2.2 GROUNDWATER LEVEL OBSERVATION

2.2.1 SELECTION OF OBSERVATION WELLS

Existing wells in the study area can be almost recognized as shallow dug wells which are generally used for drinking and domestic water. Large scale groundwater development for agricultural purpose is non-existent.

Taking account of topographical conditions, groundwater basin structure, maintenance of equipment and so on, the following wells are selected as observation well for automatic recording water level gauge;

i) K. Mujur basin (5 wells)

- Upper reach ; Sumber Mujur I and II
- Middle reach ; Tumpeng,
  Kertosari I and II

ii) K. Rejali basin (9 wells)

- Upper reach ; Curah Kobo'an I and II
- Middle reach ; Sumber Wuluh I and II
  Urang Gantung I and II
- Lower reach ; Tempeh Kidul I and II
  Selok Awar-Awar

iii) K. Lengkong basin (3 wells)

- North side ; Sumber Urip Krajan
  Rekesan
- South side ; Tumpak Nanas

The location of these observation wells is as shown in Fig.-2.1.

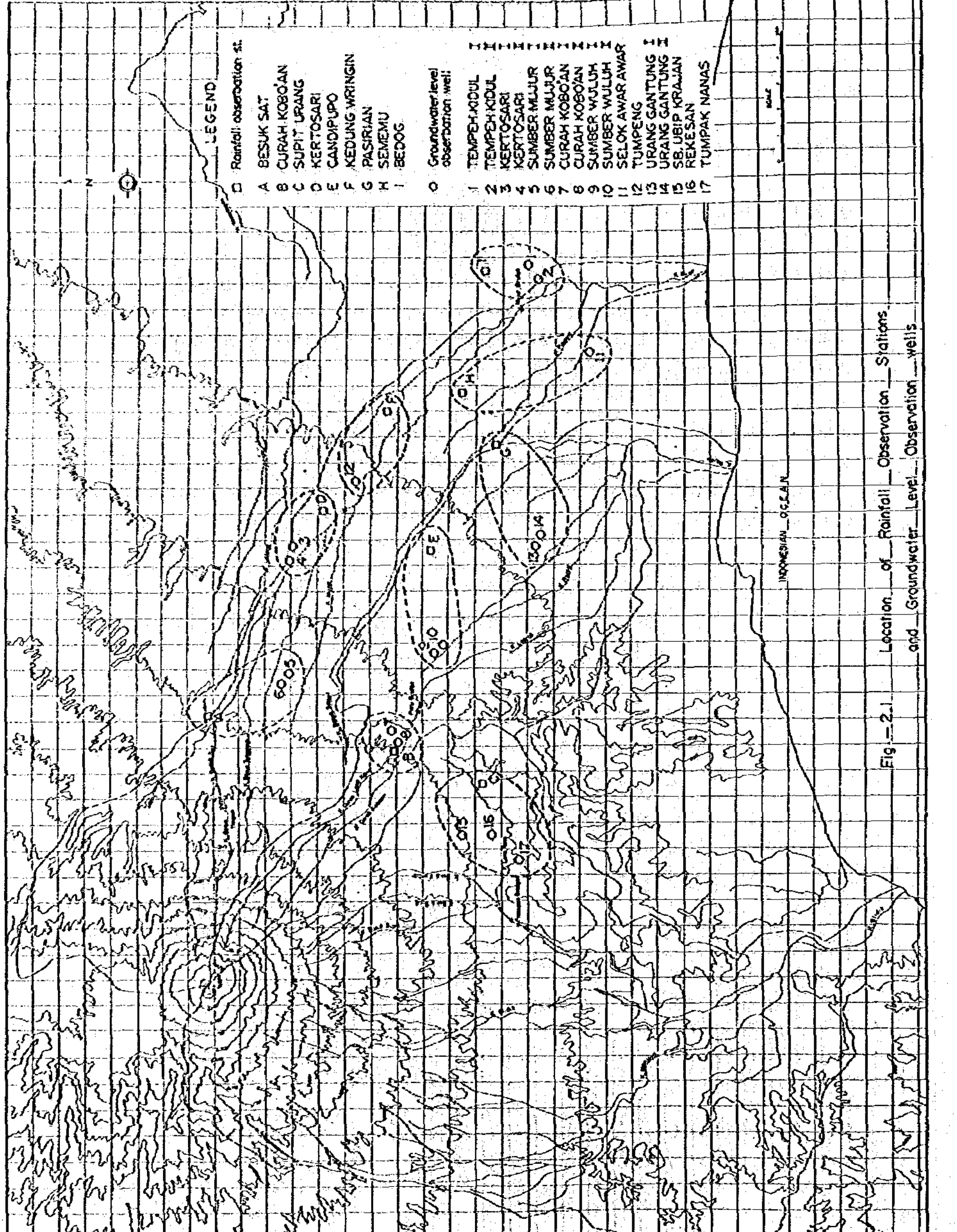


Fig. 2.1 Location of Rainfall Observation Stations and Groundwater Level Observation wells

2.2.2 METHODOLOGY OF GROUNDWATER LEVEL OBSERVATION

(1) Equipments

Necessary equipments for groundwater level observation were provided by JICA, based on the requests of the Government of Indonesia.

i) Automatic Recording Water Level Gauges

a) Delivery;
11 gauges in December 1981
6 gauges in March 1982

b) Model;
W-301 Float-type automatic recording Water level gauge made by NAKAASA SOKKI Co., Ltd. (Fig.-2.2)

c) Specifications;

Measurement range	; 3 or 6 m
Precision	; ±2% of total span
Recording duration	; 7 days
Diameter of float	; ø180 mm
Dimension	; 330(W) x 280(H) x 175(D) mm
Weight	; about 4.5 kg

ii) Portable Water Level Gauges

a) Delivery;
2 gauges in December 1981

b) Model;
SKT-2B Portable water level gauge made by SAKATA DENKI Co., Ltd. (Fig.-2.3).

c) Specifications;

Measurement range ; 50 m
Precision ; ±1 mm
Diameter of sensor plumb; ø16 mm
Dimension ; 220(W) x 30(D) x 280(H) mm
Weight ; 1.8 kg

(2) Installation

The installation of automatic recording water level gauges was carried out by Mt. Semeru Project Office, under the technical guidance given by Mr. SAKAI (Japanese expert of the Ministry of Public Works).

(3) Execution of Observation

Groundwater level observation using automatic recording water level gauge is being executed under the charge of Mt. Semeru Project Office. Renewal of recording sheet and water level check are executed once a week by proprietor of well.

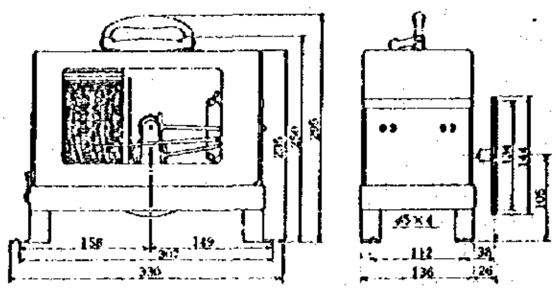


Fig.-2-2 Automatic Recording Water Level Gauge

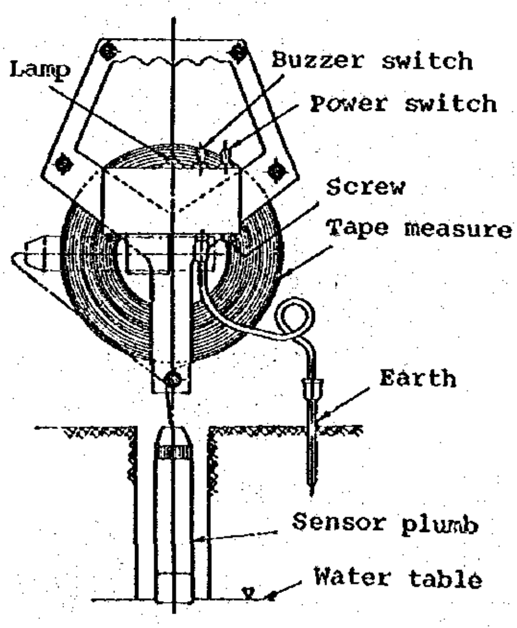


Fig.-2.3 Portable Water Level Gauge

2.2.3 INSPECTION OF OBSERVATION WELLS

Inspection of observation wells which intend to check and correct actual observation conditions of each automatic recording water level gauge was carried out two times, upto the present; in August 1982 and in October 1983. These results obtained in collaboration with Mt. Semeru Project Office is compiled in Appendix C-1: Well Inventory.

2.2.4 OBSERVATION RESULTS

The original recording sheets of groundwater level observation are under control of Mt. Semeru Project Office. From the reading of water level check values marked in these recording sheets, weekly observation results of groundwater level are compiled in the supplement C-1; WEEKLY OBSERVATION RESULTS OF GROUNDWATER LEVEL.

Taking account of the availability for analysis, observation condition can be classified into the following three groups;

Group	Equipment Condition	Water Level Check	Availability for Analysis
I	Good	Done	Available
II	Good	Nothing	Only recognize some behaviors of fluctuation
III	No good	Nothing	Nothing

According to the abovementioned classification, observation condition and period at each wells can be expressed as shown in Table-2.1(1) and (2).

Table-2.1(1) Observation Condition and Period of Groundwater Level Observation Wells

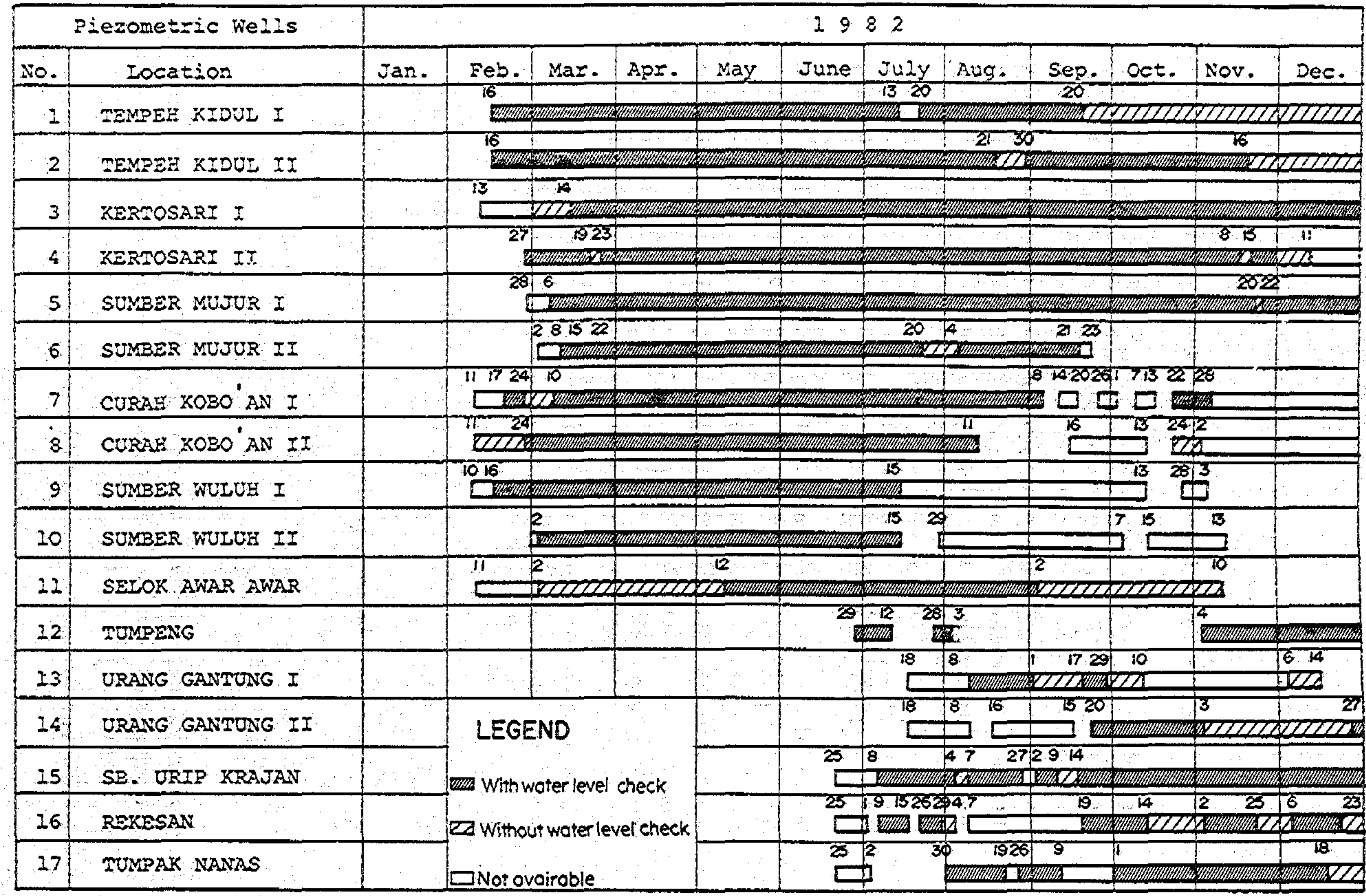


Table-2.1(2) Observation Condition and Period of Groundwater Level Observation Wells

Piezometric Wells		1 9 8 3											
No.	Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	TEMPEH KIDUL I		7 20			3 31				27			
2	TEMPEH KIDUL II	10	1 14 16			3 31				27			
3	KERTOSARI I				12 19						25		
4	KERTOSARI II				12 19						25		
5	SUMBER MUJUR I		14 21		19		28	12		6	4		
6	SUMBER MUJUR II												
7	CURAH KOBO'AN I		14	8	12 26		28	5		6 13	4		
8	CURAH KOBO'AN II		14	15	5 26		29	6	29	6	11		
9	SUMBER WULUH I				14			28	11	29			
10	SUMBER WULUH II						2	21	11	1 22	29		
11	SELOK AWAR AWAR	27	9 16	16	6 21		22	29			6		
12	TUMPENG	8	24	3 29	6		15						
13	URANG GANTUNG I												
14	URANG GANTUNG II			11	6 21						4		
15	SB. URIP KRAJAN				6 14						13		
16	REKESAN	20	3		21						13		
17	TUMPAK NANAS				7						13		

2.3 INTERPRETATION AND CONSIDERATION

2.3.1 INTERPRETATION OF GROUNDWATER LEVEL FLUCTUATION

The principal tactic to reveal the characteristics of groundwater level fluctuation at each well is generally to compare a groundwater level fluctuation with rainfall amount of which the station is located in the vicinity of the well under consideration. The correspondence of an observation well point to a rainfall station is given in Fig.-2.1 and graphical representation of groundwater level at each well related to rainfall amount are as shown in Fig.-2.4(1) to (9).

Taking into consideration the regional condition of observation well points, such as topography, geology, land use and so on, the characteristics of groundwater level fluctuation can be classified into the following three groups;

i) Group A

Group A is characterized by the small range of groundwater level fluctuation, and observed at near 800 m in elevation where many springs are distributed. Well points of Mujur I, II, and Sumber Urip Krajan belong to this group.

ii) Group B

Groundwater level fluctuation of Group B shows an strong influence of groundwater recharge from paddy field and its fluctuation range is slightly greater than that of Group A. Well points of Kertosari I, II and Tumpak Nanas.

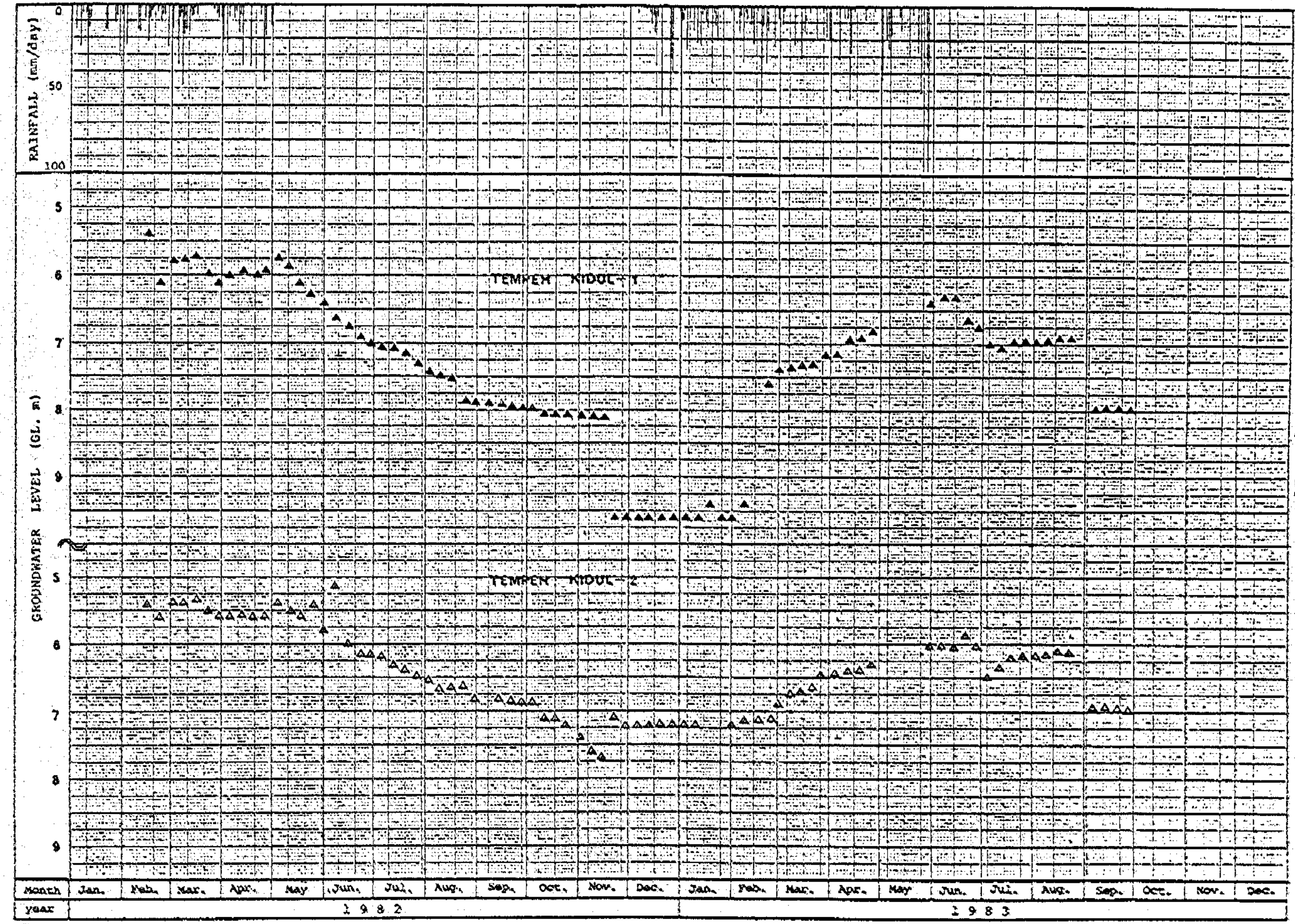


Fig 2.4 (1) Groundwater Level Fluctuation

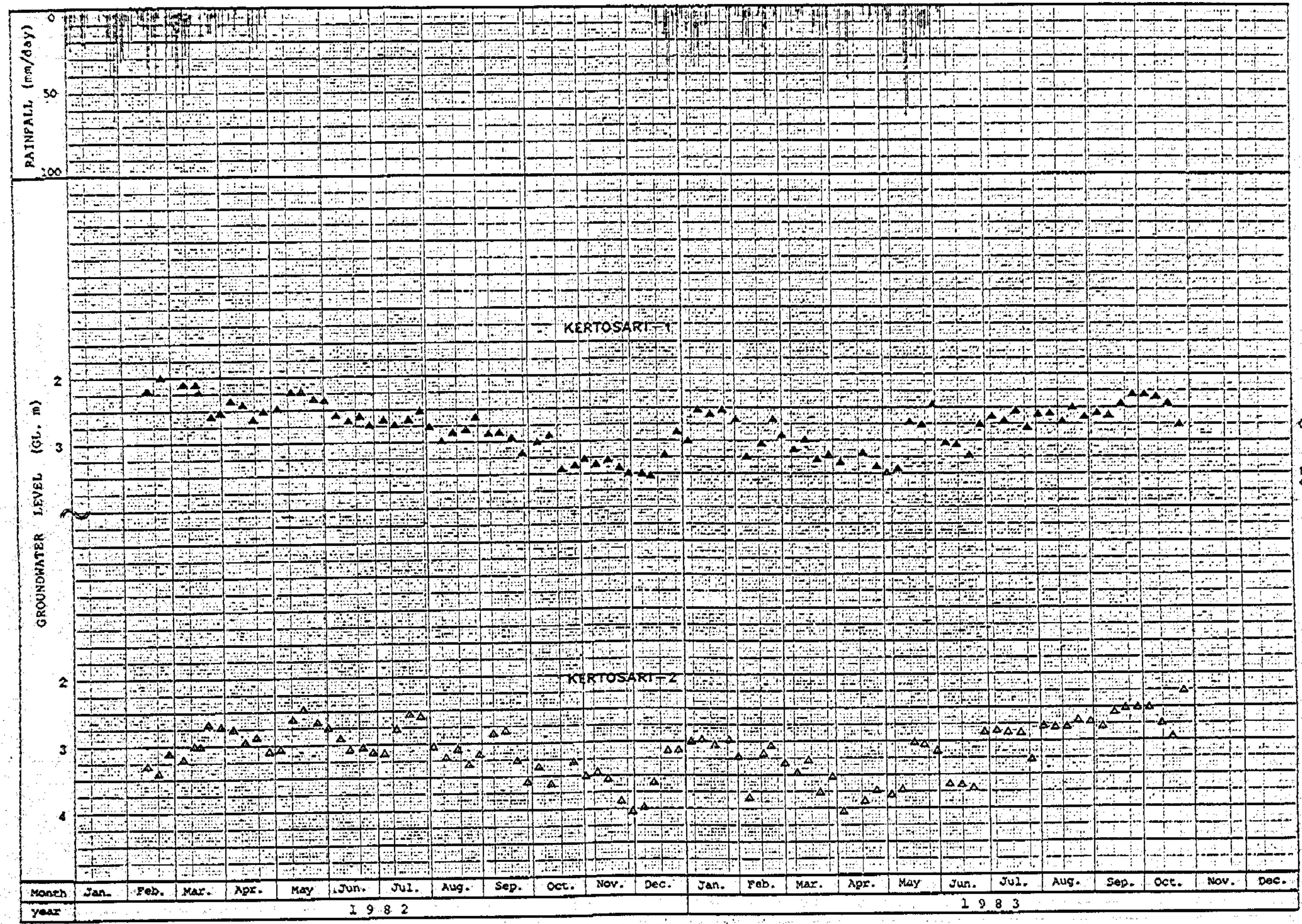


Fig 2.4 (2) Groundwater Level Fluctuation

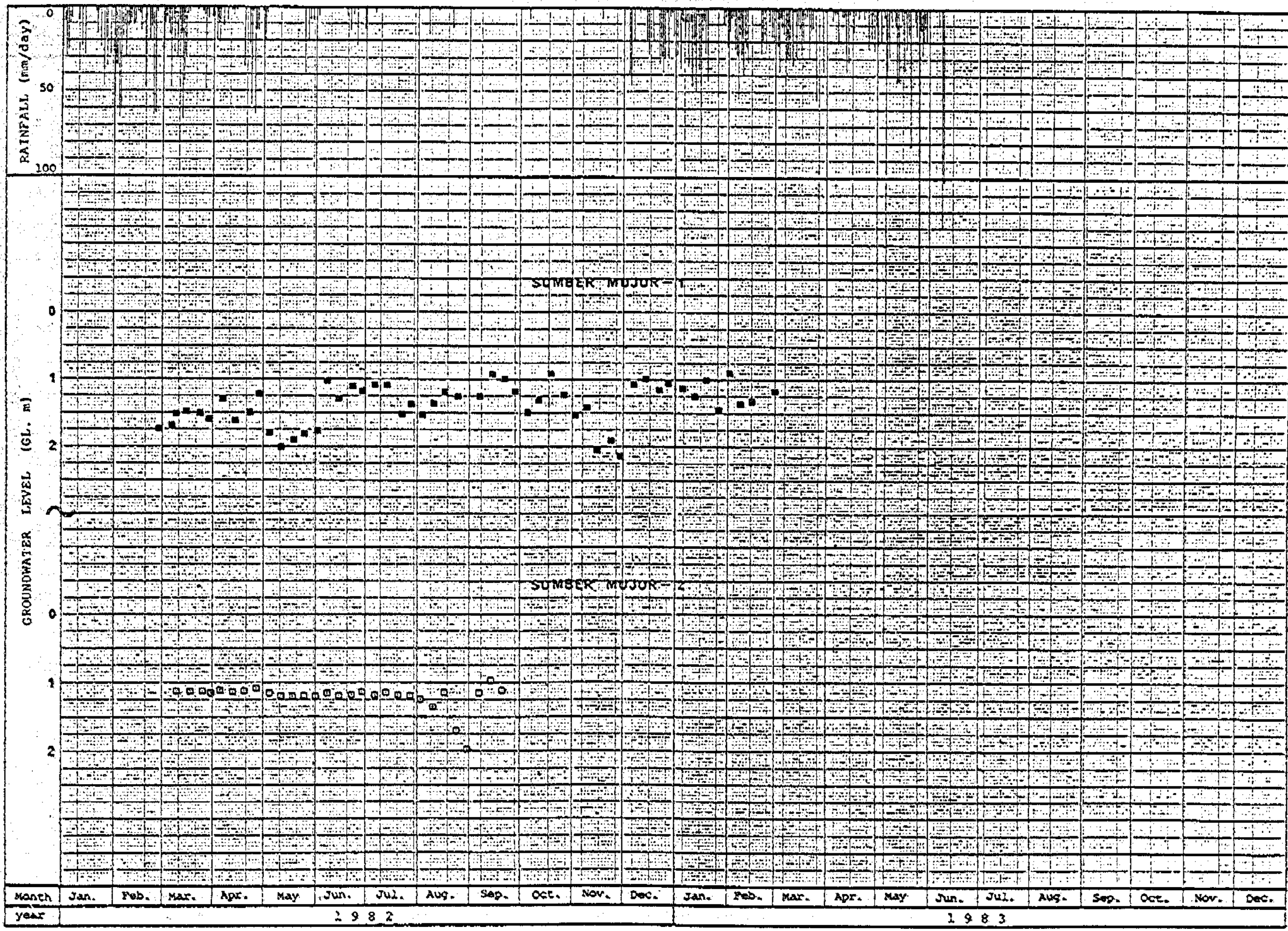


Fig 2.4 (3) Groundwater Level Fluctuation

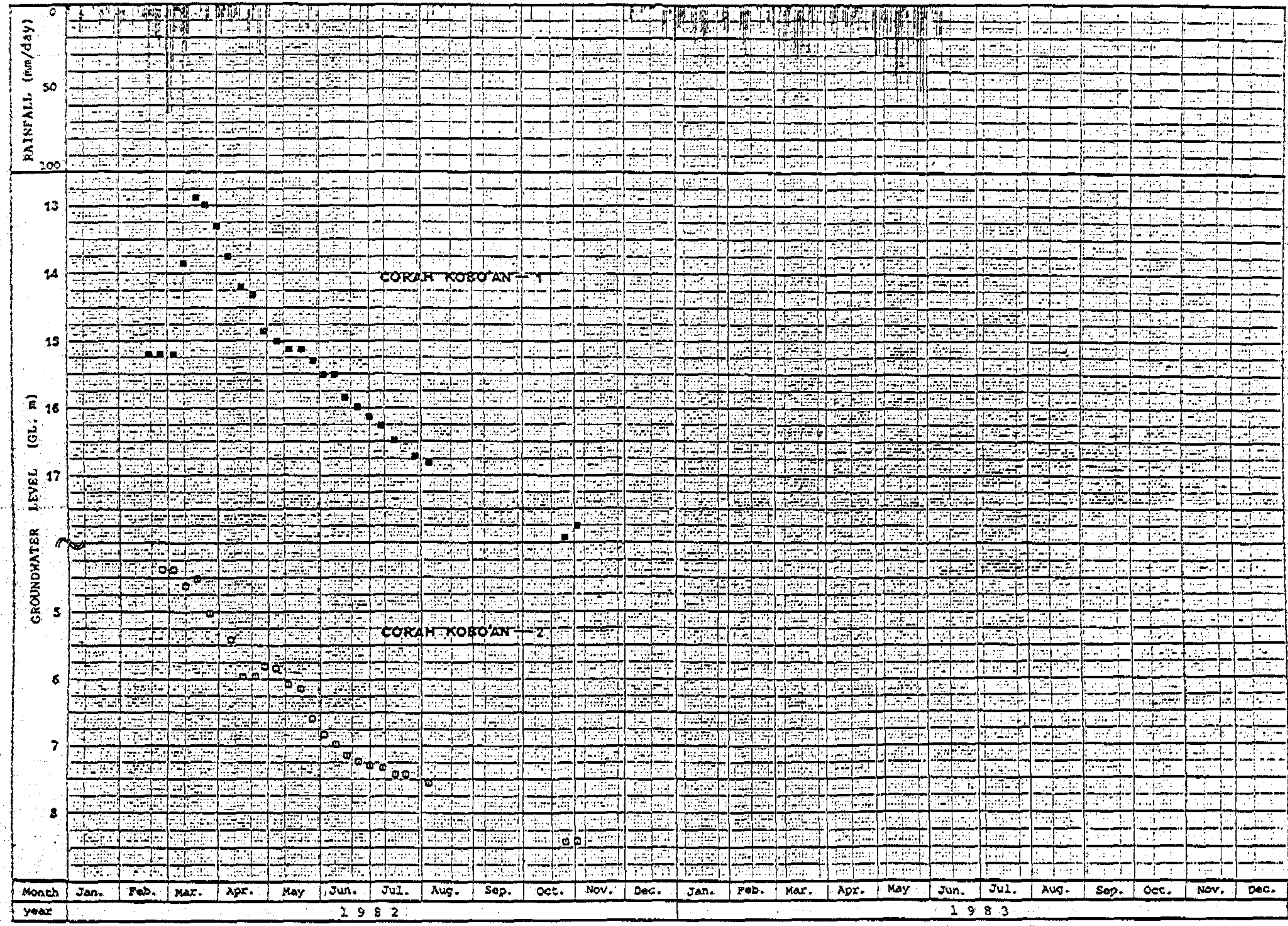


Fig 2.4 (4) Groundwater Level Fluctuation

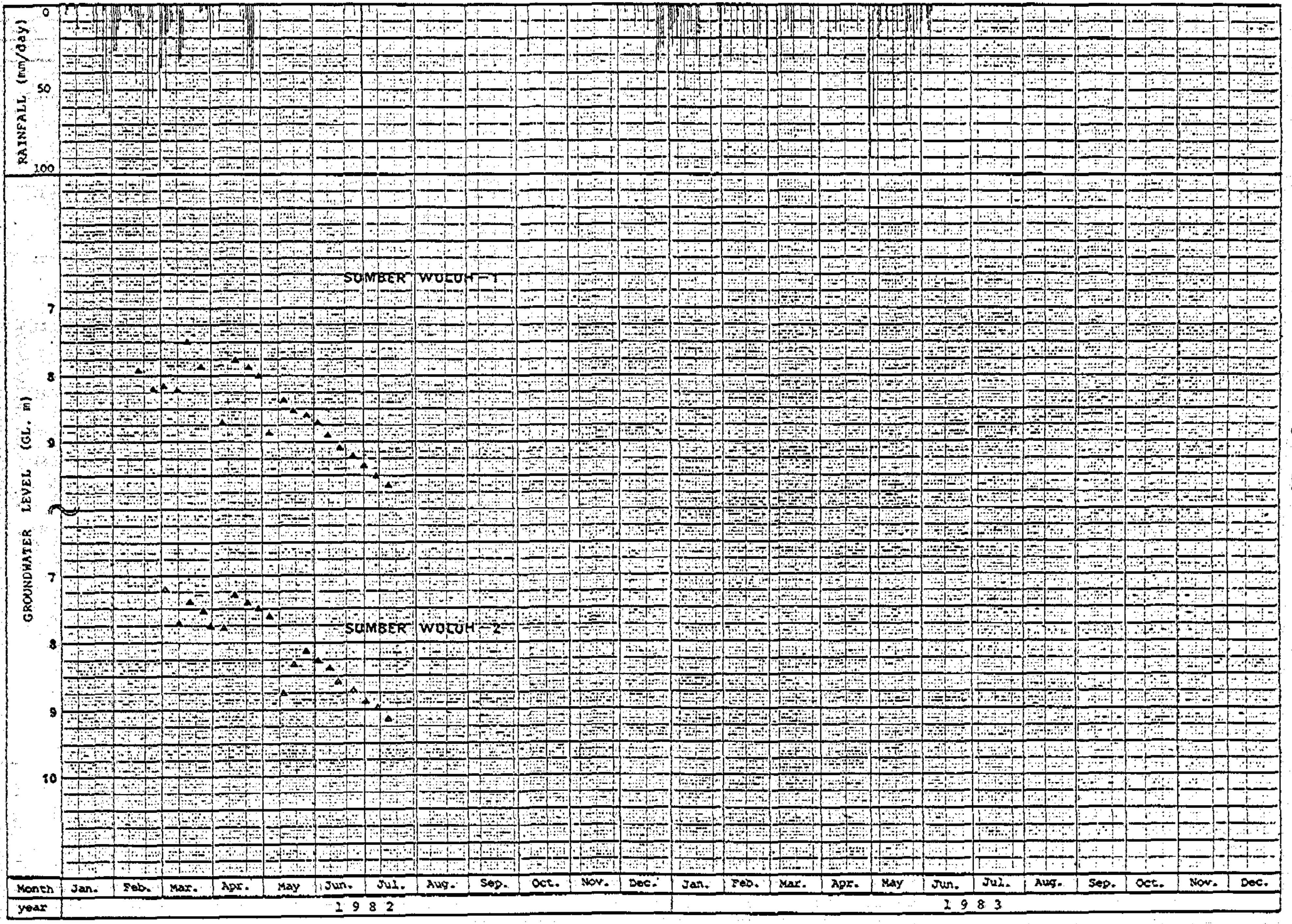


Fig 2,4 (5) Groundwater Level Fluctuation

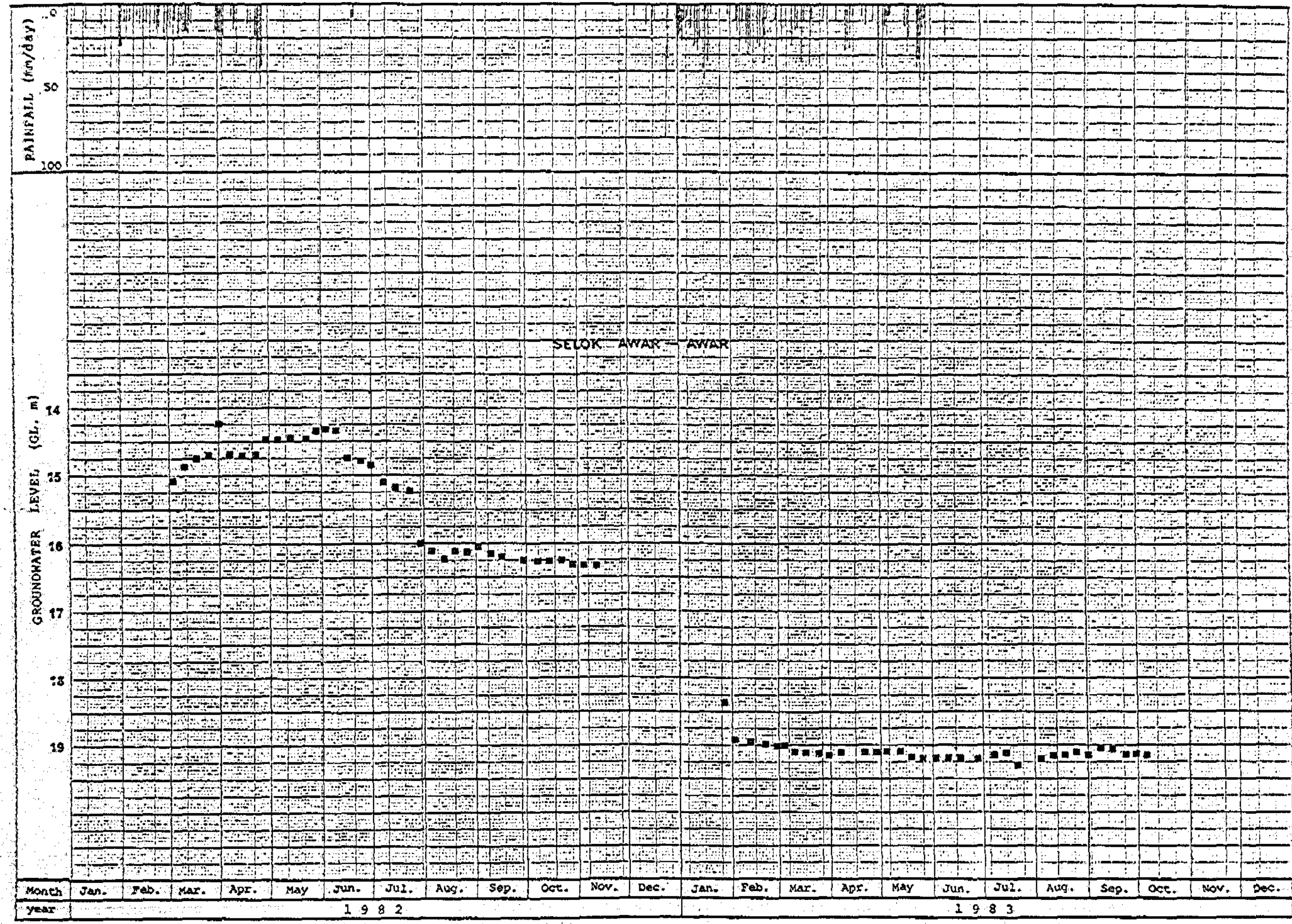


Fig 2.4 (6) Groundwater Level Fluctuation

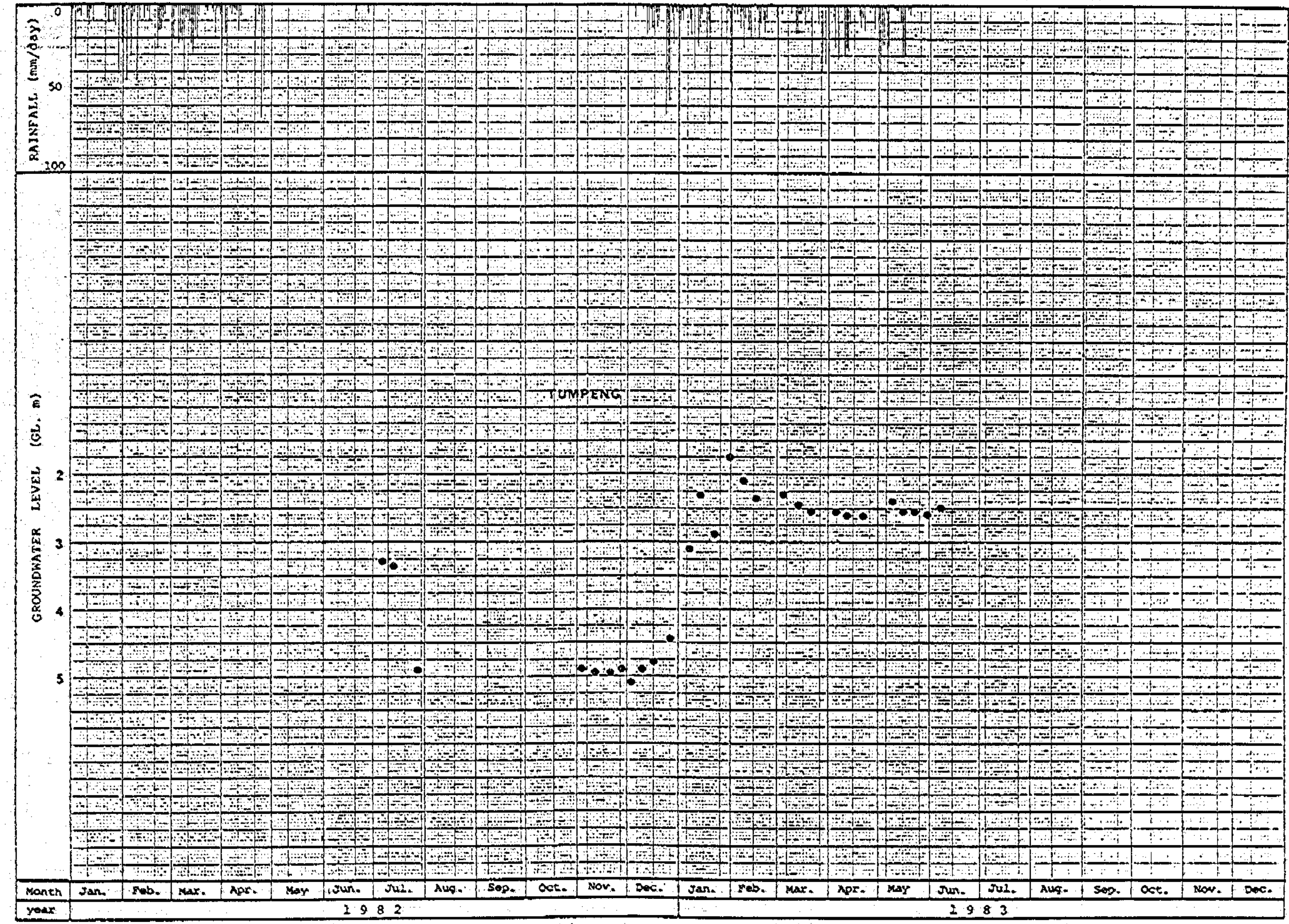


Fig 2.4 (7) Groundwater Level Fluctuation

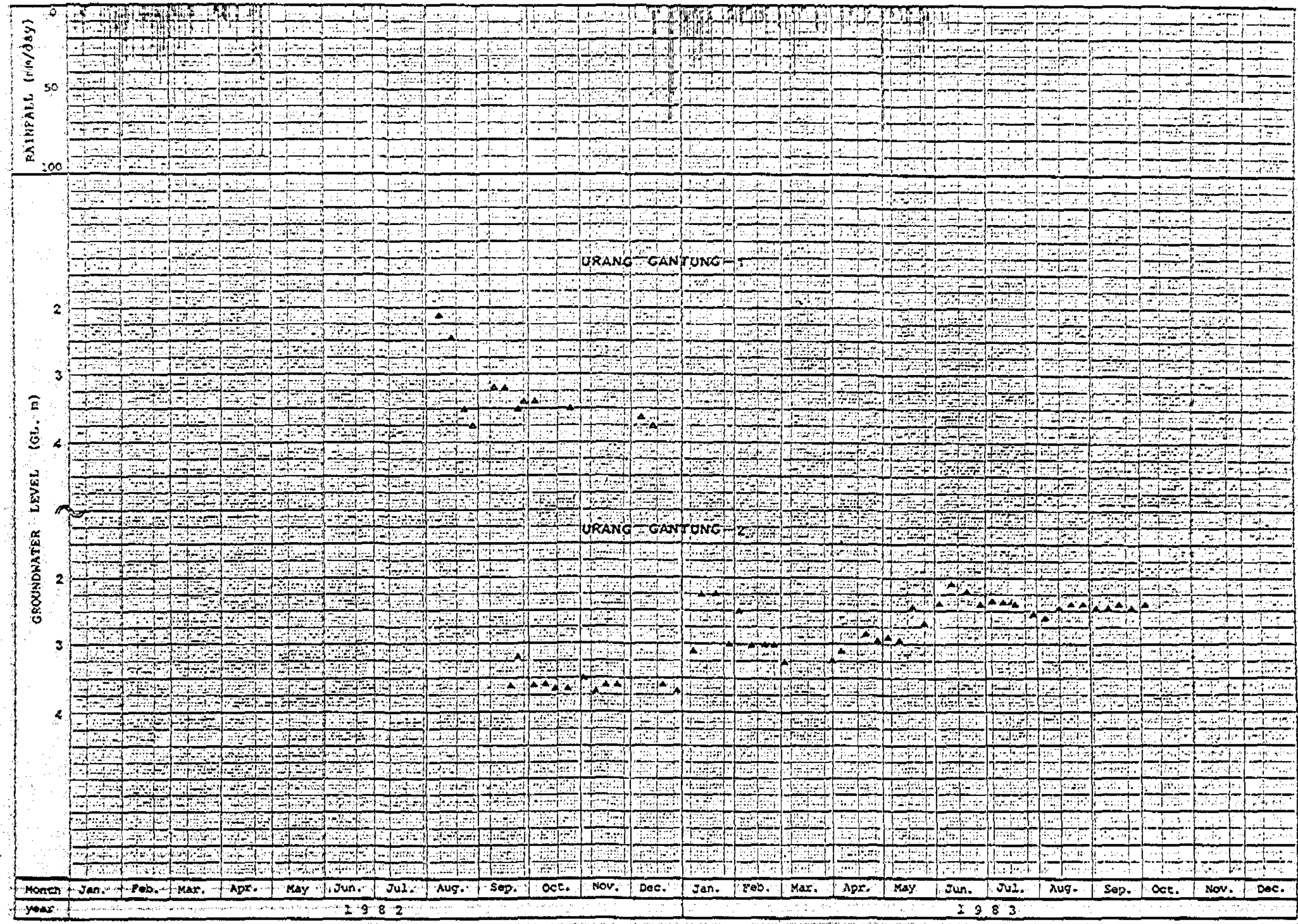


Fig 2.4 (8) Groundwater Level Fluctuation

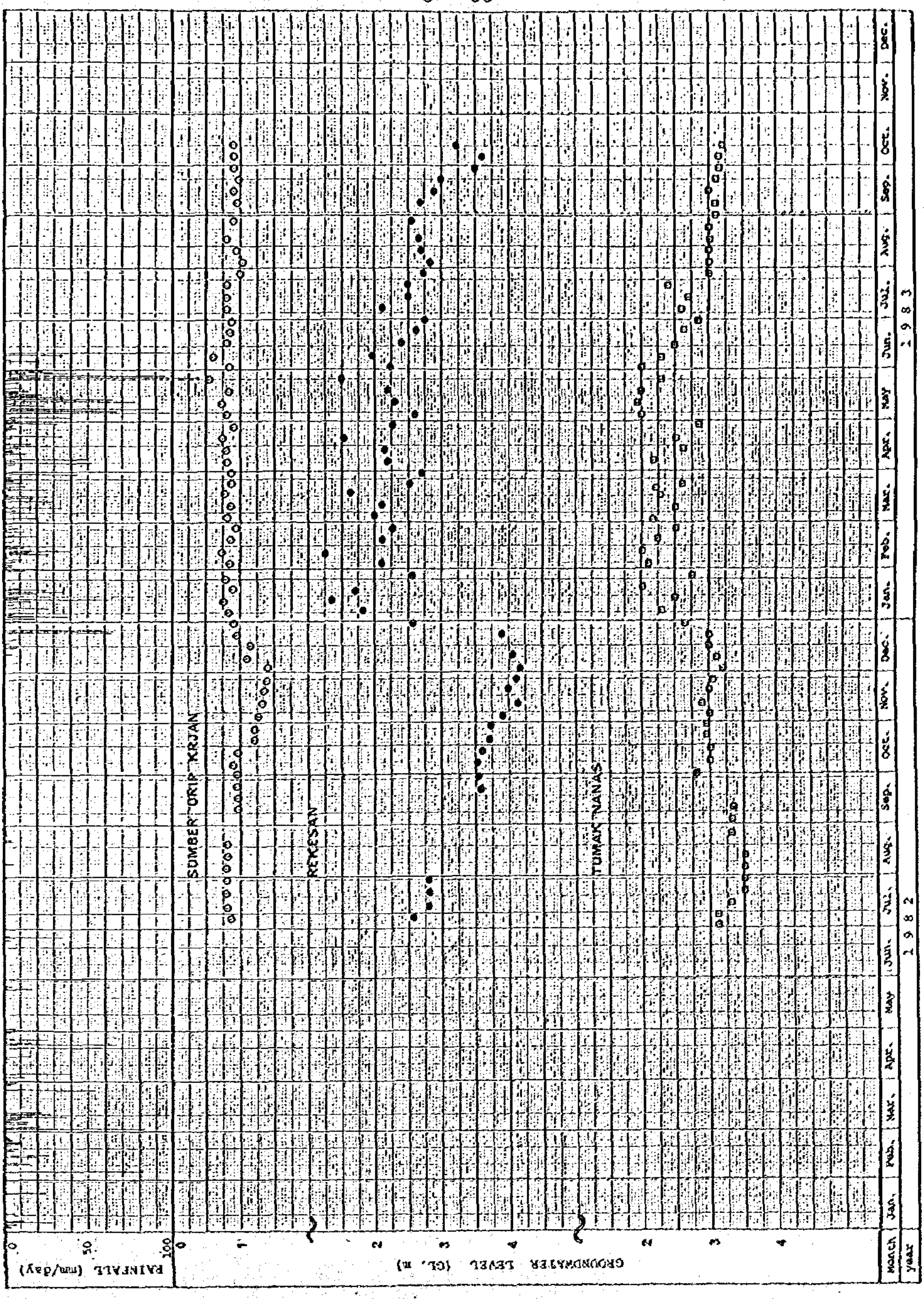


Fig 2.4 (9) Groundwater Level Fluctuation

iii) Group C

Groundwater level fluctuation of Group C represents good correspondence with rainfall. Groundwater level rises few later of the beginning of rainy season and falls after the end of rainy season. Well points of Tempeh Kidul I, II, Curakobo'an I, II, Sumber Wuluh I, II, Tumpeng and Rekesan.

2.3.2 HYDROGEOLOGICAL CONSIDERATION

Groundwater is one of the continuous water movement in the hydrological cycle caused by the solar radiation energy and exists whenever water penetrates beneath the surface.

Its movement and storage condition depend largely on geomorphological and geological conditions of the area under consideration.

From the field reconnaissance and groundwater level observation, hydrogeological characteristics can be summarized as follows;

- The study area is mostly affected by the volcanic fan structure of Mt. Semeru and its inflection points of slope is often the changing point of groundwater flow regimes.

- In the upstream of an inflection point, grain size is larger than that of the downstream, its permeability is high and its hydraulic gradient is steep; consequentially, the groundwater discharge in the upstream is estimated to be larger than that in the downstream. It is the principal reason that the springs are found in the vicinity of inflection point of slope.

- Groundwater level observed at well in paddy field is generally shallow at the depth of 1 to 3 m and it signifies that the groundwater recharge amount from paddy field is not negligible. Conceptual relationship between topography and land use is given in Fig.-2.5.

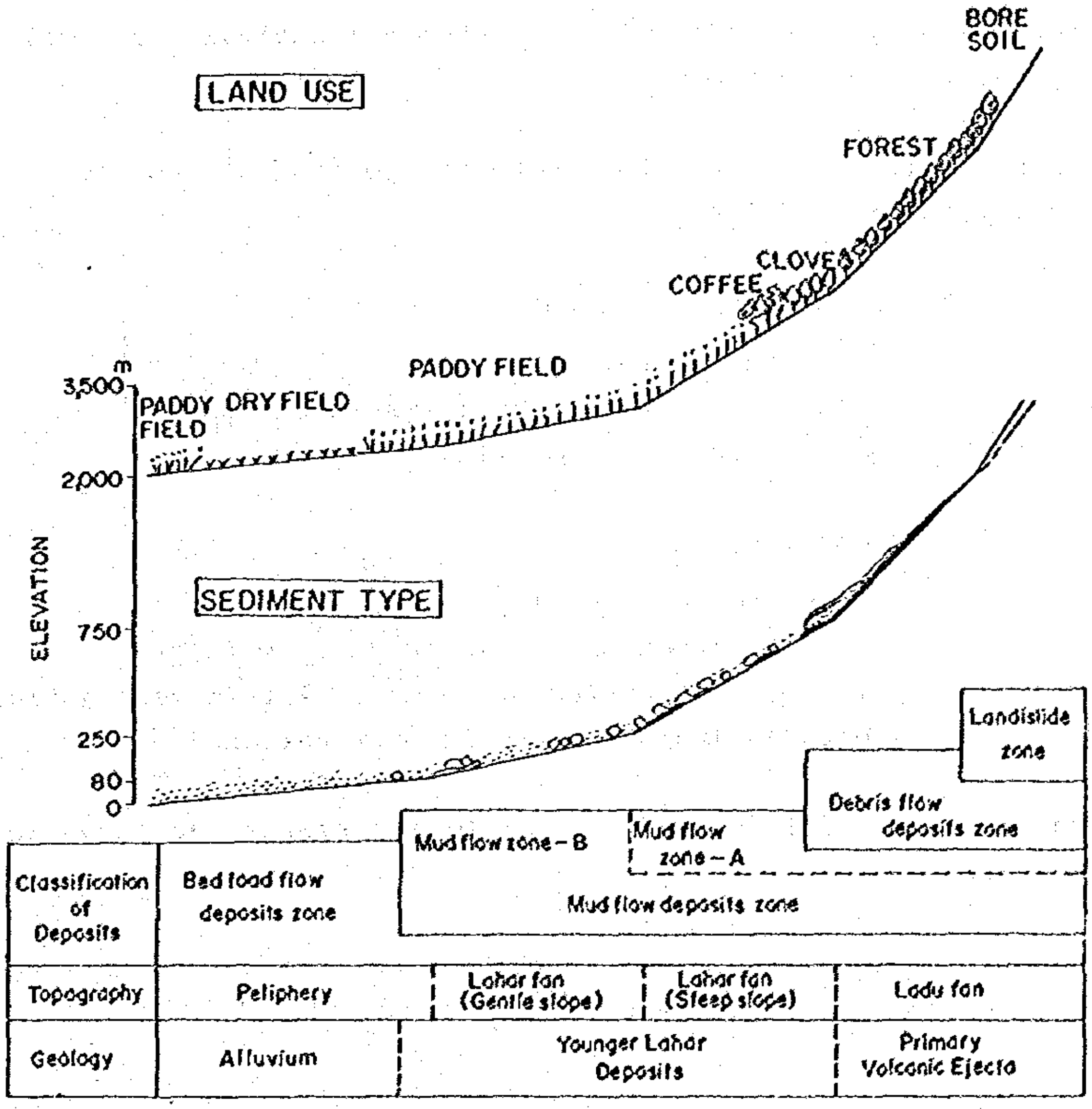


Fig-2.5 Conceptual Sketch between Topography and Land Use

3. WATER QUALITY INVESTIGATION

3.1 GENERAL

Water quality investigation aims to obtain fundamental informations not only on the delineation of groundwater system, but also on the evaluation of water quality for use.

The in-situ investigation of water quality consists mainly of simplified water quality test and chemical analysis of sampling waters in laboratory.

The work allocation for the Indonesian Government and JICA Study Team is as follows;

i) Indonesian Government

- Sampling of water
- Charge of chemical analysis in laboratory
- Simplified water quality test

ii) JICA Study Team

- Selection of sampling points
- Determination of chemical analysis items
- Technical transfer of water quality investigation
- Data analysis and its interpretations

The flowchart of investigation can be represented as shown in Fig.-3.1.

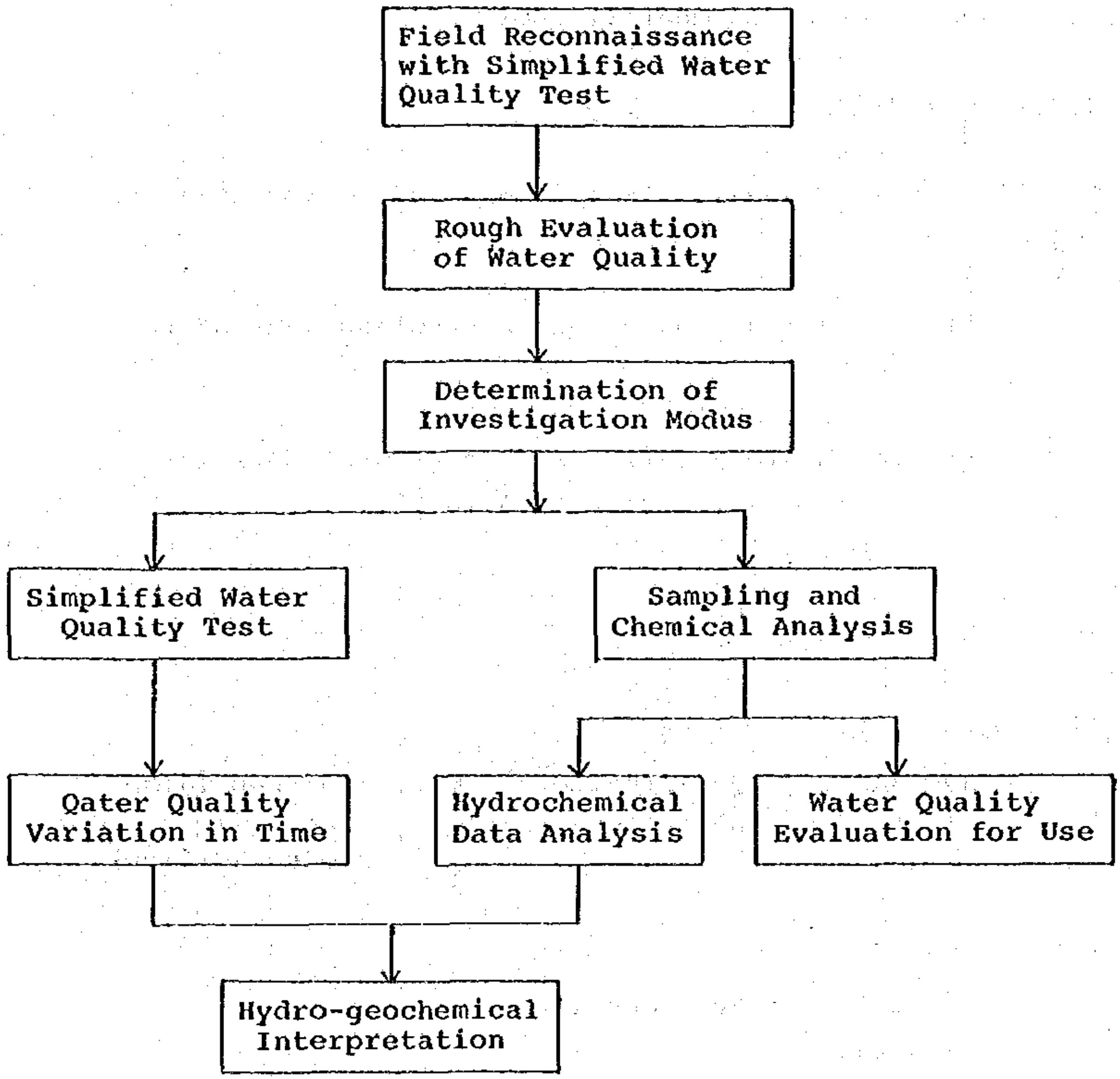


Fig.-3.1 Flowchart of Water Quality Investigation

3.2 SIMPLIFIED WATER QUALITY TEST

3.2.1 OBJECTIVES

Simplified water quality test is applied to the following objectives.

i) To have a provisional acknowledgement of water quality

ii) To obtain a series of measurement data for the water quality variation in time.

3.2.2 METHODOLOGY

(1) Equipments

- HORIBA Water Quality Checker U-7; 2 pieces (JICA)
- Electric Conductivity Meter ; 1 piece (Mt. Semeru Project Office)

(2) Measurement Items

- Potential of hydrogen (pH)
- Temperature (T)
- Electric conductivity (EC)
- Dissolved Oxygen (DO)
- Turbidity (Turb.)

(3) Measurement Points and Times

- 50 points (Fig.-3.2)
- Every 2 months in principle

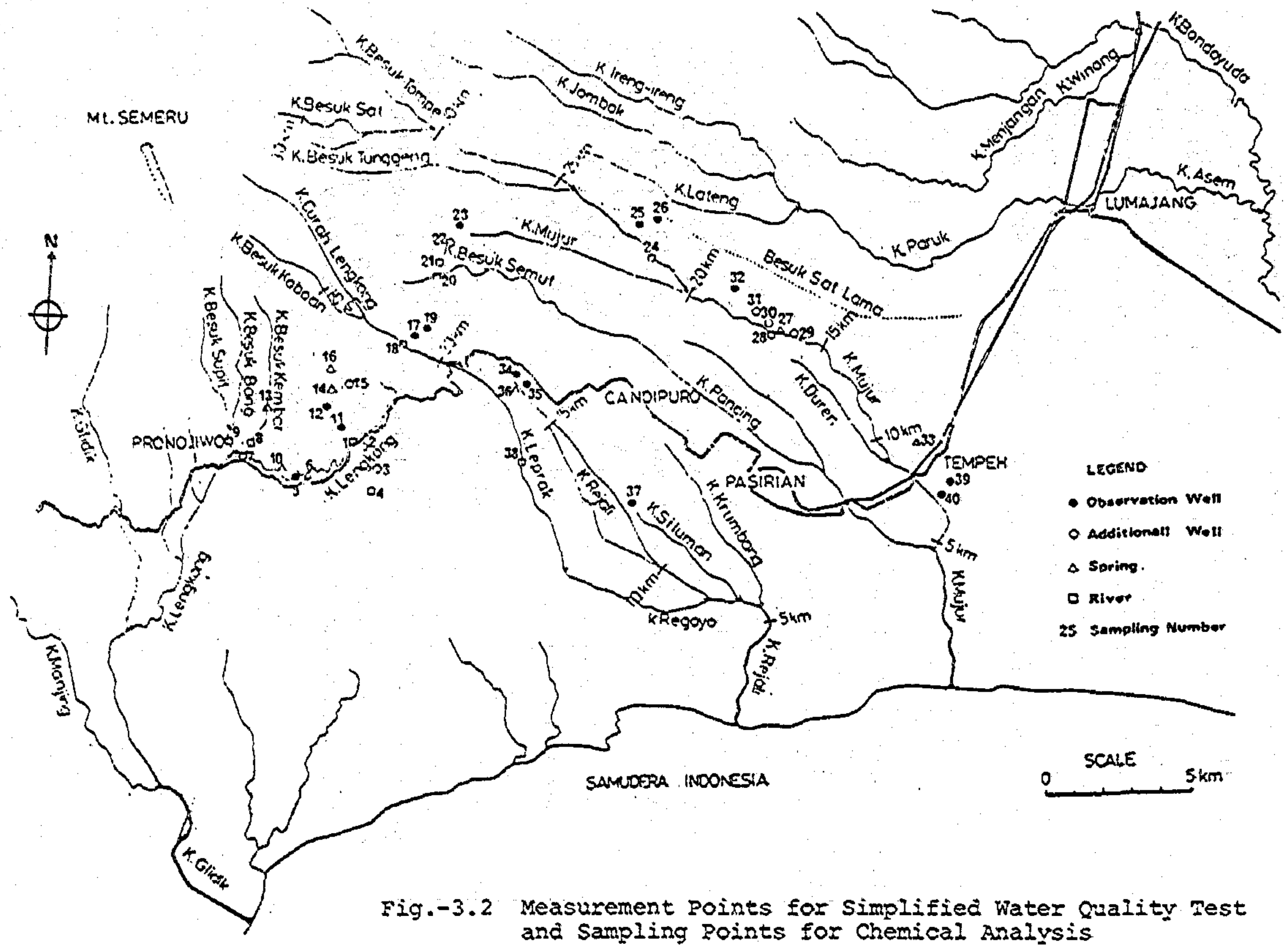


Fig.-3.2 Measurement Points for Simplified Water Quality Test and Sampling Points for Chemical Analysis

(4) Remarks of the IN-SITU Measurement

- As the sensibility of the Water Checker U-7 in conductance was not satisfying in accuracy from the first in-situ measurement, Electric Conductivity Meter provided by Mt. Semeru Project Office was employed thereafter.

- Concerning turbidity measurement, values can easily vary with the arrangement conditions and show only relative tendency.

3.2.3 MEASUREMENT RESULTS

(1) Execution of Measurement

- First measurement : 26 Aug. to 27 Aug. 1982, 22 points
- Second measurement : 1 Sep. to 3 Sep. 1982, 40 points
- Third measurement : 25 Nov. to 6 Dec. 1982, 39 points
- Fourth measurement : 5 Jan. to 10 Jan. 1983, 41 points
- Fifth measurement : 3 May to 7 May 1983, 35 points
- Sixth measurement : 4 Jul. to 8 Jul. 1983, 38 points
- Seventh measurement: 5 Sep. to 9 Sep. 1983, 37 points

(2) Compilation of Measurement Results

Taking into consideration the measurement modus established in the end of September 1982, measurement results obtained by Mt. Semeru Office is compiled in Appendix C-2; Measurement Results of Simplified Water Quality Test.

3.2.3 INTERPRETATION

(1) General Tendency of Measurement Results

In order to know the general tendency of measurement results, mean values and standard deviation of measurement items are calculated and are as shown in Table-3.1.

Table-3.1 Mean Values and Standard Deviation of Measurement Items

Items \ Month Year		Nov. Dec. 1982	Jan. 1983	May 1983	July 1983	Sep. 1983
pH	$\bar{x}$	6.85	6.89	7.23	6.71	6.13
	σ_x	0.71	0.64	0.95	0.73	1.29
EC (Ʊ/cm)	$\bar{x}$	216	235	259	265	220
	σ_x	100	134	124	123	87
T (°C)	$\bar{x}$	26.9	25.6	25.9	24.7	25.7
	σ_x	2.6	2.1	2.2	1.8	2.4
DO (ppm)	$\bar{x}$	7.6	5.1	4.8	2.7	4.6
	σ_x	3.5	2.2	2.7	1.6	1.4
Turb. (ppm)	$\bar{x}$	7.1	5.2	64.1	20.3	2.5
	σ_x	7.8	3.8	124.9	49.0	2.8

Note: pH: Potential of Hydrogen, EC: Electric Conductivity,
T : Temperature, DO: Dissolved Oxygen, Turb.: Turbidity,
$\bar{x}$: mean value, σ_x: Standard Deviation

General tendency of measurement results can be summarized as follows;

- The mean value in pH measurement is high in May, but low in September. In both measurement periods, great deviated values from mean value appear at some measurement points.

- EC value increases from November to July, but decreases after July. It seems that EC value increases during rainy season and decreases during dry season.

- Temperature of measurement points reflects more or less the yearly variation of atmospheric temperature at ground surface. Temperature of the study area is estimated to be high in July and low in November/ December.

- DO value has a close relationship with temperature. When temperature has a high value, DO value is also high. Contrarily, DO value is small with low temperature.

- Concerning turbidity variation in year, it will be thought that the portion of suspended material in water plays important role.

(2) Graphical Representation

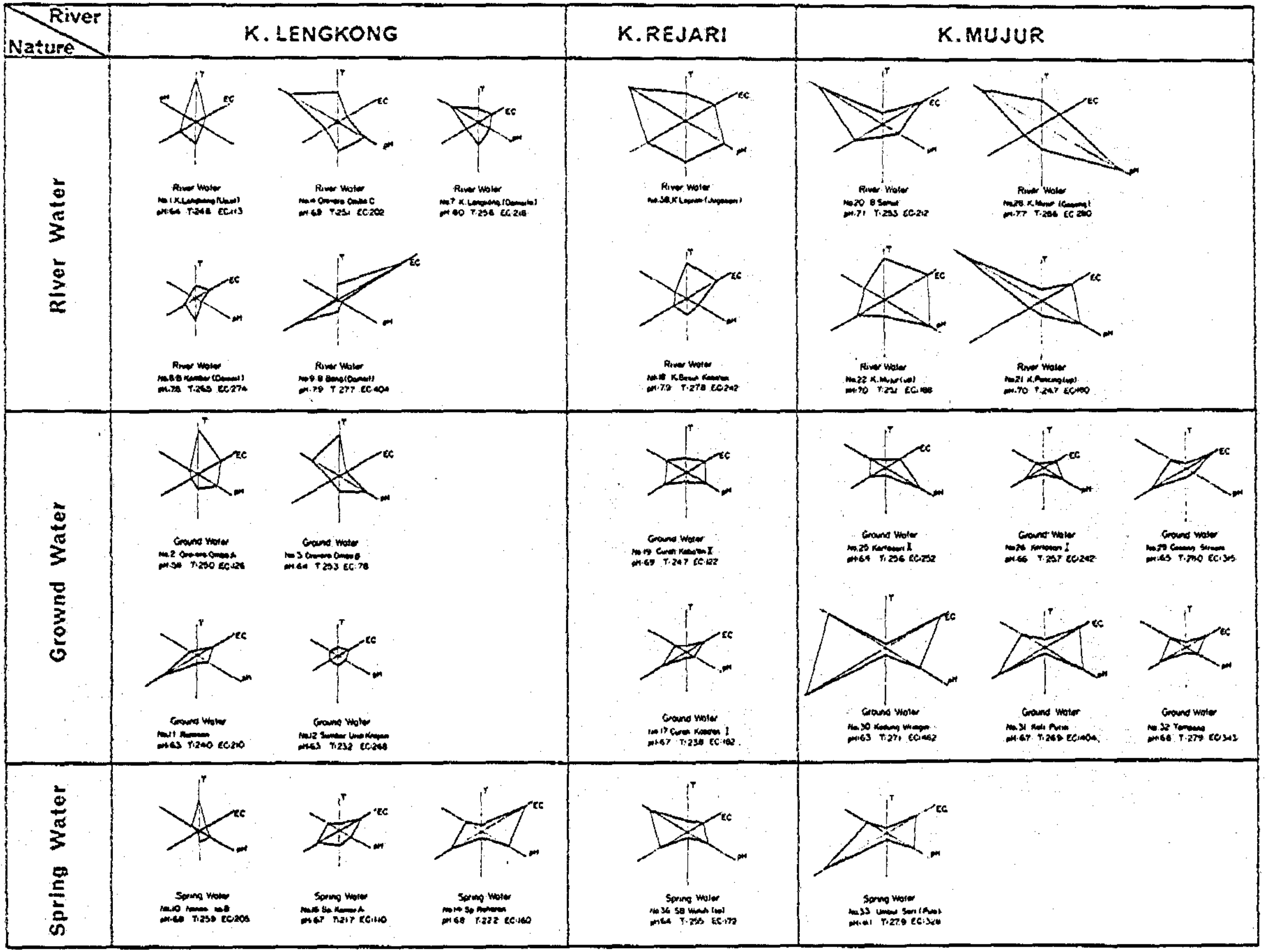
As the principal index of simplified water quality test are the values of temperature (T), potential of hydrogen (pH) and electric conductivity (EC). Variation ranges of T, pH and EC values can be graphically represented in Table-3.2.

(3) Relationship between Temperature and Elevation

As the elevations of sampling point are well distributed in K. Mujur Basin, the relationship between temperature and elevation was examined.

As shown in Fig.-3.3, the lowest temperature of groundwater and river water is observed in July. The response of temperature of water to atmospheric temperature is thought to be quick. In consequence, the velocity of groundwater flow in shallow aquifer will be remarkably high.

Table-3.2 Graphical Representation of Temperature, Potential of Hydrogene and Electric Conductivity Variations



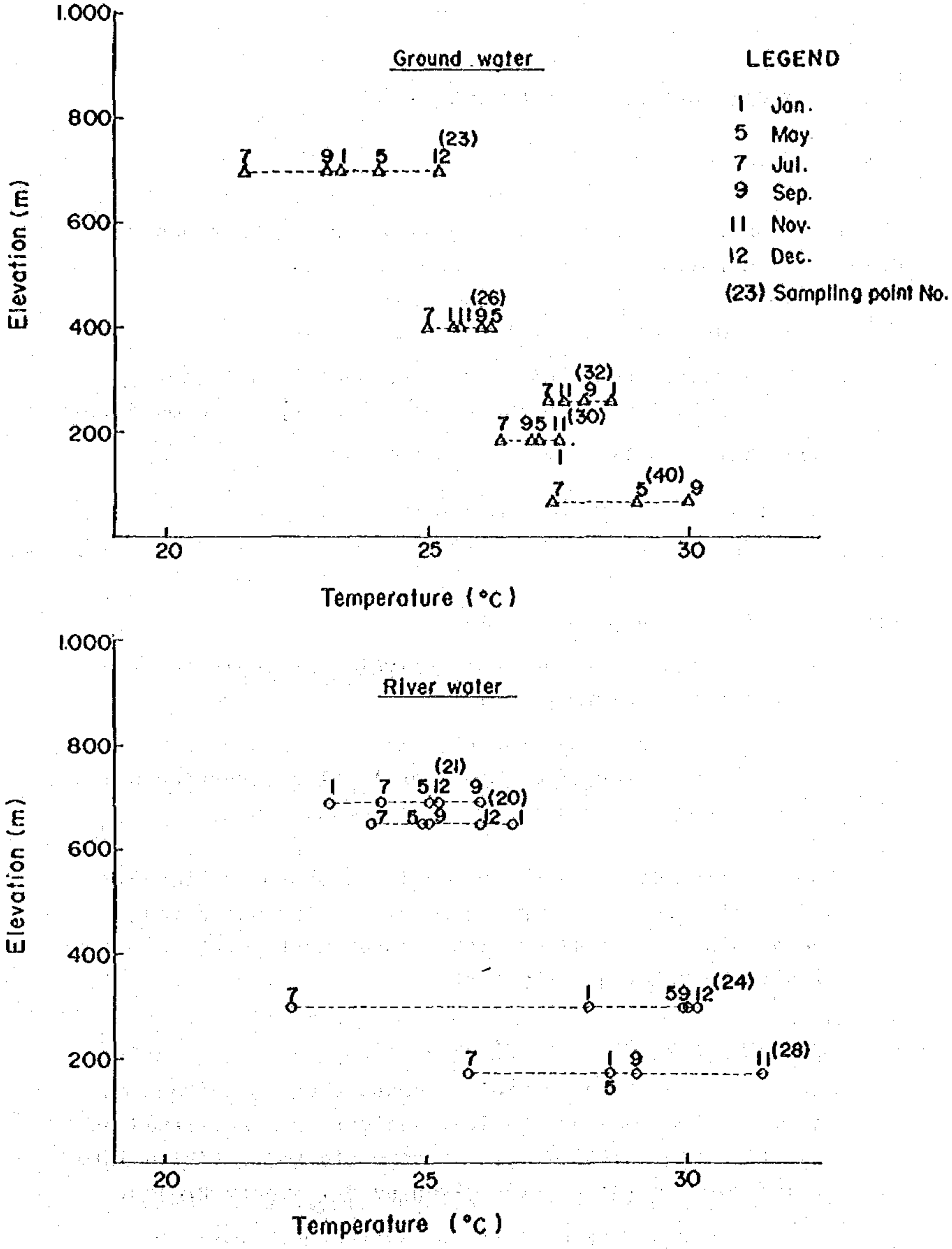


Fig 3.3 Relationship between Temperature and Elevation in K. Mujur

3.3 CHEMICAL ANALYSIS OF SAMPLING WATERS

3.3.1 OBJECTIVES

Chemical analysis of sampling waters intends to have basic data for the following study items;

i) Hydrogeological Delineation

- Relationship between water quality and geology
- Relationship between water quality and groundwater

ii) Water Quality Evaluation for Use

3.3.2 METHODOLOGY

(1) Selection of Sampling Points

Sampling points for chemical analysis were selected from the following informations;

- Field reconnaissance
- Inspection of groundwater level observation wells
- Prospective sites of sabo facilities

The location of sampling points is as shown in Fig.-3.2 and total number of sampling points is 40 points and these points are included into measurement points of simplified water quality test.

(2) Specifications of Chemical Analysis

After the execution of field reconnaissance, a draft on the specifications of chemical analysis was submitted on Aug. 1982 and modified into practicable form, taking into account of the information given by Mt. Semeru Project Office.

(3) Chemical Analysis Items

i) Principal Items for Hydrogeology

- Sodium ion (Na^{+})
- Potassium ion (K^{+})
- Magnesium ion (Mg^{++})
- Calcium ion (Ca^{++})
- Chloride ion (Cl^{-})
- Sulfate ion (SO_4^{--})
- Bicarbonate ion (HCO_3^{-})

ii) Items for Water Use

Chemical analysis items for water use were determined in concordance of the drinking criteria in Indonesia.

3.3.3 CHEMICAL ANALYSIS RESULTS

(1) Execution of Sampling

- on the 1st Sep. 82 : points
- on the 2nd Sep. 82 : points
- on the 3rd Sep. 82 : points

Total : 40 points

(2) Laboratory

Chemical analysis in laboratory was executed under the technical cooperation between Mt. Semeru Project Office and Firma Prima Lumajang Company.

(3) Compilation of Chemical Analysis Results

Chemical analysis results obtained from the Firma Prima Lumajang Company are represented in Table-3.3.

Table- 3.3 Chemical Analysis Results of Sampling Water Sep. 1982

Sampling				pH	T	DO	EC	TDS	Na^+	K^+	Mg^{++}	Ca^{++}	Fe	Cl^-	SO_4^{--}	HCO_3^-	CO_2	PO_4^{---}	NH_4	NO_2	Mn
No.	Location	Date	Type		°C	ppm	μV/cm	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
1	K. Lengkong (Upstream)	1 Sep.	R.	7.4	22.5	6.8	205	208	11.59	3.59	8.04	19.84	0.26	6.34	0.57	146.52	3.45	0.1	0.0	0.016	0.0
2	Oro-oro Ombo A	"	G.	5.9	24.8	3.7	100	112	4.23	1.17	2.81	9.92	0.9	8.24	0.77	54.14	18.1	0.0	0.0	0.008	very small
3	Oro-oro Ombo B	"	G.	6.0	21.6	2.8	70	107	4.05	0.86	3.20	5.29	0.08	6.66	7.5	42.10	11.21	0.0	0.0	very small	0.0
4	Oro-oro Ombo C	"	R.	7.1	21.0	4.6	100	116	5.52	0.94	3.22	10.58	0.12	5.07	1.95	67.28	5.45	0.0	0.0	0.008	0.0
5	Tumpak Nanas	"	G.	6.6	22.9	1.8	207	203	0.10	2.18	8.035	21.16	0.13	10.14	1.07	127.94	11.64	very small	0.0	0.016	very small
6	Sb. Tumpak Nanas(Left B)	"	S.	6.3	24.9	0.4	230	219	9.94	0.62	13.67	13.23	1.06	6.97	4.39	131.04	19.84	very small	0.0	very small	0.0
7	K. Lengkong (Dam Site)	"	R.	8.4	29.3	6.3	260	216	13.43	4.84	9.64	20.50	0.34	7.29	1.17	144.08	0.0	0.02	0.0	0.02	0.0
8	B. Kembar (Dam Site)	"	R.	8.1	26.0	6.5	300	242	19.32	4.37	12.05	21.16	0.32	10.46	16.98	158.49	0.0	0.14	0.0	very small	0.0
9	B. Bang (Dam Site)	"	R.	8.1	25.4	6.7	410	336	28.34	8.74	18.88	26.45	0.42	14.89	20.88	230.53	0.0	0.44	0.0	very small	0.0
10	Sb. Tumpak Nanas (Right)	"	S.	6.8	24.7	0.0	280	271	15.27	3.51	9.24	21.16	6.24	6.02	0.98	165.84	25.87	0.02	0.0	0.0	2.64
11	Rekasan	2 Sep.	G.	6.9	22.8	3.2	230	214	11.96	6.40	9.25	21.16	0.08	6.02	0.89	148.97	6.86	0.36	0.0	0.0	0.0
12	Sb. Urip krajan	"	G.	7.0	21.2	1.4	200	218	15.27	7.33	0.46	17.86	0.46	10.46	1.78	130.97	14.66	0.0	0.0	0.0	0.88
13	B. Kembar	"	S.	7.8	23.8	6.7	220	214	15.46	4.13	0.34	21.82	0.34	7.92	14.06	126.72	7.33	0.04	0.0	0.0	0.0
14	Sb. Raharan	"	S.	7.0	21.3	6.1	92	132	9.75	3.20	0.10	10.58	0.10	5.71	1.68	81.70	8.62	0.54	0.0	very small	0.0
15	Oro-oro Ombo D	"	G.	6.8	22.3	3.4	270	272	12.51	3.59	0.08	27.78	0.08	5.71	1.58	175.80	34.49	0.04	0.0	0.0	very small
16	Sb. Kamar A	"	S.	5.6	19.7	8.2	110	127	9.75	2.96	0.15	9.20	0.15	6.66	3.27	72.67	4.74	0.74	0.0	very small	0.0
17	Curah Kobo'an I	"	G.	6.9	22.7	6.8	170	181	9.38	4.13	3.41	21.26	0.09	8.87	1.58	104.53	12.94	0.28	0.0	0.04	0.0
18	K. Besuk Kobo'an	"	R.	8.4	23.9	8.4	190	178	11.41	3.74	5.83	19.18	0.20	6.02	2.28	122.47	0.0	0.24	0.0	0.0	0.0
19	Curah Kobo'an II	"	G.	7.1	21.4	6.8	130	180	7.36	2.89	3.62	13.89	0.18	5.71	3.27	75.10	8.19	0.06	0.0	0.0	0.0
20	Besuk Semut	"	R.	7.0	22.1	8.6	180	171	18.40	3.90	5.22	13.89	0.16	6.34	3.96	116.49	4.31	0.80	0.0	very small	0.0
21	K. Panching (Upstream)	"	R.	5.9	21.2	8.4	110	127	9.02	3.04	2.40	11.93	0.09	5.71	0.39	86.48	5.17	0.26	0.0	0.0	0.0
22	K. Mujur (Upstream)	"	R.	7.6	21.2	8.3	120	136	9.02	2.89	3.62	14.55	0.22	5.71	0.20	90.73	7.33	0.32	0.0	0.0	0.0
23	Sumber Mujur I	"	G.	7.1	19.9	6.8	120	140	9.75	4.37	2.80	13.87	0.16	6.34	3.12	84.67	6.47	0.14	0.0	0.08	0.0
24	B. Sat (Kertosari)	"	R.	7.8	23.9	7.8	220	202	11.22	3.90	8.84	19.18	0.46	7.29	0.39	135.11	6.47	0.04	0.0	0.0	0.0
25	Kertosari II	"	G.	6.6	23.3	6.6	190	184	9.02	3.74	6.03	20.50	0.06	5.39	2.83	109.36	14.86	0.10	0.0	0.0	0.0
26	Kertosari I	"	G.	6.6	23.3	5.2	180	190	8.10	7.80	4.82	17.86	0.06	5.39	2.15	127.94	11.64	0.08	0.0	very small	0.0
27	Sb. Gesang (Left B)	3 Sep.	S.	8.1	23.8	8.5	300	322	19.14	4.76	16.87	34.39	0.11	8.87	2.24	237.73	0.0	0.0	0.0	0.0	0.0
28	K. Mujur (Gesang)	"	R.	8.1	28.4	7.6	270	246	14.17	4.52	12.46	21.82	0.58	8.24	2.15	177.41	1.94	0.18	0.0	0.0	0.0
29	Gesang Stream	"	G.	6.8	26.8	4.4	320	312	14.72	6.08	12.87	26.45	0.07	8.24	1.07	213.83	22.64	0.42	0.0	0.0	0.0
30	Kedung Wringin	"	G.	6.9	26.6	2.4	390	336	15.64	17.32	13.66	29.76	0.18	12.68	2.93	234.83	22.85	0.64	0.0	0.0	0.88
31	Kali Putih	"	G.	7.0	25.8	2.1	360	316	16.93	6.79	13.65	29.76	0.28	8.24	3.71	212.10	23.72	0.54	very small	0.12	3.3
32	Tumpeng	"	G.	6.8	27.1	5.1	300	260	12.70	8.11	11.25	21.82	0.08	8.56	3.80	177.80	17.25	0.70	0.0	very small	0.0
33	Umbulsari, Pulo	"	S.	6.8	27.6	1.4	370	412	16.74	12.48	14.09	27.07	0.06	129.95	0.78	194.77	15.52	0.94	0.0	0.0	0.0
34	Sumber Wuluh II	"	G.	7.0	25.2	4.0	170	171	10.49	4.60	2.81	19.84	2.0	8.56	2.24	111.12	8.19	0.30	0.0	0.02	0.0
35	Sumber Wuluh I	"	G.	6.9	24.5	5.1	180	250	10.86	4.60	3.60	20.50	0.16	8.87	0.68	177.77	12.07	0.34	0.0	0.0	0.0
36	Sb. Sumber Wuluh	"	S.	6.8	25.0	3.6	190	171	11.41	3.96	2.82	17.85	0.06	7.29	2.63	115.95	15.09	0.40	0.0	0.0	0.0
37	Urang Gantung II	"	G.	7.1	25.6	2.3	430	358	25.58	7.49	18.88	31.75	0.06	16.80	7.90	254.05	9.06	0.32	0.0	0.0	0.0
38	K. Lemak (jugosari)	"	R.	8.5	26.0	6.8	230	212	13.25	3.98	8.84	23.15	0.10	7.61	5.56	143.51	5.61	0.20	0.0	0.0	0.0
39	Tempeh Kidul I	"	G.	7.2	27.1	3.9	320	341	17.48	7.17	15.27	29.76	0.14	9.5	0.59	225.93	29.32	0.34	0.0	1.20	0.0
40	Tempeh Kidul II	"	R.	7.1	26.9	3.3	320	320	16.56	5.77	13.67	25.13	0.09	10.78	0.20	202.47	26.27	0.24	0.0	1.40	0.0

Concentration of ions are commonly reported in parts per million (ppm). One ppm means one part by weight of dissolved constituent in a million parts by weight of solution. Original data expressed in mg/liter; ppm and mg/liter are numerically almost the same.

Taking into consideration the availability on graphical interpretation of principal chemical compositions such as Na + K, Mg, Ca in cation and Cl, SO_4, HCO_3 + CO_3 in anion, these concentrations are expressed in equivalent per million (epm) calculated by dividing ppm by the equivalent weight of ion under consideration. The epm value can be also calculated, using conversion factors given in Table-3.4. The principal chemical compositions in epm are compiled in Appendix C-3; Hydrochemical charts.

Table-3.4 Conversion Factors; ppm to epm

Cation Ion		Multiply by	Anion Ion		Multiply by
Sodium	(Na^+)	0.04350	Chloride	(Cl^-)	0.02820
Potassium	(K^+)	0.02558	Sulfate	(SO_4^{--})	0.02082
Magnesium	(Mg^{++})	0.08224	Bicarbonate	(HCO_3^-)	0.01639
Calcium	(Ca^{++})	0.04990	Carbonate	(CO_3^{--})	0.03333

3.4 INTERPRETATION OF CHEMICAL ANALYSIS DATA

3.4.1 CORRELATION BETWEEN CHEMICAL DATA

A correlation coefficient is an index to indicate the relationship between two variable series, expressed by the following equation;

$$\gamma = \frac{Cov\ (X \cdot Y)}{\delta x \cdot \delta y} \qquad \ldots\ldots\ldots\ldots\ldots (3.1)$$

where;

COV (X·Y) : Covariance of variable, X and Y

δx, δy : Deviation of variable, X and Y, respectively

Variables dealt with here are as follows;

- Cation ions ; Na, K, Mg, Ca, Fe
- Anion ions ; Cl, SO_4, HCO_3, PO_4
- Others ; pH, EC, TDS (SISA), Mn, $KMnO_4$, CO_2, $NO_2 + NO_3 + NH_4$

Correlation coefficients between chemical data above-mentioned, calculated by the equation (3.1), are as shown in Table-3.5.

The coefficient γ falls in the range of $-1 \leq \gamma \leq 1$; plus value of γ indicates positive correlation and minus value, negative correlation. As the absolute value of γ nears the degree of correlation grows strong; on the contrary, as γ approaches 0, the degree of correlation grows weak.

From Table-3.5, high correlation coefficients more than 0.8 in absolute value are obtained in the following relationships;

TDS - EC ; 0.95

TDS - HCO_3 ; 0.94

HCO_3 - EC ; 0.94

Table-3.5 Correlation Coefficients between Chemical Data

	pH	SISA	NO_3^-	SO_4^{--}	HCO_3^-	Cl^-	Mn	Fe	Ca^{++}	Mg^+	KMnO4	Na	K	PO_4	EC	CO_2
pH	1.0	0.11	-0.36	0.40	0.16	-0.03	-0.09	-0.05	0.26	0.21	0.24	0.32	-0.06	-0.22	0.21	-0.62
SISA		1.0	0.40	0.17	0.94	0.46	0.22	0.04	0.89	0.80	0.12	0.75	0.72	0.03	0.95	0.38
NO3			1.0	-0.26	0.37	0.32	-0.01	0.14	0.30	0.20	-0.11	0.17	0.21	0.14	0.23	0.45
SO4				1.0	0.16	-0.03	-0.07	-0.07	0.12	0.25	-0.11	0.47	0.11	0.03	0.31	-0.31
HCO_3					1.0	0.21	0.18	0.00	0.91	0.82	0.17	0.78	0.66	0.13	0.94	0.32
Cl						1.0	-0.09	-0.07	0.22	0.26	-0.18	0.21	0.45	-0.13	0.32	0.07
Mn							1.0	0.57	0.19	0.13	0.43	0.18	0.07	0.02	0.24	0.35
Fe								1.0	-0.02	0.03	0.40	0.07	-0.12	-0.10	0.06	0.22
Ca									1.0	0.69	0.18	0.67	0.63	0.05	0.89	0.29
Mg										1.0	0.15	0.72	0.49	0.04	0.85	0.07
KMnO4											1.0	0.22	-0.08	-0.39	0.14	0.05
Na												1.0	0.55	0.19	0.80	-0.00
K													1.0	0.30	0.71	0.23
PO4														1.0	0.10	-0.00
EC															1.0	0.29
CO2																1.0

HCO_3	-	Ca	;	0.91
TDS	-	Ca	;	0.89
Ca	-	EC	;	0.89
Mg	-	EC	;	0.85
HCO_3	-	Mg	;	0.82
TDS	-	Mg	;	0.80
Na	-	EC	;	0.80

The high correlationship between total dissolved solids (TDS) and electric conductivity is well known and these factors are not representative as chemical properties.

In consequence, the principal chemical compositions which play the major role of the water quality in the study area are HCO_3, Ca, Mg and Na in the order.

The correlation between chemical data are given in the supplement C-2 : CORRELATION BETWEEN CHEMICAL DATA. Some of them is as shown in Fig.-3.4(1) and (2).

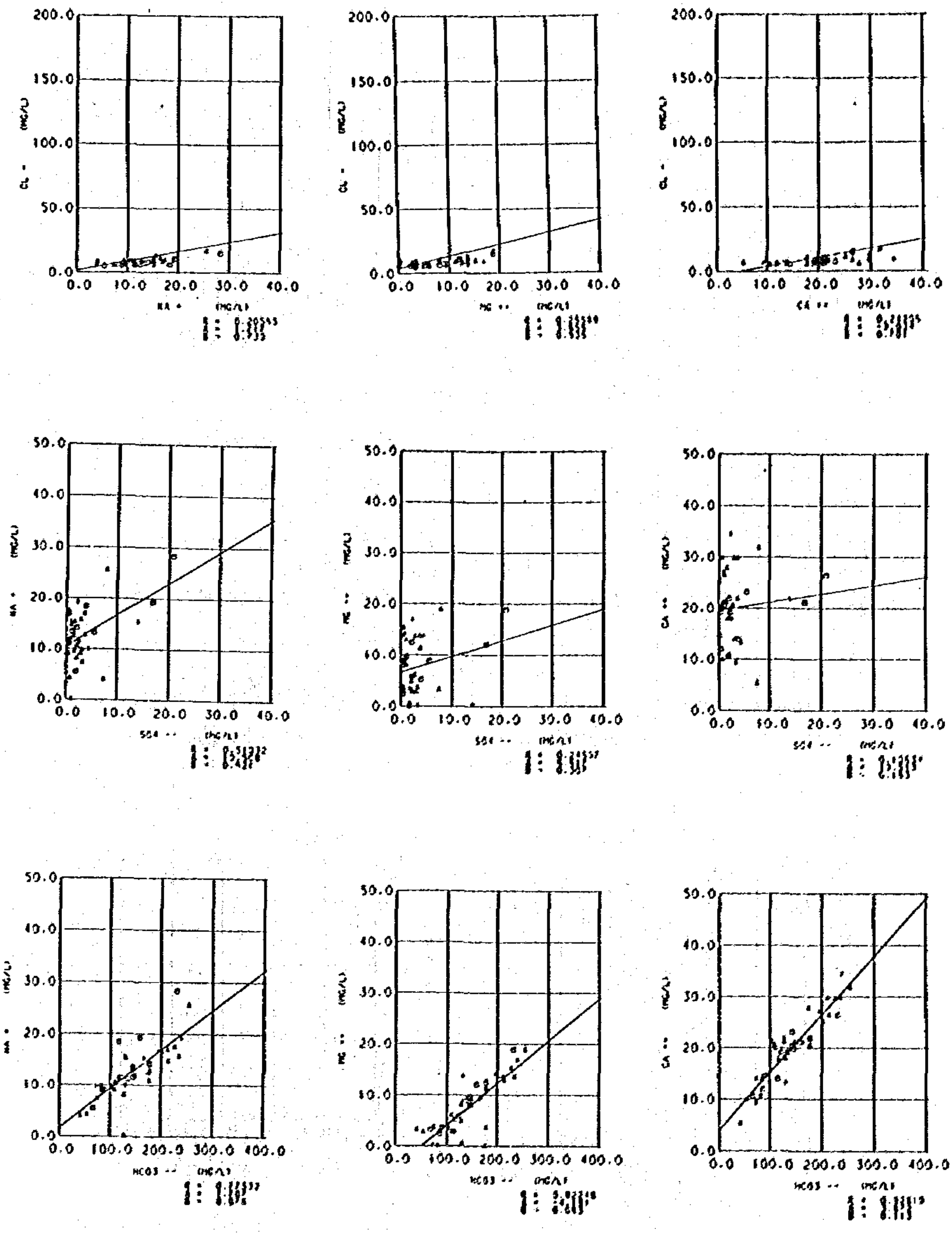


Fig.-3.4(1) Correlationship between Chemical Data

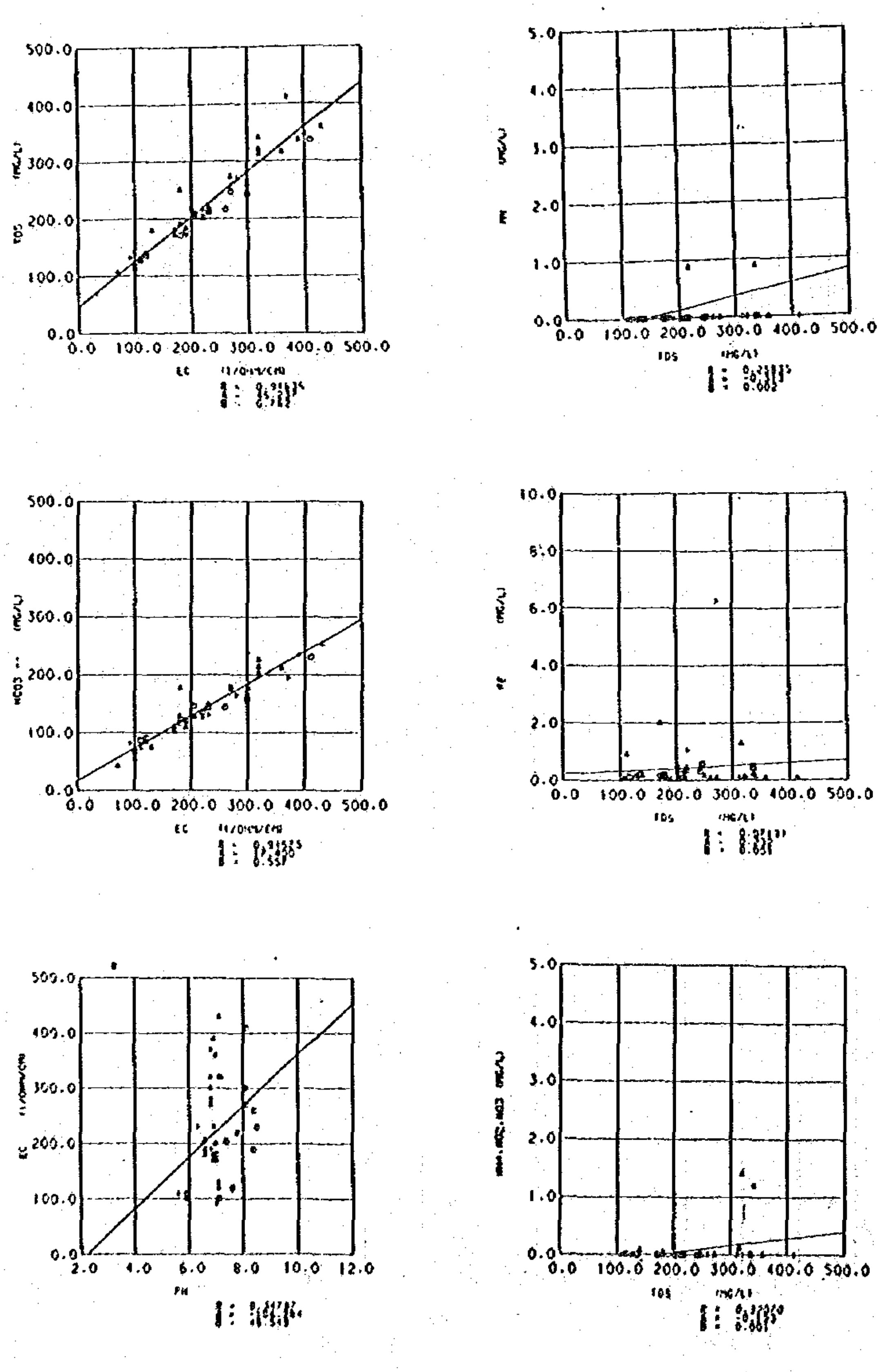


Fig.-3.4(2) Correlationship between Chemical Data

3.4.2 GRAPHICAL INTERPRETATION

Chemical analysis data compiled in Hydrochemical Charts (Appendix C-3) will be graphically interpreted, according to the key diagram method and the hexa-diagram method.

(1) Key Diagram Method

Key diagram, also called Piper trilinear diagram, combines three distinct fields; two triangular fields at the lower left and lower right, respectively, an intervening diamond-shaped field. All three fields have scales reading in 100 parts. In the triangular field at the lower left, the percentage reacting values of the three cation groups (Ca, Mg, Na + K) are plotted as a single point according to conventional trilinear coordinates. The three anion groups (HCO_3, SO_4, and Cl) are plotted likewise in the triangular field at the lower right. Thus, two points on the diagram, one in each of the two triangular fields, indicate the relative cationic and anionic concentrations. The subtotal of all cation equivalents per million is taken as the 100 percent base for computing percentage reacting values of the several cation variables; likewise for the several anion variables. The central diamond-shaped field is used to show the overall chemical character of the water by a third single-point plotting, which is at the intersection of rays projected from the plottings of cations and anions. The position of this plotting indicates the relative composition of a water in terms of the cation-anion pairs that correspond to the four vertices of the field.

According to the key diagram method, chemical properties of K. Mujur, K. Rejali and K. Lengkong are given in Fig.-3.5(1) to (3) and can be summarized as follows;

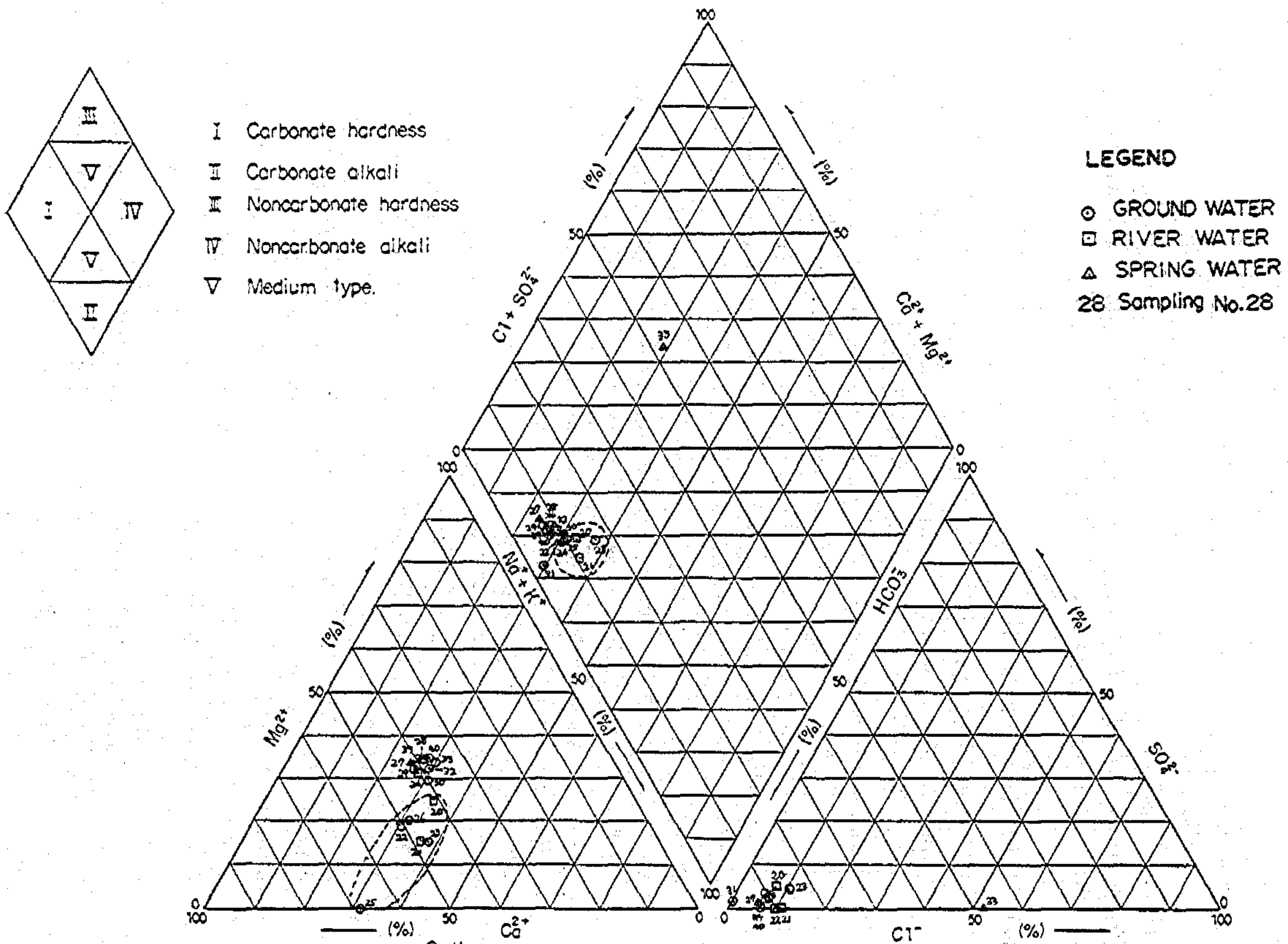


Fig.- 3.5(1) KEY DIAGRAM (K. MUJUR)

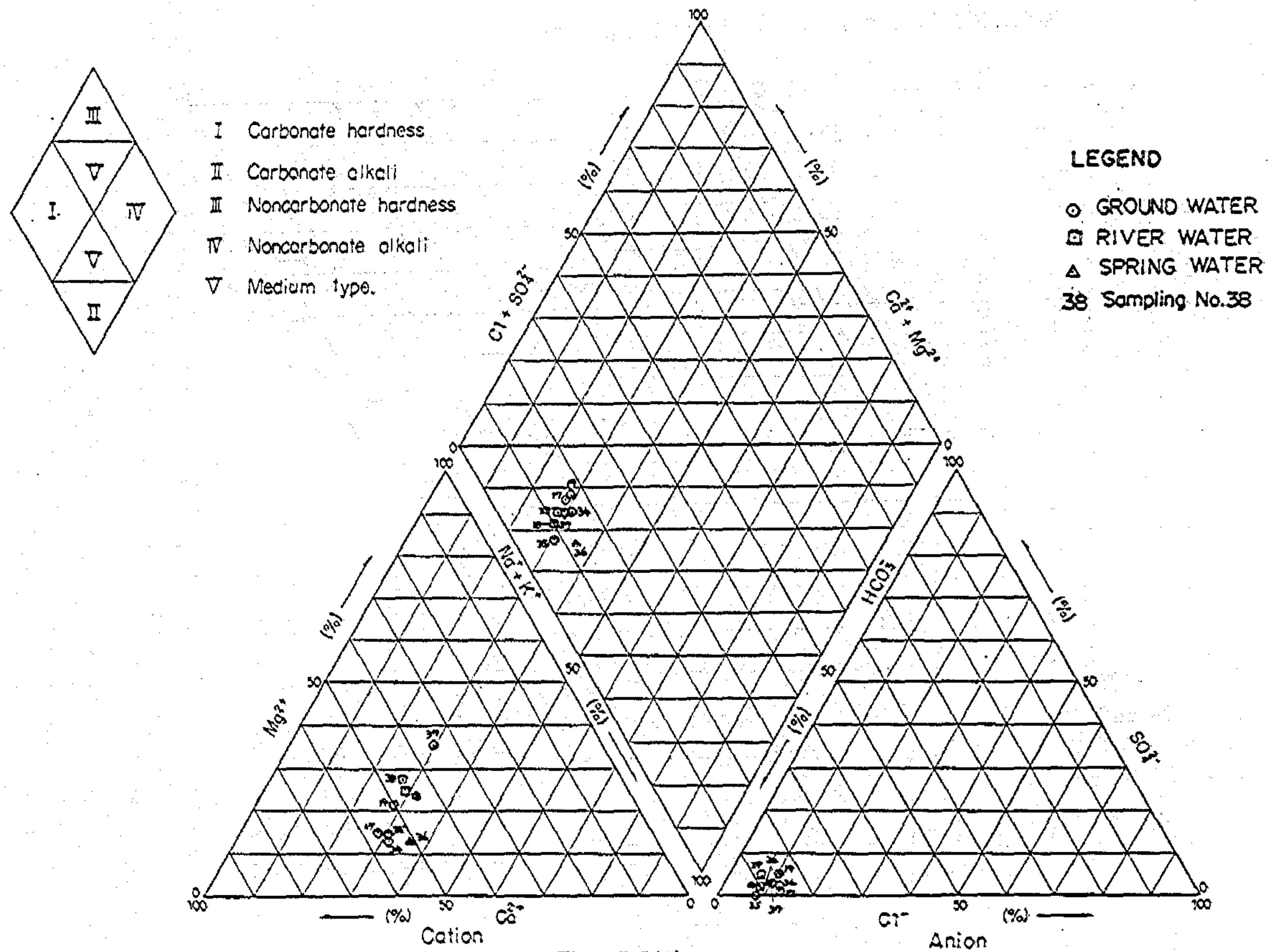


Fig.-3.5(2) KEY DIAGRAM (K. REJALI)

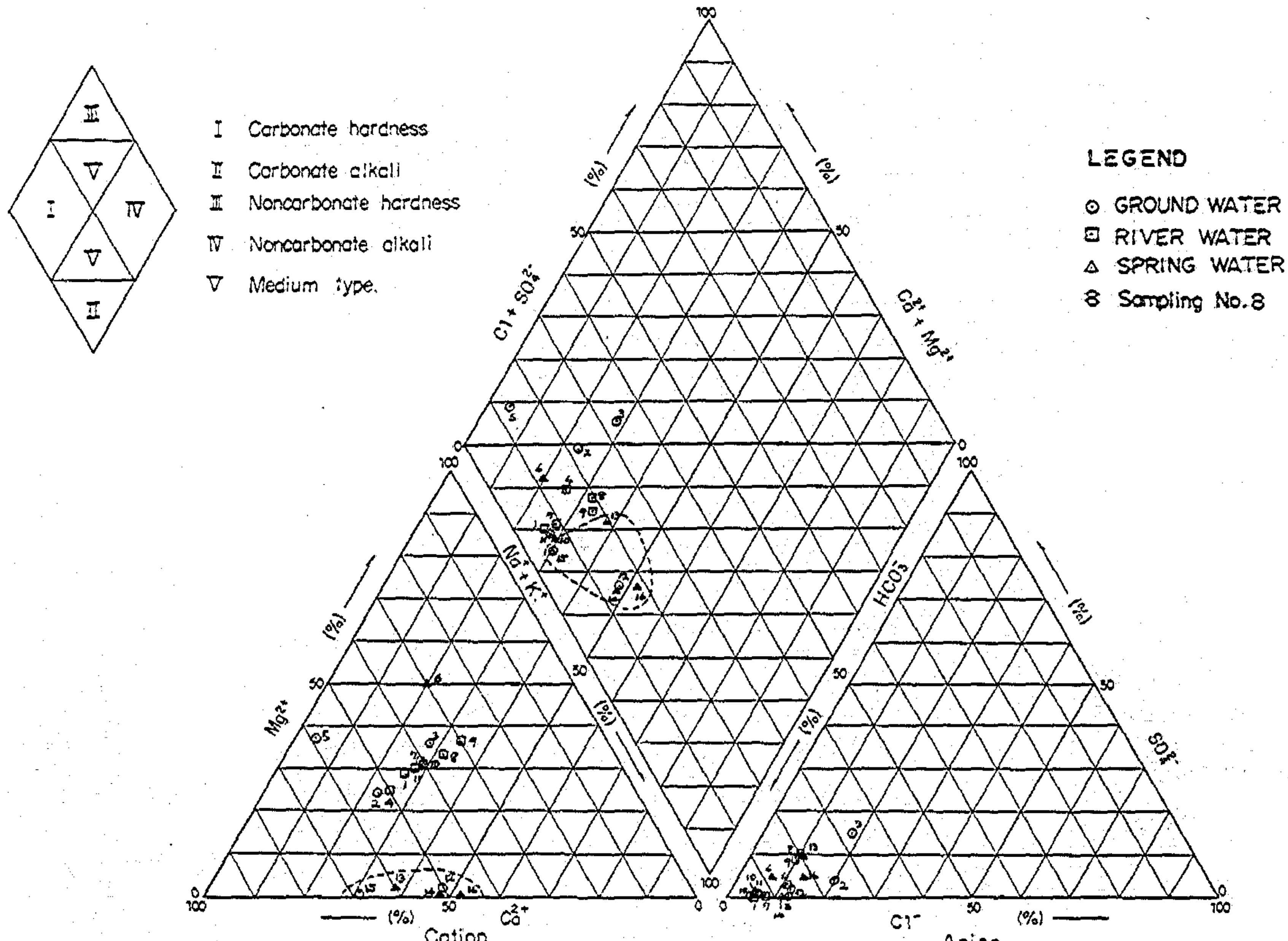


Fig.- 3.5(3) KEY DIAGRAM (K. LENGKONG)

- All of the sampling points except No. 33 belongs to carbonate hardness.

- Significant grouping can be made in the cationic triangular field, but nothing in the anionic one.

(2) Hexa-diagram Method

The Hexa-diagram Method using three parallel horizontal axes and one vertical axis may be useful in making comparisons of water. Three cations are plotted along each axis to the left of the zero point and three anions on the right. Concentrations are expressed in equivalents per million. Connecting points representing anions and cations give a close figure or "pattern" whose shape is more or less characteristic of a given water.

Hexa-diagram of each sampling water is given in Fig.-3.6 and some remarks from this graphical representation are as follows:

- As the ratio of Na/Cl is not significant, the influence of wind-born salt is not important.

- Sulfate content is very small on the whole of the sampling water.

- Magnesium content varies irregularly with comparison of those of sodium, calcium and bicarbonate.

- Chemical property of sampling water having high T.D.S. value belongs to bicarbonate prominent type.

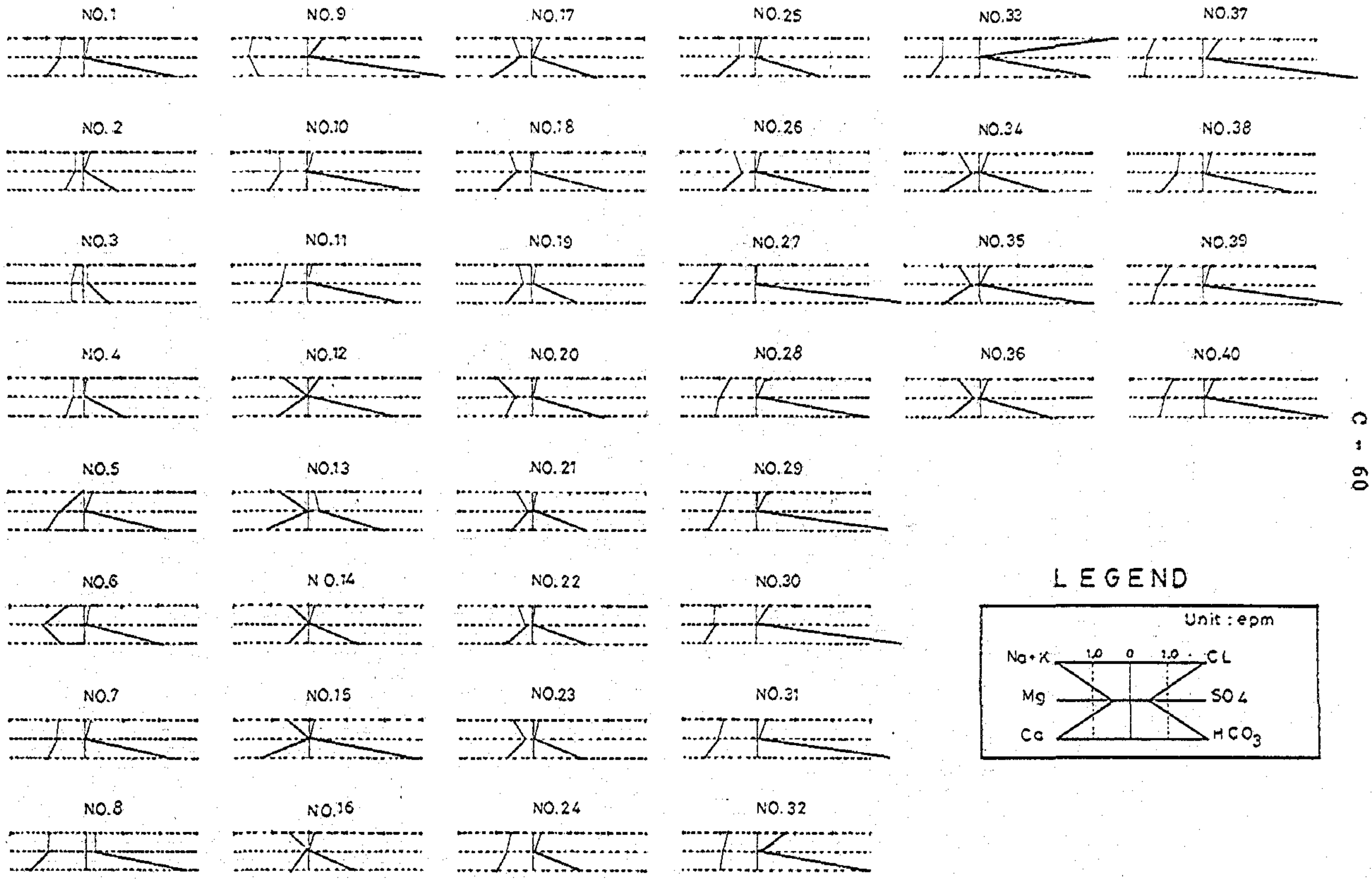


Fig-3.6 Hexa-diagram

3.4.3 HYDRO-GEOCHEMICAL INTERPRETATION

In order to clarify the relationship between geology and chemical properties of water, a hydro-geochemical map is prepared as shown in Fig.-3.7 and hydrogeochemical properties in the study area can be summarized as follows;

- Waters from andesite and tertiary formations have very similar chemical properties; pH value shows slightly acidity and water quality is excellent.

- Waters from younger Lahar deposits belong to bicarbonate prominent type and total dissolved solids are higher than the others; pH value shows slightly alcalinity.

- Waters from old Lahar deposits show intermediate properties between andesite/tertiary formations and younger Lahar deposits.

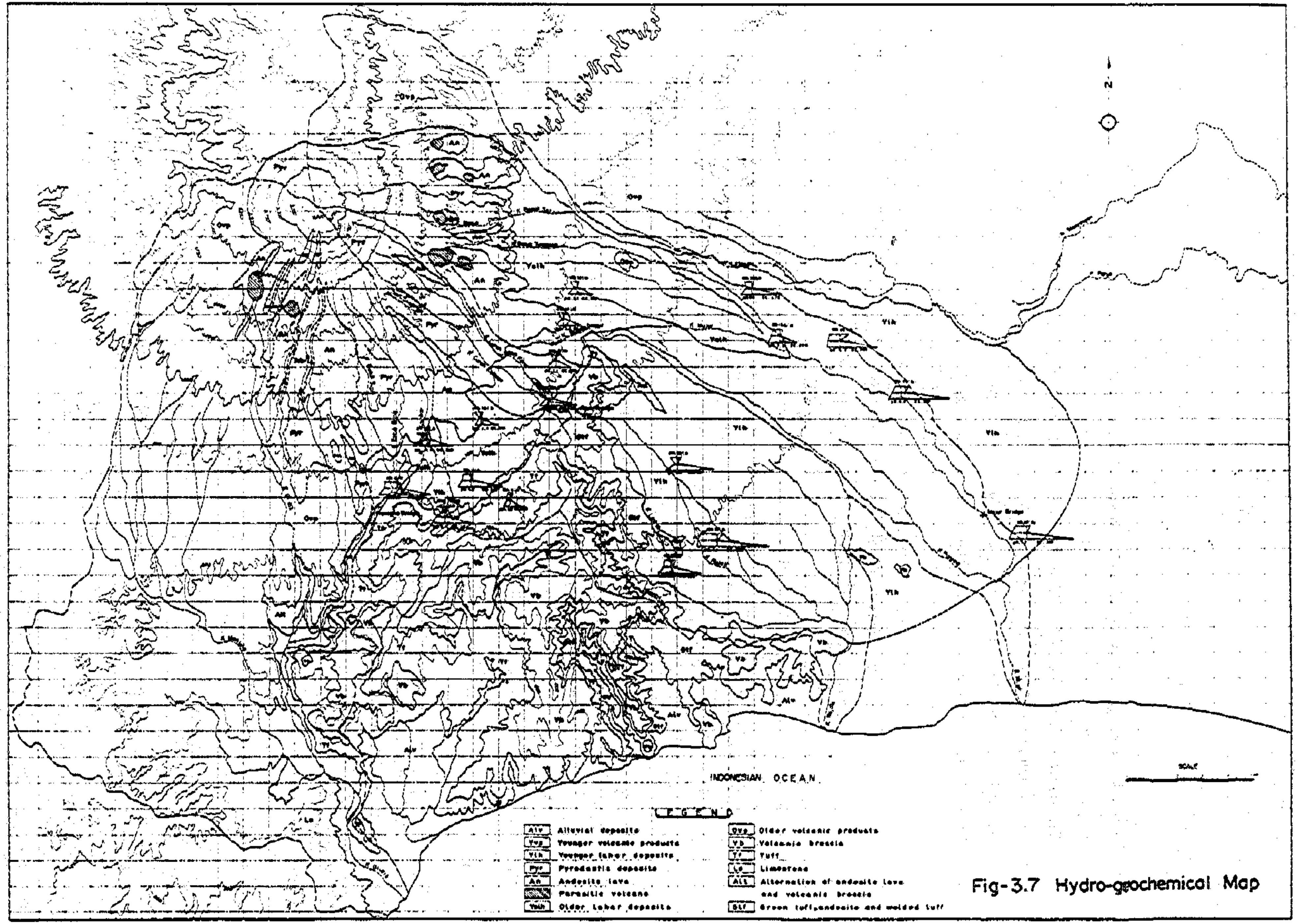


Fig-3.7 Hydro-geochemical Map

3.5 WATER QUALITY EVALUATION FOR USE

In this section, water quality evaluation will be made to determinate whether or not the water is satisfactory in quality for drinking and/or agricultural use, based on the chemical analysis results of sampling waters.

3.5.1 DRINKING USE

According to the drinking criteria established by the Department of Public Health of Indonesia, the following chemical substances should not be present in a water in excess of the listed concentrations.

Calcium	(Ca)	200 mg/ℓ
Chloride	(Cl)	600 "
Chromium (hexavalent)	(Cr^{6+})	0.05 "
Copper	(Cu)	1.5 "
Iron	(Fe)	1.0 "
Lead	(Pb)	0.10 "
Magnesium	(Mg)	150 "
Manganese	(Mn)	0.5 "
Nitrate	(NO_3)	20 "
Nitrite	(NO_2)	0.0 "
Sulfate	(SO_4)	400 "
Total dissolved solids		1,500 "

From the chemical analysis results of sampling water, some sampling points in the study area are not suitable in quality for drinking use, due to the following reasons;

i) The waters taken from sampling point No.6, No.10, No.12, No.30 and No.31 are in excess of the permissible limit concentration in Manganese (Mn).

ii) The waters taken from sampling point No.31, No.39 and No.40 are in excess of the permissible limit concentration of Nitrite (NO_2).

iii) The waters taken from sampling point No.10 and No.34 are in excess of the permissible limit concentration in Iron (Fe).

The location and nature of these sampling points is as follows;

Sampling Point	Location	Nature
No. 6	Nanas sp.A	Spring Water
No. 10	Nanas sp.B	Spring Water
No. 12	Sumber Urip Krajan	Groundwater
No. 30	Kedung Wringin	Groundwater
No. 31	Kali Putih	Groundwater
No. 34	Sumber Wuluh II	Groundwater
No. 39	Tempeh Kidul I	Groundwater
No. 40	Tempeh Kidul II	Groundwater

In conclusion, a careful chemical analysis should be carried out to examine whether or not a water of a given quality is suitable for drinking use, especially when groundwater will be considered to be drinking water supply sources.

3.5.2 AGRICULTURAL USE

The water quality of the study area belongs to the carbonate hardness type and its principal characteristics related to agricultural use can be denoted as follows;

pH	:	5.9 ∿ 8.5
Total dissolved solids	:	107 ∿ 412 mg/ℓ

(Quoted from Table-3.3)

The pH value of 5.9 to 8.5 represents neither strong acidity nor alkalinity for irrigation use. Also, the value of 107 to 412 mg/litre in total dissolved solids is largely satisfactory with regard of salinity permissible limit.

From field reconnaissance, the spring distribution line at 800 to 830 m in elevation is in good concordance with the upper limits of paddy cultivation.

Furthermore, the study area has an abundant amount of rainfall and all of the sampling waters is thought to be fresh water supplied by rainfall. Therefore, both surface and underground water is estimated to be good resources for agricultural use.

4. HYDROGEOLOGY OF K. LENGKONG BASIN

4.1 GENERAL

K. LENGKONG basin can be roughly approximated to a fragment of circle; its center is the top of Mt. Semeru and its arc is the watershed of Tertiary mountains located at the south of Mt. Semeru. The western and eastern boundaries of this basin will be determinated by groundwater devides existing between K. Lengkong basin and the neighbour one. K. Lengkong meanders down toward west along the foot of Tertiary mountains.

From the topographical and geological viewpoints, K. Lengkong basin is expected to have a large depression structure, of which impermeable bottom is composed of the high weathered surface layers of old volcanic product and tuff; the former belongs to Jambangan Volcanic Complex and the later to Tertiary formation.

Furthermore, K. Lengkong Fan, located on the southern slope of Mt. Semeru, damaged by Lahar in 1977 and 1978, and a considerable part of rich paddy field extending on this fan was covered with sand and gravels.

As K. Lengkong basin is expected to have the highest potential for groundwater development, hydrogeological investigations, such as electric sounding, drilling works, groundwater level observation, water quality test and so on, have been already carried out.

In this Chapter, hydrogeological characteristics of K. Lengkong will be discussed, based these results obtained.