361	0.392	0.383	0.190	0.190

Table-3.3 (2) : Computer Output of Long-term Base Flow Simulation

********** K.REJALI (ST. CHD NO.1) 1953-1982 ********** RUNOFF (m^3/s)

	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	MEAN
1953	1.251	1.158	1.176	1.119	1.141	0.974	0.801	0.766	0.596	0.547	0.595	0.715	10.838	0.903
1954	0.876	0.898	0.761	0.865	0.865	0.957	0.959	0.996	0.847	0.721	0.880	1.118	10.742	0.895
1955	1.126	1.040	0.980	0.817	0.756	1.178	1.657	1.615	1.554	1.576	1.425	1.335	15.060	1.255
1956	1.178	1.182	1.035	0.853	0.831	0.786	0.934	0.994	0.862	0.864	0.866	1.054	11.439	0.953
1957	0.999	1.014	1.293	1.235	1.066	0.979	1.966	1.741	1.497	1.229	0.961	1.045	15.025	1.252
1958	0.991	1.024	1.075	0.985	0.890	1.140	1.188	1.280	1.111	1.150	1.066	1.080	12.981	1.082
1959	1.155	1.267	1.167	1.116	1.227	1.166	1.221	1.006	0.961	0.858	0.881	0.935	12.960	1.080
1960	1.067	1.059	1.237	1.125	1.020	1.323	1.186	1.123	0.953	0.905	0.874	0.774	12.646	1.054
1961	0.967	0.986	0.940	0.848	0.821	0.651	0.643	0.511	0.427	0.341	0.297	0.388	7.820	0.652
1962	0.533	0.661	0.725	0.779	0.804	0.874	1.184	1.109	0.924	0.933	0.821	0.961	10.308	0.859
1963	1.172	1.079	1.214	1.256	1.000	0.845	0.657	0.506	0.404	0.490	0.566	0.735	9.923	0.827
1964	0.814	0.872	1.047	1.075	1.367	1.226	1.069	0.971	1.102	1.436	1.408	1.257	13.643	1.137
1965	1.285	1.158	1.118	1.047	0.890	0.834	0.690	0.547	0.454	0.412	0.580	0.600	9.617	0.801
1966	0.746	0.862	0.999	1.014	1.110	1.025	0.832	0.805	0.756	1.103	1.319	1.363	11.935	0.995
1967	1.353	1.398	1.217	1.015	0.858	0.699	0.667	0.577	0.516	0.460	0.400	0.662	9.821	0.818
1968	0.745	0.776	0.896	1.025	1.328	1.273	1.928	1.852	1.821	1.640	1.391	1.372	16.048	1.337
1969	1.376	1.395	1.336	1.398	1.152	1.030	0.907	0.812	0.709	0.748	0.707	0.850	12.420	1.035
1970	0.865	0.850	0.792	0.808	0.934	1.027	1.011	0.867	0.840	0.797	0.982	1.088	10.858	0.905
1971	1.192	1.197	1.136	0.940	1.078	1.151	0.974	0.827	0.883	0.988	1.025	0.962	12.353	1.029
1972	1.026	0.995	1.024	0.909	0.873	0.761	0.610	0.479	0.367	0.295	0.421	0.517	8.278	0.690
1973	0.829	0.936	1.087	1.143	1.302	1.397	1.550	1.365	1.657	1.636	1.481	1.333	15.716	1.310
1974	1.270	1.327	1.215	1.083	0.954	0.824	0.691	1.005	1.194	1.653	1.627	1.624	14.466	1.206
1975	1.637	1.493	1.456	1.377	1.255	1.080	0.886	0.908	0.994	1.110	1.076	1.078	14.351	1.196
1976	1.031	1.046	1.070	0.976	0.810	0.667	0.581	0.489	0.404	0.866	1.414	1.303	10.656	0.888
1977	1.374	1.291	1.300	1.301	1.099	0.920	0.803	0.639	0.559	0.492	0.440	0.598	10.816	0.901
1978	0.745	0.871	0.883	0.953	1.132	1.189	1.147	1.079	1.116	1.082	1.006	0.931	12.133	1.011
1979	0.970	1.154	1.081	1.078	1.112	1.706	1.527	1.556	1.319	1.071	1.164	1.123	14.860	1.238
1980	1.146	1.028	0.891	0.849	0.767	0.605	0.492	0.699	0.597	0.969	0.989	1.005	10.038	0.836
1981	0.967	1.044	0.943	0.848	1.057	1.240	1.367	1.261	1.132	0.964	1.029	0.957	12.808	1.067
1982	0.850	0.883	0.941	0.873	0.728	0.599	0.469	0.378	0.289	0.221	0.161	0.196	6.588	0.549
TOTAL	31.535	31.943	32.034	30.710	30.227	30.125	30.597	28.761	26.844	27.558	27.853	28.960	357.147	29.761
MEAN	1.051	1.065	1.068	1.024	1.008	1.004	1.020	0.959	0.895	0.919	0.928	0.965	11.905	0.992
S.D.	0.235	0.194	0.173	0.167	0.179	0.254	0.394	0.384	0.398	0.401	0.374	0.316	2.338	0.195
CE	0.223	0.182	0.162	0.163	0.178	0.253	0.386	0.400	0.445	0.437	0.403	0.327	0.196	0.196

Table-3.3 (3) : Computer Output of Long-term Base Flow Simulation

**********K.GLIDIK (ST. PRONOJIWO DAM) 1953-1982 ********** RUNOFF (m^3/s)

	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	MEAN
1953	2.959	2.991	2.991	2.940	2.923	2.774	2.537	2.279	1.962	1.746	1.644	1.666	29.413	2.451
1954	1.818	1.972	2.006	2.104	2.131	2.249	2.331	2.415	2.353	2.224	2.176	2.291	26.071	2.173
1955	2.447	2.559	2.557	2.395	2.251	2.400	2.627	3.219	3.523	3.631	3.554	3.487	34.849	2.904
1956	3.317	3.177	2.955	2.668	2.385	2.145	2.130	2.202	2.207	2.222	2.207	2.319	29.934	2.494
1957	2.383	2.485	2.697	2.799	2.804	2.718	3.248	3.468	3.742	3.570	3.173	2.906	35.993	2.999
1958	2.705	2.592	2.581	2.527	2.372	2.433	2.500	2.773	2.841	2.883	2.785	2.748	31.741	2.645
1959	2.747	2.842	2.853	2.845	2.853	2.809	2.884	2.775	2.680	2.479	2.365	2.295	32.427	2.702
1960	2.375	2.436	2.635	2.670	2.668	2.841	2.846	2.898	2.761	2.589	2.406	2.246	31.372	2.614
1961	2.241	2.262	2.304	2.264	2.200	2.021	1.943	1.750	1.578	1.375	1.191	1.114	22.244	1.854
1962	1.174	1.347	1.551	1.748	1.892	2.048	2.351	2.522	2.575	2.549	2.374	2.357	24.487	2.041
1963	2.480	2.537	2.717	2.818	2.719	2.575	2.293	1.982	1.695	1.515	1.423	1.528	26.283	2.190
1964	1.672	1.859	2.118	2.337	2.723	2.878	2.928	2.808	2.753	2.900	3.053	3.115	31.143	2.595
1965	3.134	3.002	2.900	2.789	2.607	2.457	2.212	1.914	1.639	1.428	1.412	1.436	26.930	2.244
1966	1.594	1.785	2.041	2.244	2.476	2.549	2.493	2.390	2.219	2.332	2.549	2.816	27.488	2.291
1967	3.008	3.153	3.103	2.977	2.737	2.430	2.176	1.896	1.661	1.459	1.307	1.387	27.295	2.275
1968	1.517	1.716	1.952	2.181	2.545	2.786	3.421	3.751	4.104	4.117	3.916	3.689	35.695	2.975
1969	3.535	3.418	3.314	3.286	3.053	2.871	2.604	2.402	2.197	2.085	1.946	1.973	32.683	2.724
1970	1.998	2.051	2.061	2.078	2.163	2.298	2.406	2.390	2.333	2.209	2.257	2.360	26.605	2.217
1971	2.537	2.642	2.722	2.595	2.755	2.852	2.884	2.748	2.575	2.478	2.492	2.536	31.817	2.651
1972	2.528	2.454	2.453	2.334	2.314	2.199	2.005	1.709	1.381	1.063	0.958	0.952	22.350	1.862
1973	1.199	1.534	1.965	2.278	2.591	2.811	3.010	3.068	3.021	3.172	3.267	3.342	31.258	2.605
1974	3.333	3.244	3.059	2.864	2.619	2.313	2.007	2.136	2.255	2.969	3.454	3.931	34.184	2.849
1975	4.094	4.126	4.064	4.039	4.002	3.743	3.375	2.936	2.830	2.969	3.205	3.355	42.738	3.562
1976	3.333	3.218	3.098	2.954	2.705	2.397	1.994	1.633	1.335	1.464	1.983	2.355	28.470	2.372
1977	2.737	2.740	2.732	2.734	2.681	2.521	2.318	1.980	1.683	1.427	1.231	1.102	25.885	2.157
1978	1.069	1.089	1.258	1.467	1.818	2.296	2.826	3.274	3.686	3.979	4.044	3.945	30.751	2.563
1979	3.705	3.485	3.229	3.090	2.967	3.102	3.090	3.095	2.873	2.606	2.504	2.404	36.148	3.012
1980	2.369	2.297	2.134	2.010	1.901	1.743	1.582	1.547	1.439	1.580	1.708	1.851	22.161	1.847
1981	1.961	2.008	1.941	1.879	1.957	2.251	2.709	3.036	3.154	3.177	3.150	3.105	30.329	2.527
1982	2.950	2.746	2.543	2.326	2.062	1.784	1.484	1.204	0.929	0.685	0.498	0.485	19.695	1.641
TOTAL	74.922	75.766	76.532	76.240	75.873	75.294	75.414	74.203	71.985	70.881	70.233	71.094	888.439	74.036
MEAN	2.497	2.526	2.551	2.541	2.529	2.510	2.514	2.473	2.399	2.363	2.341	2.370	29.615	2.468
S.D.	0.763	0.677	0.573	0.501	0.434	0.402	0.484	0.614	0.774	0.861	0.889	0.891	4.933	0.411
CV	0.305	0.268	0.225	0.197	0.172	0.160	0.193	0.248	0.323	0.364	0.380	0.376	0.167	0.167

3.2 GROUNDWATER OF K. LENGKONG FAN

3.2.1 GROUNDWATER RESERVOIR

The hydrogeological structure of K. Lengkong Fan consists of impervious layers of Tertiary volcanic rocks and Quarternary Older volcanic products, and of a aquiclude layer of younger volcanic products from Mt. Semeru. (Refer to Fig.-3.8 and 3.9)

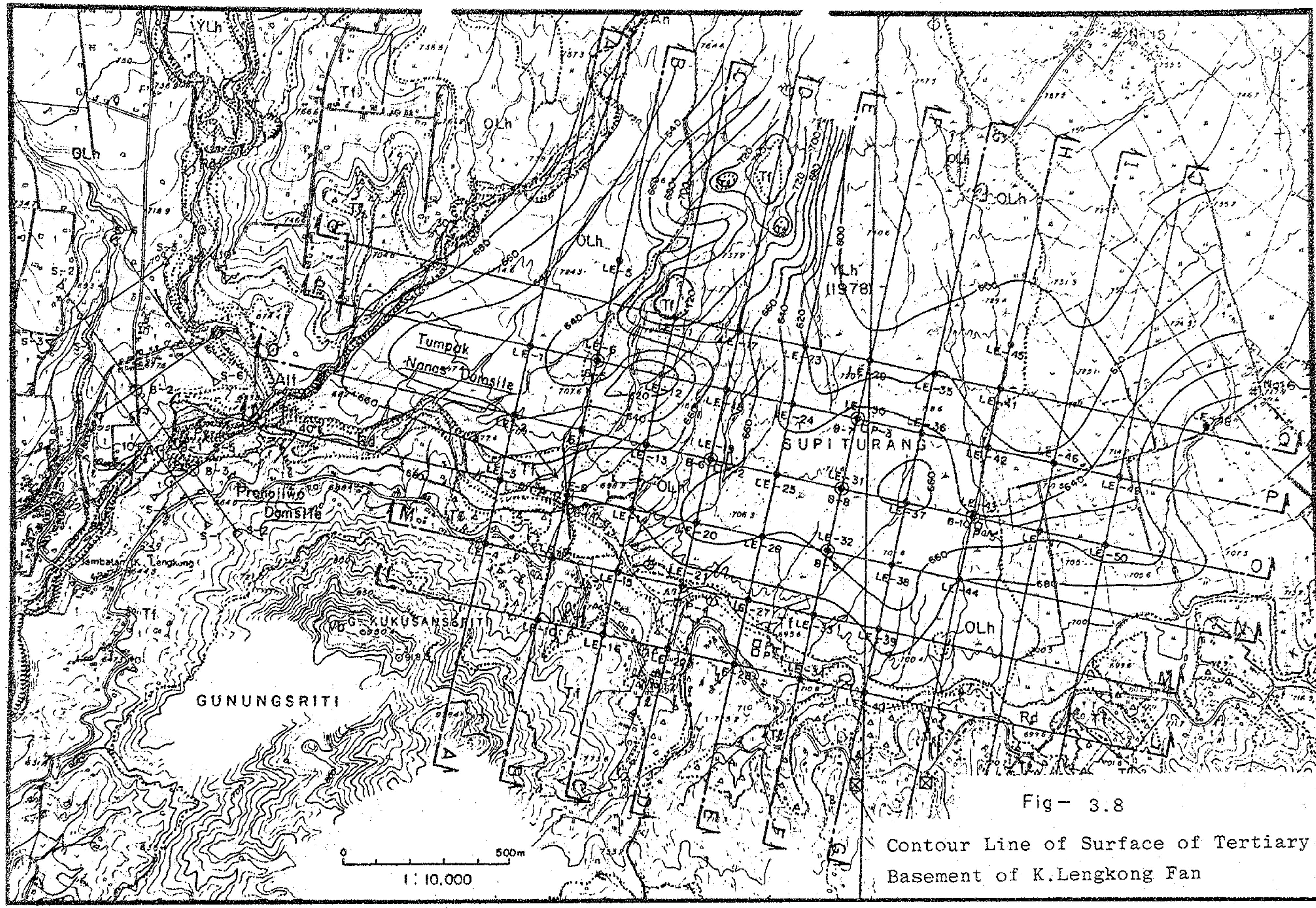
It seems that the ridge of impervious layers, which runs south to north in the western part of the fan, blocks the flow of ground water to further west of the fan.

According to the in-situ permeability test conducted on the surface of K. Lengkong Fan, the coefficient of permeability of Lahar deposits is small at $K = 5 \times 10^{-4}$ cm/s.

The electric sounding, however, suggests that various layers of high permeability such as auto- brecciated lava and pyroclastic deposits, consisting mainly of lava block and containing almost no fine grains, are irregularly intercalated in the older Lahar deposits.

Consequently, the permeability of the Lahar deposits is not considered uniform and varies from $K = 10^{-2}$ cm/s. to $K = 10^{-4}$m/s.

The top layer of Tertiary basement under older Lahar deposits consists of highly weathered tuff. The coefficient of permeability of this layer is estimated at $K = 10^{-6} - 10^{-7}$ cm/s according to the laboratory soil test and other studies and appears to be capable of acting as an adequate impervious basement.



Fig— 3.8

Contour Line of Surface of Tertiary Basement of K.Lengkong Fan

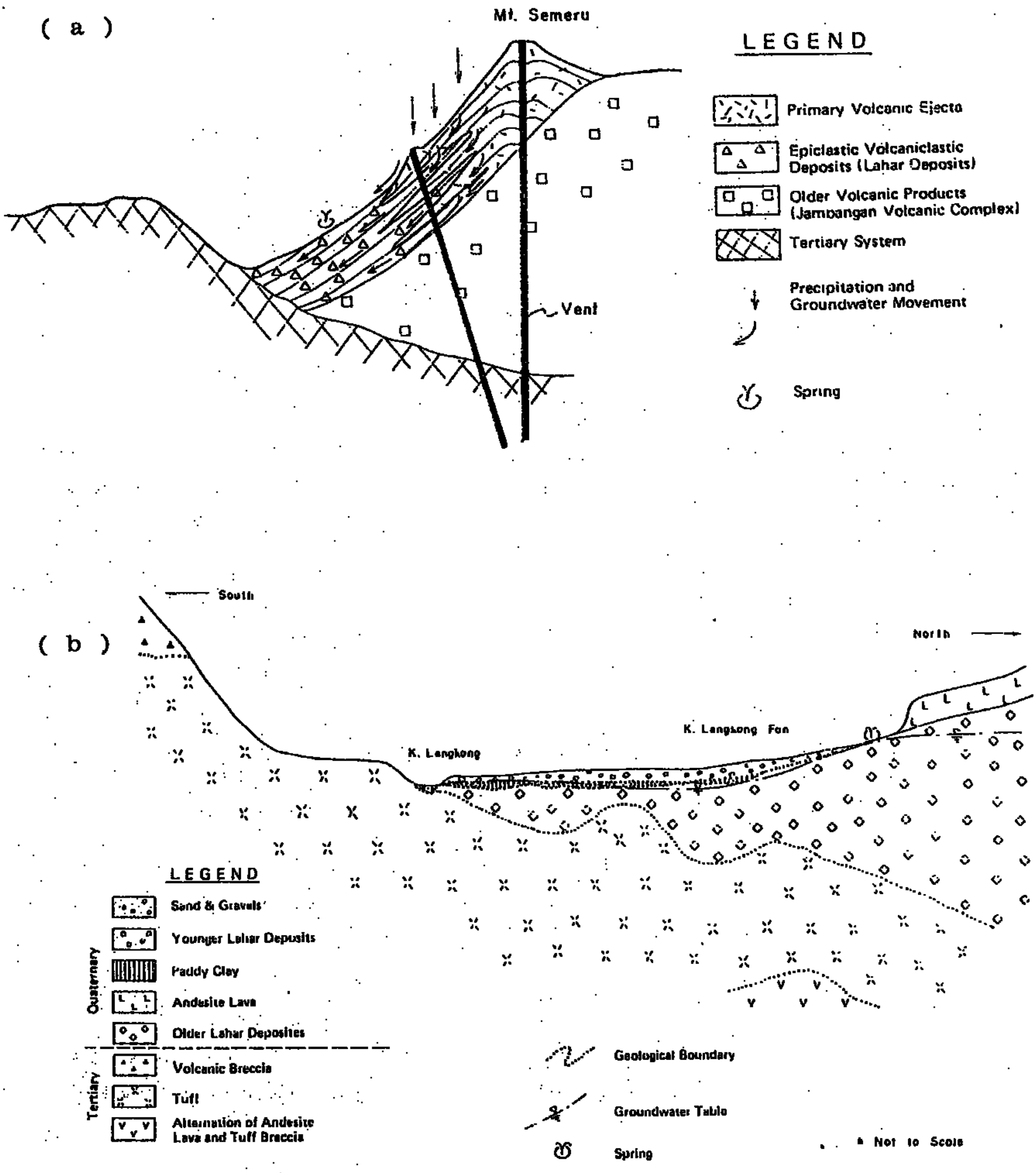


Fig. - 3.9 Schematic Hydrogeological Model of K.Lengkong Fan

3.2.2 GROUNDWATER POTENTIAL

The following three estimation methods are employed to evaluate the groundwater potential in K. Lengkong Fan:

① Estimation from the reservoir size of groundwater;

② Estimation from the water balance;

③ Estimation from the simulation of groundwater movement.

(1) Estimation from the Reservoir Size of Groundwater

The developable area (Ag) of groundwater in K. Lengkong Fan, which is surrounded by the following boundaries, is about 10 km^2

- North boundary;
  EL. 800 m contour line of Mt. Semeru

- South boundary;
  National road along K. Lengkong

- West boundary;
  Impervious underground ridge of tuff

- East boundary;
  K. Curah Kobo'an

On the basis of the information obtained so far, we assume the chracteristics parameters of groundwater reservoir as follows:

Hg = 50 m, mean aquifer depth
Rev = 0.2, effective void rate

From the above data, the maximum groundwater volume (Vg) can be estimated as follows:

$$Vg = Ag \times Hg \times Rev$$
$$= 10 \times 10^6 m \times 50\ m \times 0.2$$
$$= 100 \times 10^6 m^3$$

If an annual cycle of extraction and recharge is possible, Vg ($100 \times 10^6 m^3$) means the annual average discharge of 3.2 m^3/s.

(2) Estimation From Water Balance

The rainwater falling on the ground surface will circulate in the form of 1) surface runoff, 2) infiltration or 3) evapotranspiration which are all inter-related. However, since this study aims to outline groundwater development, a simplified model of water balance should be considered here.

The equation of water balance is given as follows.

$$R = Q/A + f.E + I$$

Where, A = Area of watershed (m^2)
R = Rainfall (m)
Q = Discharge (m^3)
E = Evaporation volume in evaporimeter (m)
I = Infiltration volume (m)
f = Factor = 0.5 = (actual evaporation volume/ evaporation volume in evaporimeter)

The data are incomplete for the above items regarding K. Lengkong Fan area.

Table-3.4 shows the water balance in the area of K. Bandyudo, near K. Lengkong, based on observation data collected from the area, however, the main items of data were observed at the following locations.

1. Rainfall .... Gugialit
2. Discharge .... Dam Umbul (catchment area = 412.75 km^2)
3. Evapotranspiration .... Gebuk Domes Hillir

It is conceivable from Table-3.4 that some 30% of rainfall may infiltrate into the ground.

If we can apply this infiltration rate of 30% to the K. Lengkong Fan area, at the developable groundwater (Vg) of annual cycle with no artificial recharge can be calculated as follows:

$$\begin{aligned} Vg &= A \times R \times frg \\ &= 10 \times 10^6 m^2 \times 3.5\ m \times 0.3 \\ &= 10.5 \times 10^6 m^3 \end{aligned}$$

Where, A: Area of K. Lengkong Fan
R: Annual mean rainfall
frg: Infiltration rate of rain water

(3) Estimation from the Simulation of Groundwater Movement

(a) Basic Equation

Since the groundwater in K. Lengkong Fan is considered unconfined, the basic equations of groundwater flow are as follows:

Table - 3.4 Water Balance of K.Bondyudo Basin

YEAR / ITEM / MONTH	1979/80					1980/1981				
	RAINFALL R(mm)	RUNOFF $Q(\times 10^6 m^3)$	RUNOFF q(mm)	EVAPORA-TION E(mm)	G.W. RECHARGE (mm)	RAINFALL R(mm)	RUNOFF $Q(\times 10^6 m^3)$	RUNOFF q(mm)	EVAPORA-TION E(mm)	G.W. RECHARGE (mm)
SEP.	25	9.292	23	72	- 72	0	10.931	26	78	- 104
OCT.	101	7.773	19	75	7	406	11.514	28	77	301
NOV.	624	10.038	24	(70)	530	0	26.818	65	45	- 110
DEC.	283	13.336	32	74	177	499	(26.701)	65	39	395
JAN.	249	14.907	36	67	146	161	(23.726)	57	60	44
FEB.	317	14.927	36	51	230	138	19.886	48	61	29
MAR.	36	24.762	60	71	- 95	0	47.156	114	73	- 187
APR.	175	23.010	56	73	46	52	16.695	40	62	- 50
MAY	8	15.300	37	82	- 111	162	8.408	20	74	68
JUN.	0	19.882	48	91	- 129	210	9.277	22	75	113
JUL.	50	21.309	52	71	- 73	124	10.209	25	76	23
AUG.	108	14.134	34	86	- 12	54	2.448	6	77	- 29
Total	1,976	-	457	873	646	1,806	-	516	797	493
RATIO	1.00	-	0.23	0.44	0.33	1.00	-	0.29	0.44	0.27

STATION: RAINFALL ; Gugialit
RUNOFF ; Dam Umbul (CA = 412.75 km^2)
EVAPORATION; Gebuk Dams Hillir

$$f_{rg} = \frac{\text{Groundwater Recharge}}{\text{Rainfall}} = \frac{0.33 + 0.27}{2} = 0.30$$

$$S \cdot \frac{\partial H}{\partial t} = k \cdot (H - Z) \cdot \left(\frac{\partial^2 H}{\partial x^2} + \frac{\partial^2 H}{\partial y^2}\right) + Q \qquad \ldots\ldots (1)$$

Where, H = Groundwater level (El. m)

Z = Elevation of impermeable bedrock (EL. m)

k = Permeability (m/day)

Q = Groundwater recharge or pumping volume (m^3/day)

S = Coefficient of storage

However, when fluctuation of water-stage is relatively insignificant as against the thickness of the aquifer, a simplified expression (2) of the above (1) can be applied.

$$S \frac{\partial H}{\partial t} = k{\cdot}b \cdot \left(\frac{\partial^2 H}{\partial x^2} + \frac{\partial^2 H}{\partial y^2}\right) + Q \qquad \ldots\ldots (2)$$

Where b = Thickness of aquifer (m)

In the calculation of groundwater movement, the unsteady finite different method is applied by using the above eq.(2). Fig.-3.10 shows the simulation model for the analysis of groundwater movement.

(b) Restrictive Conditions for Developable Water Volume.

In general, the following conditions are taken into consideration when estimating the volume of developable groundwater.

① Sustained yield is the volume of groundwater capable of being continuously pumped from a groundwater basin without causing any undesirable results such as increase of pump head triggered by drawdown, land subsidence and the infiltration of salty water, etc.

K.LENKONG FAN GROUNDWATER DEVELOPMENT SCHEME CASE-1

Number of Elements : 173

Number of Nodal points : 212

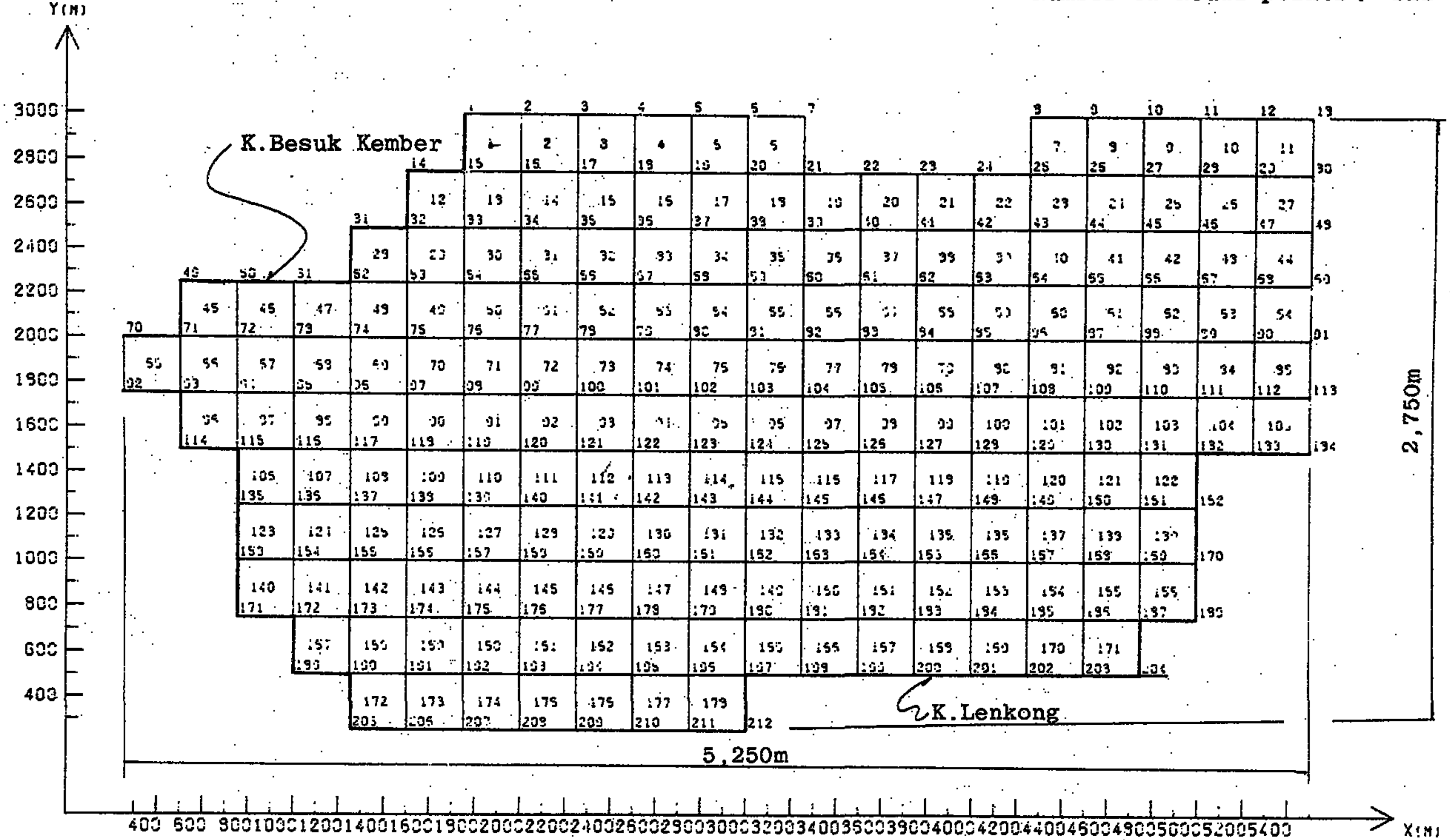


Fig.-3 10 Simulation Model

Scale 1;25,000

② Mining yield is the volume of groundwater capable of being pumped at a closed groundwater basin where water replacement cannot be expected (the same definition as recoverable resources in mining).

③ Critical water level is basically equal to ① above but the groundwater volume capable of being pumped is based on the water level in particular.

The Lengkong aquifer has a vast groundwater replacement area of the Mt. Semeru piedmonts; therefore, it is not a closed groundwater basin as ②, which suggests that the developable groundwater volume can be estimated according to the condition of ① above.

- Conditions for Sustained Yield -

① Replacement condition ..... The pumped volume does not exceed the mean annual volume replaced.

② Economic condition ..... The pumping cost shall not exceed a certain limit.

③ Water quality condition ..... The groundwater level shall not be lower than a level which invites deterioration of water quality (salified water).

④ Legislative condition that does not violate the right of water use.

The urgent requirement of supplying irrigation water running short in the dry season is imposed on the groundwater development project of K. Lengkong Aquifer. Therefore, the condition of ② above will be excluded. In addition, a deterioration of groundwater such as salification cannot be considered because the groundwater level in the K. Lengkong basin stands at El. 700 m or higher. The restrictive condition of (4) can be excluded by distributing the pumped water to the public. As a result, the developable groundwater volume will be decided according to the condition of (1).

Finally, the developable groundwater volume in K. Lengkong aquifer is determined as follows:

> "Developable groundwater volume shall not be exceeded by the mean annual replacement quantity, which means that a lowering of the groundwater level by pumping must be restored within a year."

(c) Conditions for Simulation

① Aquifer Parameters

Permeability k = 10^{-3} cm/s = 0.864 m/day
Thickness of aquifer b = 150 m (constant)
Coefficient of storage d = 0.2
Void ratio B = 0.2

② Replaceable Groundwater Volume by Rainfall (Refer to Fig.-3.11)

The replaceable groundwater volume by rainfall is 30% of the average rainfall for 28 years from 1951/52 to 1979/80 in Gudung Sawur.

③ Pumping Volume

Pumping is to be carried out at 20 points. The pumping volume is to be divided into 2 areas.

- Q = 1.0 m^3/s (= 0.5 m^3/s/point x 20 points)

- Q = 0.5 m^3/s (= 0.25 m^3/s/point x 20 points)

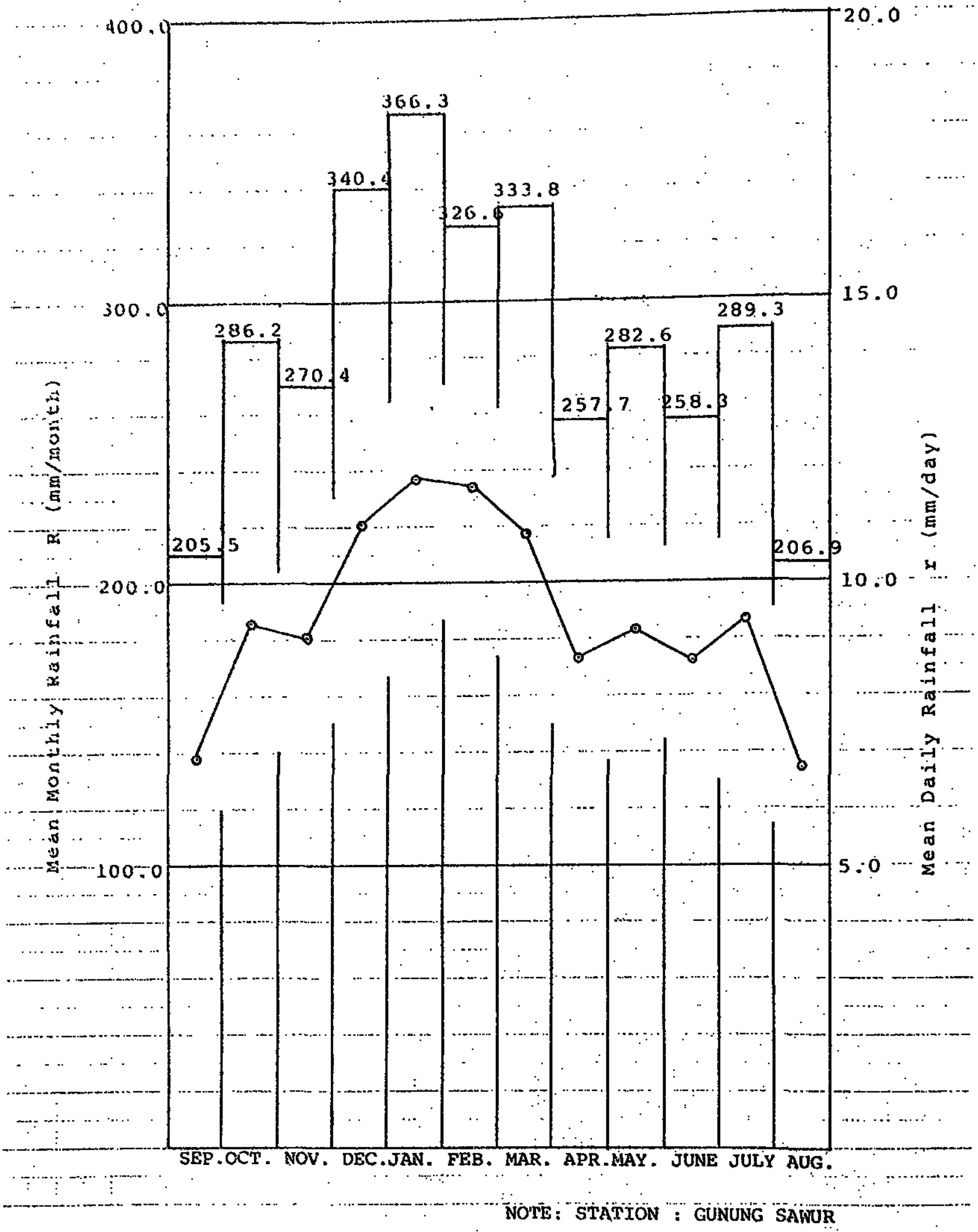


Fig. - 3.11 Mean Monthly & Daily Rainfall
(1951/52 - 1979/80)

④ The groundwater level at the boundary of K. Lengkong, K. Besuk Kembar and piedmonts of Mt. Semeru is to be kept constant.

⑤ Calculation Equation

The calculation shall be conducted for one year in 10 days periods using the unsteady finit difference method.

(a) Calculation Results

- Fluctuation in the Groundwater Level -

In accordance with the calculation conditions stated in Sec. 3.2, the results of the calculated fluctuations in the groundwater level are shown in Fig.-3.12, 3.13 and 3.14. From the said figures following points have become clear:

① Drop in the Level of Groundwater

After the commencement of pumping, the groundwater level dropped steadily. At the conclusion of pumping (180 days later), the maximum amount of drop in the level of groundwater at the well was as follows.

a) Drop of 10 m when Q = 0.5 m^3/s
(Nodal Point 127) ie EL. 765 m - EL. 755 m
= 10 m

b) Drop of 21 m when Q = 1.0 m^3/s
(Nodal Point 127) ie EL. 765 m - EL. 744 = 21 m

② Recovery in the Groundwater Level

After the passage of a 180 day recharging period counting from the conclusion of pumping, the amount of recovery in the level of ground water at the well was as follows.

a) Recovery of 5 m when Q = 0.5 m^3/s
(Nodal Point 127) ie EL. 760 m - 755 m = 5 m

Difference between before pumping and after recharging is 5 m (EL. 765 m - EL. 760 m).

b) Recovery of 9 m when Q = 1.0 m /s
(Nodal Point 127) (EL. 753 m - EL. 744 m)

Difference between before pumping and after recharging is 12 m (EL. 765 m - EL. 753).

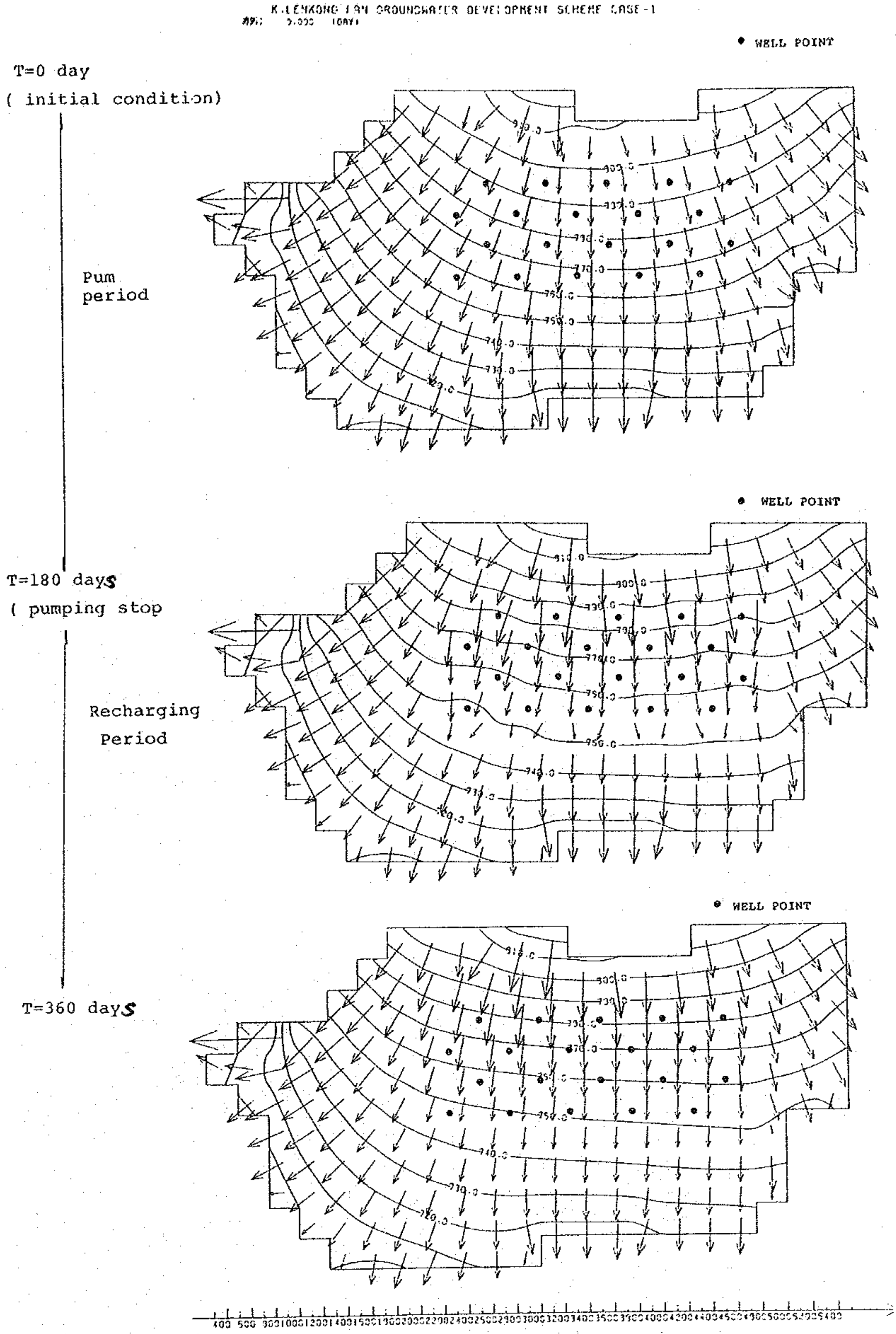


Fig.- 3.12 Groundwater Level Fluctuations
(Pumping Discharge;0.5m^3/s)

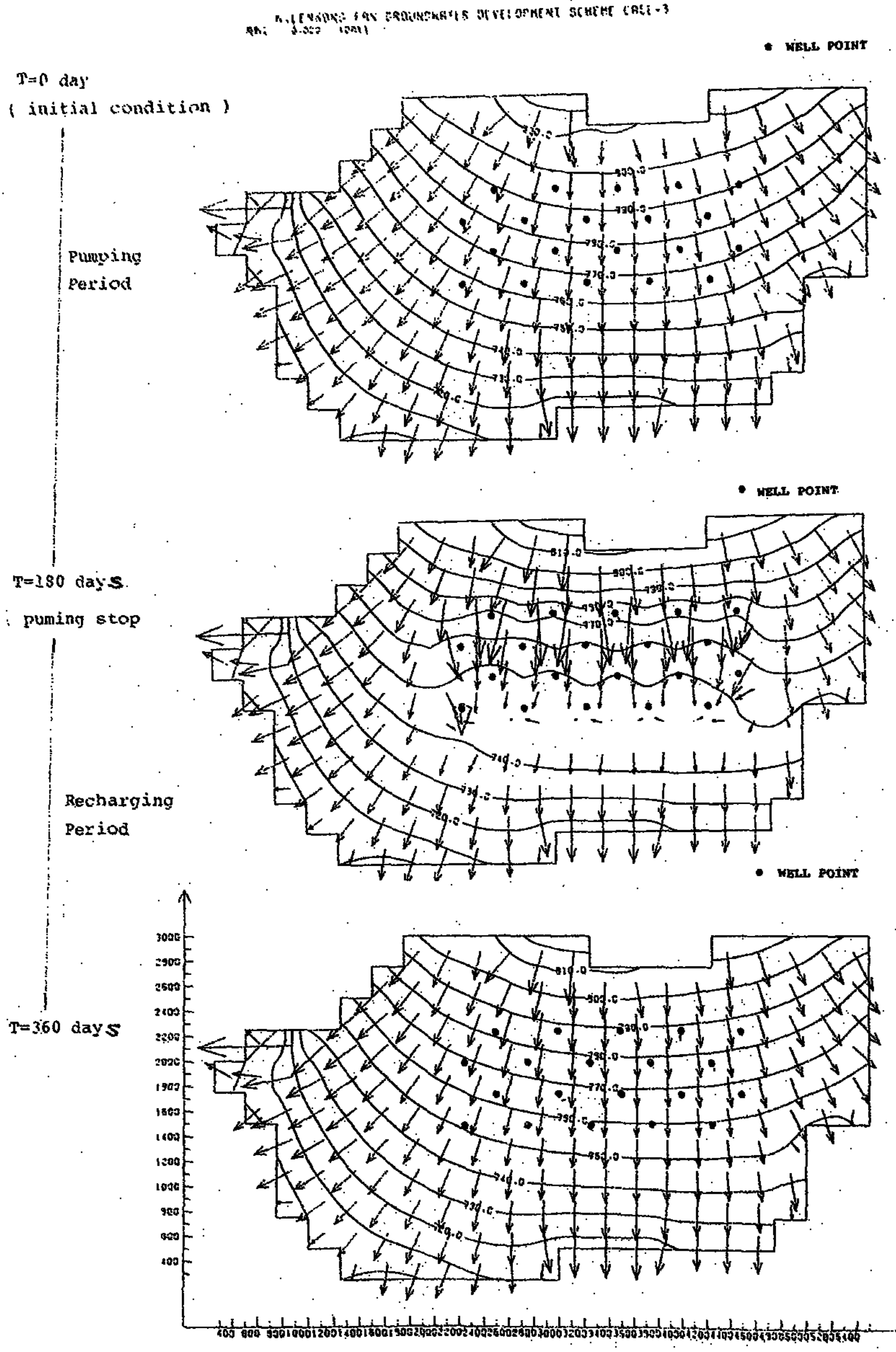


Fig.- 3 .13 Groundwater Level fluctuations
(Pumping Discharge ; $1.0m^3/s$)

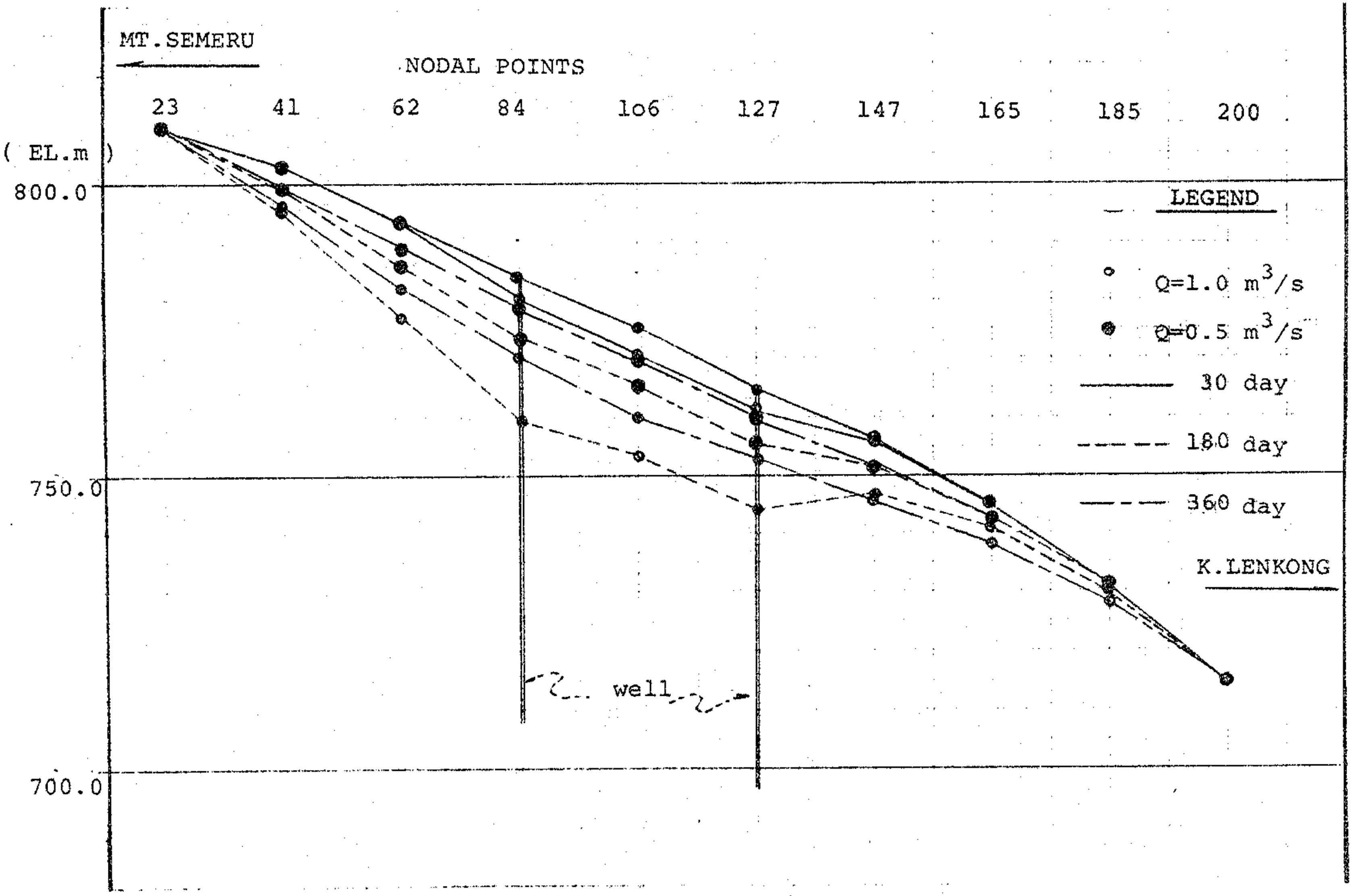


Fig. - 3.14 Fluctuations in the Groundwater Level due to Pumping

- Developable Groundwater Volume

Under the established conditions stated in the previous section, in other words, under the condition that the pumping volume will not exceed the recharging volume, developable groundwater volume will be less than 0.5 m^3/s. Furthermore, if a larger volume of water development were to be expected, an increase in the number of wells and/or artificial recharging from the river water would be required.

① Permeability coefficient 10^{-3} cm/s

② Number of wells: 20 points

③ Period of pumping: 180 days continuous

④ Period of recharging: 180 days continuous

(4) Items for Future Study

To be able to make detailed predictions of developable groundwater volume in the future, clear and accurate definition of the following aquifer conditions is required, indeed, indispensable. These data can be obtained and clarified by carrying out an appropriate hydrogeological survey.

1) Permeability coefficient
2) Thickness of aquifers
3) Groundwater level

4. WATER CONSERVATION PLANS

4.1 GENERAL

(1) Study Flowchart

The study flowchart of the water conservation preliminary plan is shown in Fig.-4.1.

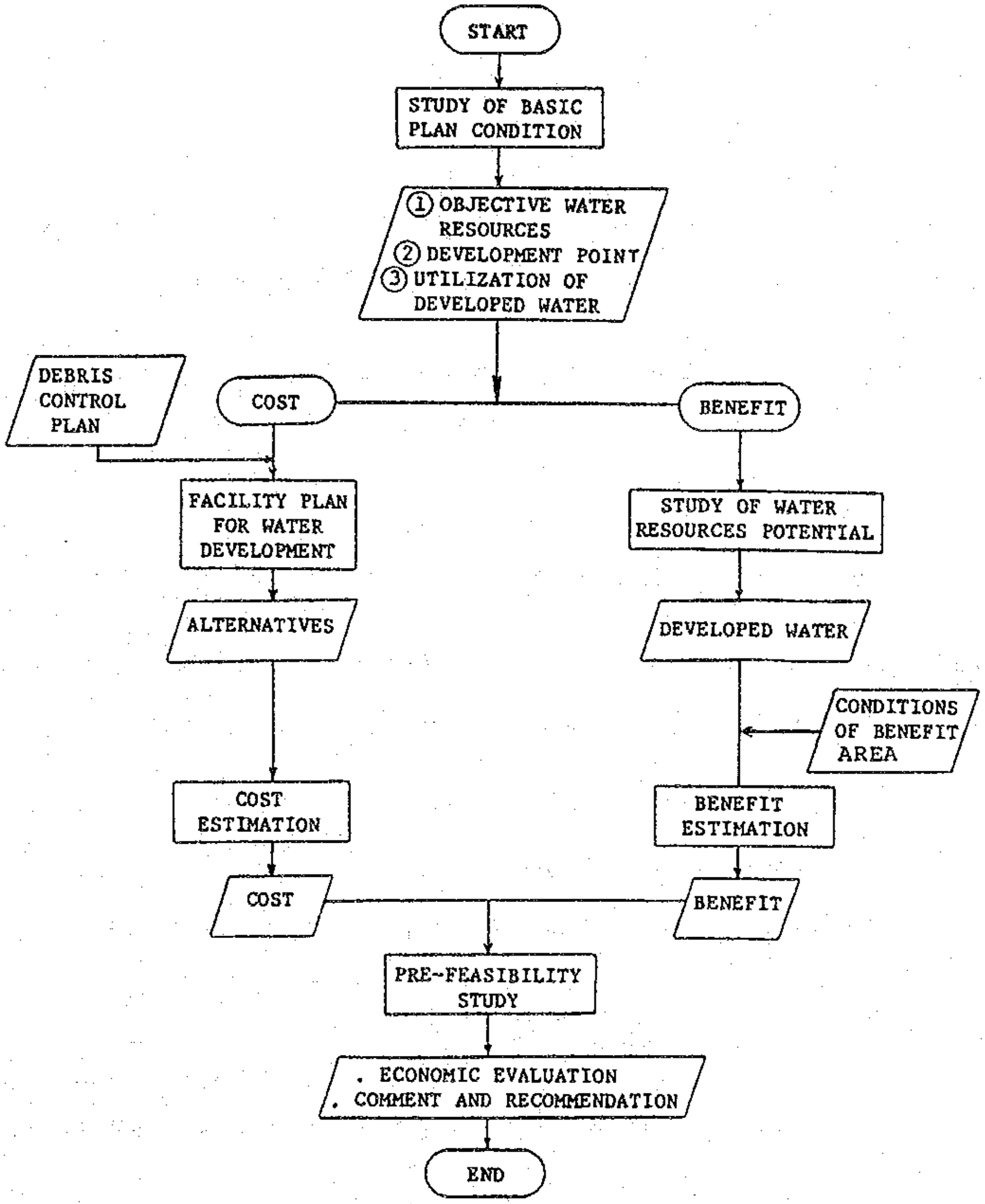


Fig.-4.1 Study Flowchart of Water Conservation Preliminary Plan

(2) Basic Plan Conditions

(a) Preconditions for Local Prevention of Disaster

① The disaster prevention in the exploitation area is assured as the sediment control plan is achieved to a certain degree.

② The Pronojiwo dam is constructed according to the diversion plan, which is an integral part of the sediment control plan.

(b) Objective Water Resources

① The base flow of K. Besuk Bang and K. Lengkong in the K. Glidik basin.

② The groundwater of the K. Lengkong Fan.

③ The base flow of K. Besuk Kobo'an in the K. Rejali basin.

(c) Exploitation Point

① The planned Pronojiwo dam site along K. Glidik.

② The sites for the check dam No. 1 of K. Rejali and of K. Leprak.

(d) Use of Exploited Water

① Purpose of Water Use

Irrigation and generation of electric power.

② Period of Water Use

Surface water (the base run-off) is used all the year round and groundwater is used during the dry season.