4.2 HYDRAULIC PROPERTIES

4.2.1 WATER LEVEL IN BOREHOLES

The term of "water level in borehole" will be introduced hereinafter instead of groundwater level found in borehole, because the water level in borehole is often changeful during drilling work, due to the existence of different piezometric pressures.

(1) Water Level in Boreholes during Drilling Works

The drilling works executed in K. Lengkong basin are as shown in Table-4.1 and hydrogeological information obtained from these drilling works will be denoted in this section.

Table-4.1 List of Drilling Works

Borehole No.	Location	Objective	Depth	Execution
B-1	Pronojiwo dam site	Geology of dam site	30 m	1982
B-2	"	"	35	"
B-3	"	"	22	"
B-4	K. Lengkong fan	Groundwater level	10	"
B-5	"	"	5	"
B-6	"	"	5	"
B-7	"	"	7	"
B-8	"	"	6	"
B-9	"	"	5	"
B-10	"	"	5	"
B-11	"	Confirmation of the base of groundwater basin	60	1983

Note: Location of drilling points is given in Fig.-4.1.

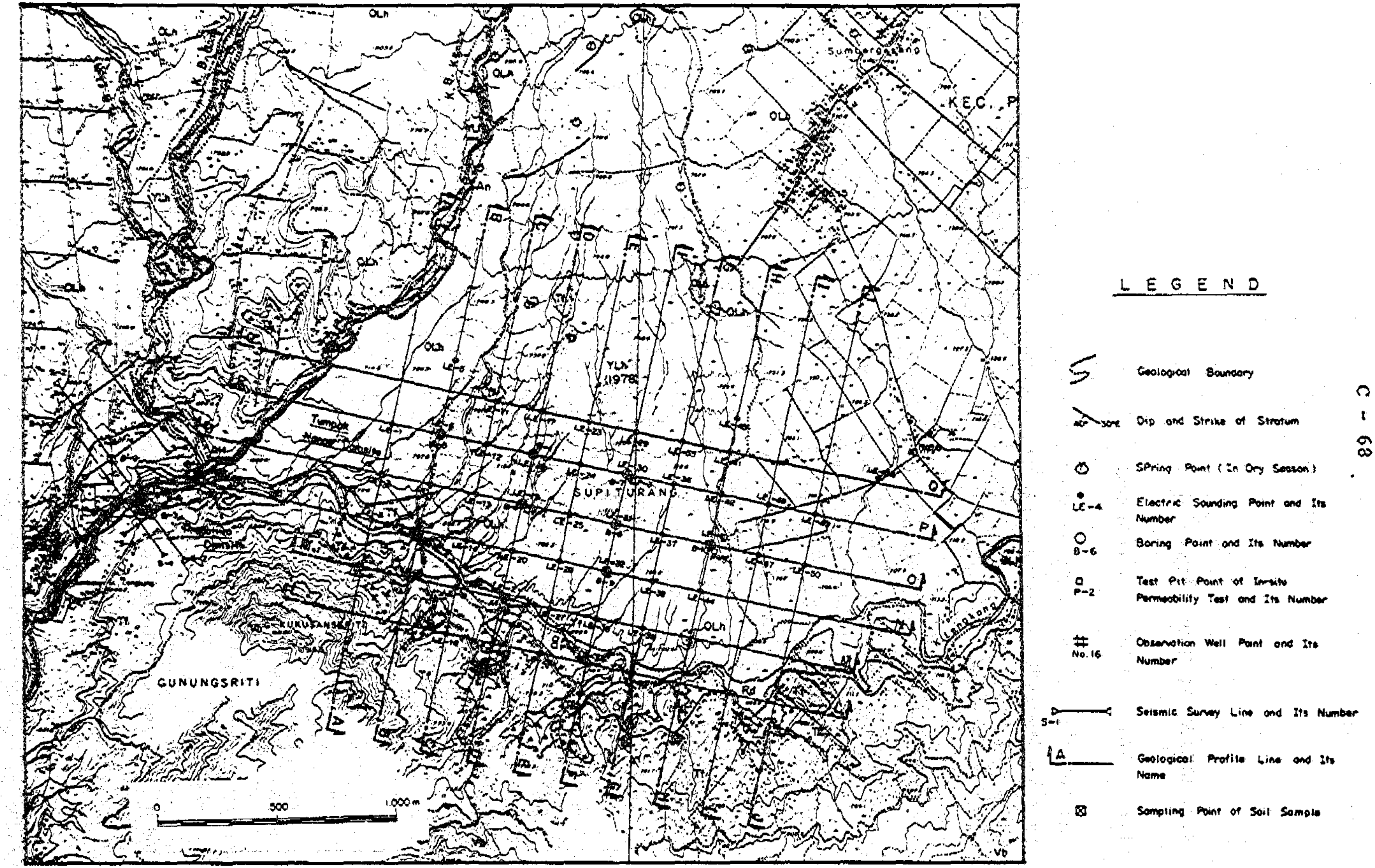


Fig.-4.1 Location of Boreholes

i) B-1 Hole

The water level in B-1 hole had a strange behavior with the progress of drilling depth, as shown in Fig.-4.2. From the depth 0 to -18 m, water level in borehole was stable at -0.4 m, but water level abruptly dropped to about -14 m when the depth approached to -18 m. This low water level continued while drilling from the depth -18 to -24 m. At the depth deeper than -24 m, water level began to recover and finally stabilized at -5.5 m. This variation of water level will signify an existence of low hydraulic potential layer in porous tuff breccia.

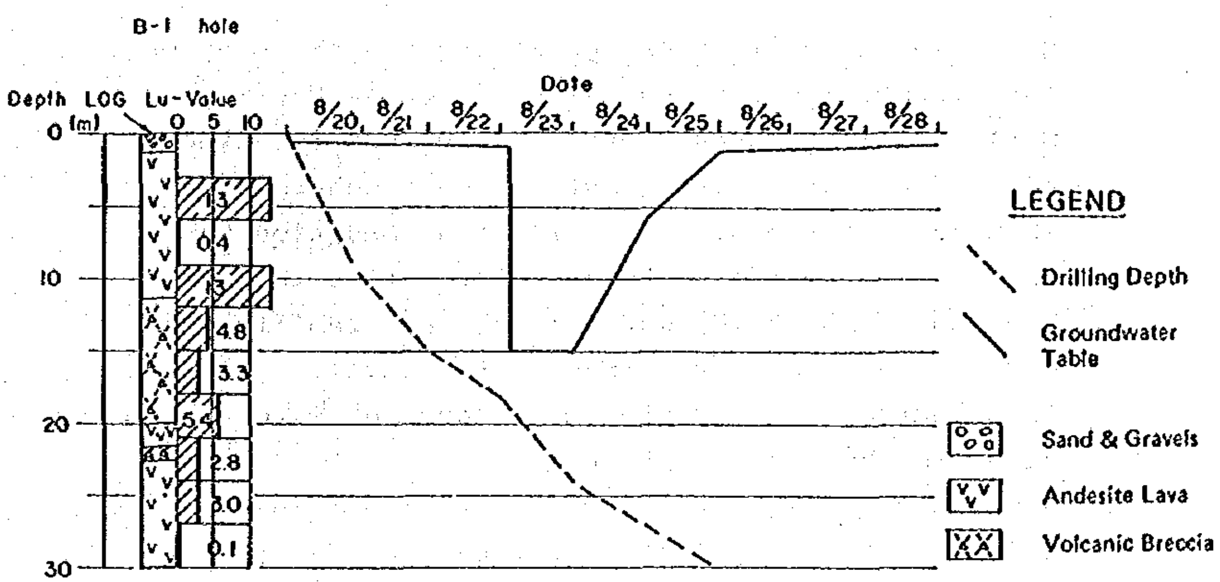


Fig-4.2 Variation of Water Level in B-1 Hole

ii) B-2 Hole

Water level in B-2 hole was found in older Lahar deposits and was stable at about -12 m during drilling work. Lugeon test was carried out in andesite at -31.5 to -35 m, a large value of 25 Lu was obtained. As older Lahar deposits are very compact, water-veins might run through this layer.

iii) B-3 Hole

Water level in B-3 hole was found in andesite and was stable at about -11 m during drilling work. Lugeon test was carried out in fresh andesite at a depth of -18 to -22 m; 2.5 Lu was obtained.

iv) B-4 Hole

B-4 hole was drilled on the riverbed of K. Lengkong; the prospective sabo dam site of Tumpak Nanas. While drilling, when a steel casing was inserted to -5.5 m, water sprang out at the discharge of about 50 liter/min. This artesian condition was observed up to the bottom; -10 m. After the completion of borehole, water level was stabilized at 0.3 to 0.5 m above the river water level. This indicates an existence of layer or water-veins with high hydraulic potential.

v) B-5 Hole

Water level in B-5 hole was found in older Lahar deposits at the depth of -4.0 m at the time of completion.

vi) B-6 Hole

Water level in B-6 hole was found in older Lahar deposits at the depth of -4.8 m at the time of completion.

vii) B-7 Hole

Water level in B-7 hole was found in paddy clay at the depth of -4.6 m at the time of completion.

viii) B-8 Hole

Water level in B-8 hole was found in younger Lahar deposits at the depth of -3.0 m at the time of completion.

ix) B-9 Hole

Water level in B-9 hole was found in younger Lahar deposits at the depth of -1.3 m at the time of completion.

x) B-10 Hole

Water level in B-10 hole was found in paddy clay at the depth of -1.5 m at the time of completion.

xi) B-11 Hole

Water level in B-11 hole had a strange behavior with the progress of drilling depth, as shown in Fig.-4.3. From the depth 0 to -27.7 m, water level in borehole was found at -1.3 to -1.7 m, but water level abruptly dropped to about -6.5 m during the drilling of -27.7 m to 31.5 m in depth.

At the depth depper than -45 m, water level slightly re-covered and stabilized at -5.5 m.
This indicates an existence of low hydraulic potential layer in older Lahar deposits.

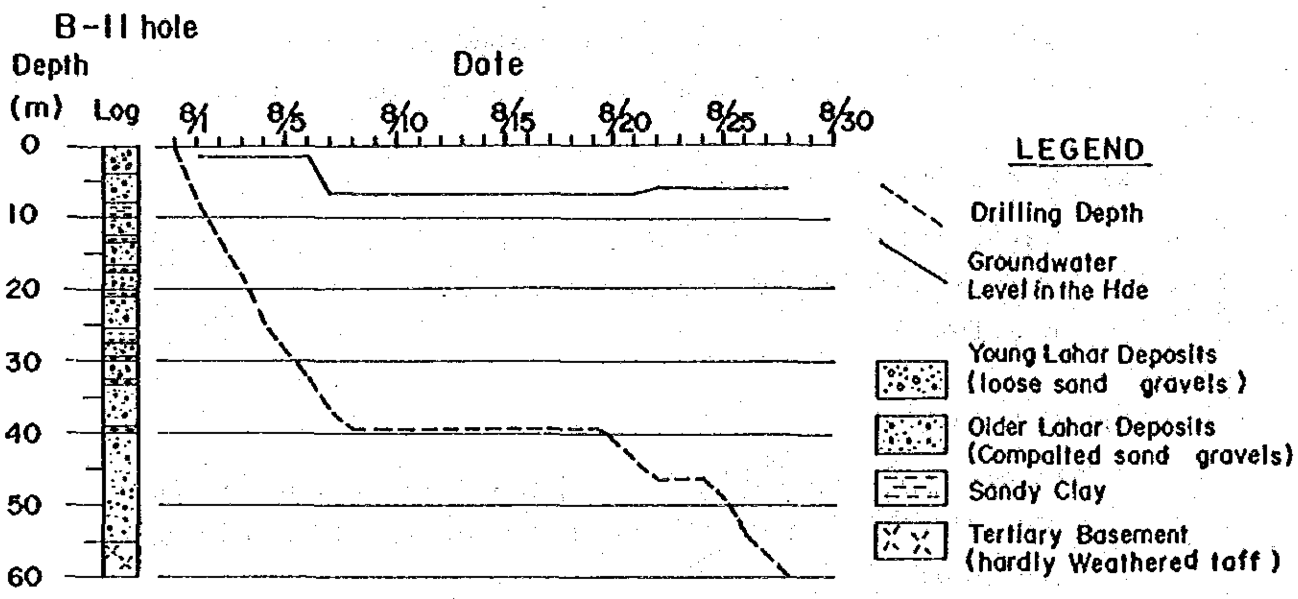


Fig- 4.3 Variation of Water Level in B-11 Hole

(2) Observation of Water Level in Borehole

In order to clarify the seasonal variation of water level in borehole, water level at each borehole (B-1 to B-10) is being carried out every two month, in charge of Mt. Semeru Project Office.
Observation results are given in Table-4.2, but sufficient results to interpretate these seasonal variation did not obtain, due to destruction of boreholes.

Table-4.2 Observation Results of Water Level in Borehole

(GL - m)

Borehole No. / Date	BH-1	BH-2	BH-3	BH-4	BH-5	BH-6	BH-7	BH-8	BH-9	BH-10	
Depth (m)	30	35	22	10	5	5	7	6	5	5	
15 Nov. 82	-	-	-	-	Dried out	-	-	-	-	-	
22 Nov. 82	0.85	-	Dried out	-	-	-	-	-	-	-	
29 Nov. 82	-	12.0	-	-	-	-	-	-	-	-	
6 Dec. 82	-	-	-	Artesian Condition	-	Dried out	5.40	Dried out	3.30	2.65	
10 Jan 83	Destroy-ed	Destroy-ed	Dried out	"	4.50	3.90	3.80	2.50	0.90	1.30	
7 Feb. 83			-	"	3.95	-	-	-	-	-	
7 Mar. 83			Dried out	"	4.50	2.30	2.20	1.20	Destroy-ed	1.40	

4.2.2 GROUNDWATER LEVEL AT EXISTING WELLS

The additional groundwater level measurement of existing wells in K. Lengkong basin aims to have a more detail information which permits to establish a groundwater level contour map. The measurement at existing wells was carried out on the 22 to 26 October 1983, using portable water level gauge.

As additional wells selected for groundwater level measurement in short period belong to shallow dug well, A tentative groundwater level contour map given in Fig.-4.4 represents groundwater table of the shallow aquifer. Some remarks related to the groundwater table in K. Lengkong basin will be given as follows;

- At the slope of Mt. Semeru near 800 m in elevation, many springs are found and groundwater level at well seems to be shallower from the ground surface than that of the vicinity; the groundwater level tends to go remarkably deeper when the elevation gets higher, on the contrary, the groundwater level tends to go slightly deeper when the elevation gets lower.

- The drainage system of K. Lengkong seems to strongly affect to the groundwater level counter map; groundwater from Mt. Semeru and Tertiary mountains flows into K. Lengkong.

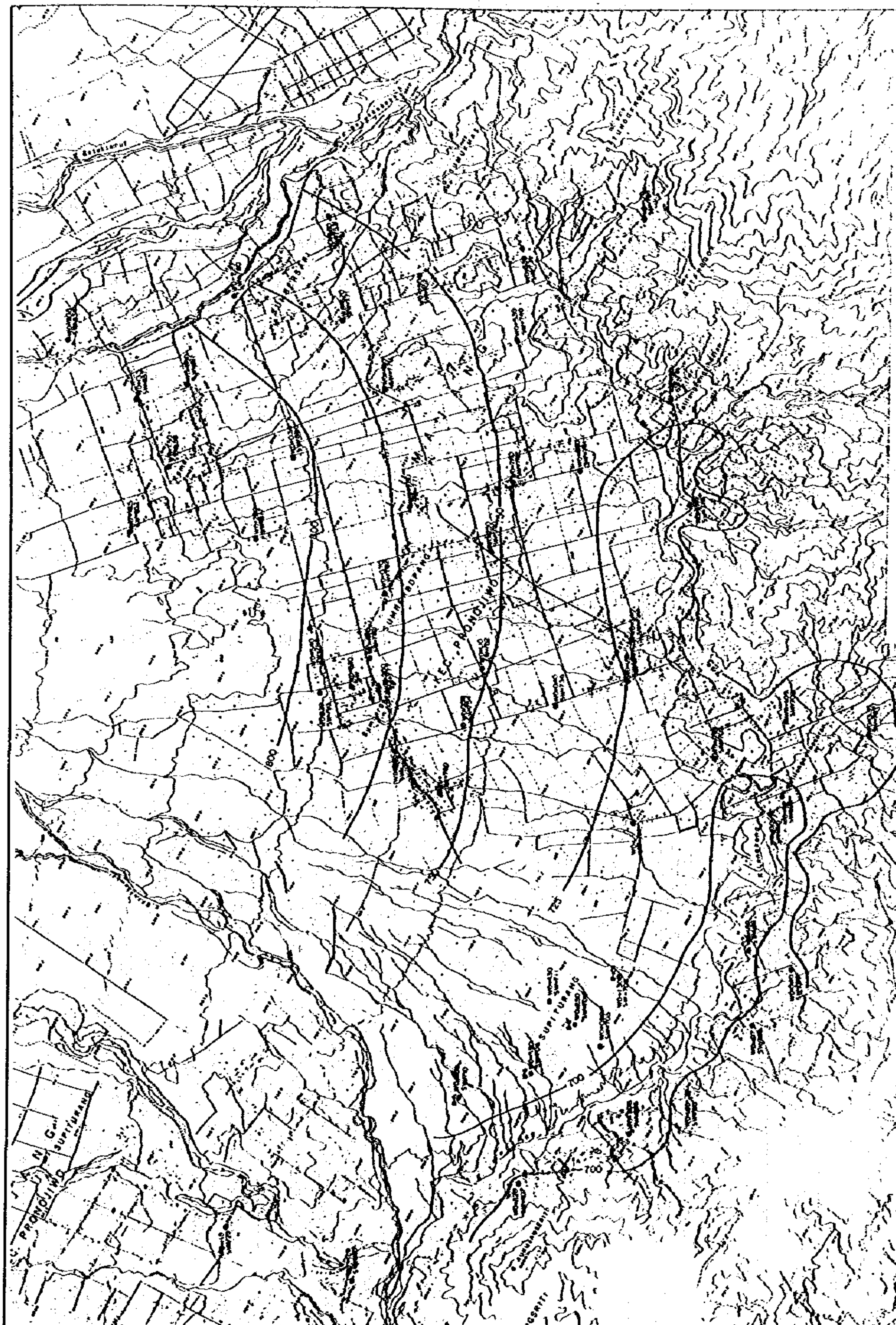


Fig-4.4 Groundwater Level Contour Map in K.Lengkong Basin

4.2.3 PERMEABILITY OF SURFACE LAYERS

The in-situ tests, such as the in-situ permeability test, field density test and soil test, were executed on the ground surface. These results are given in Table-4.3 and summarized as follows:

(1) Younger Lahar Deposits

The obtained values of permeability coefficient, 1 to 5 cm/sec., seems to be a small figure for sand/gravel layer. This may be due to the fact that pores between coarse grains are considerably filled with fine particles.

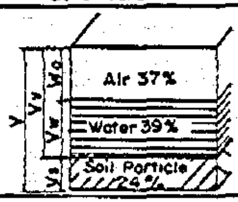
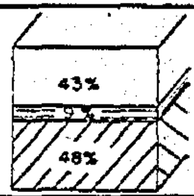
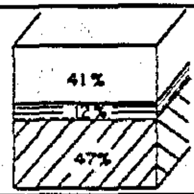
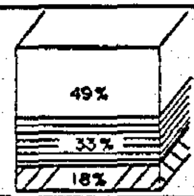
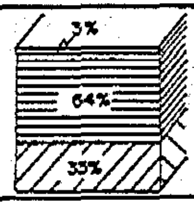
(2) Weathered Layer of Tuff (Loam Like)

The permeability coefficient of weathered tuff is about 1×10^{-2} cm/sec., a remarkably large figure for the grain composition (40 to 50% of silt and clay). This is due to the fact that void ratio is remarkably large at 3.1 to 4.7 and fabric of soil is very porous.

(3) Paddy Clay

This clay abounds in very fine grains: 58% silt and 19% clay with the permeability coefficient low at $K = 8 \times 10^{-5}$ cm/sec.

Table-4.3 Results of In-Situ Permeability Test and Soil Test

Test Item / Pit No.	P-1	P-2	P-3	P-4	P-5
Lithology	Weathered Tuff	Younger Lahar Deposits	Older Lahar Deposits	Highly Weathered Tuff	Paddy Clay
Permeability Coefficient (k)	1.4×10^{-2} cm/sec	5×10^{-4} cm/sec	4.2×10^{-4} cm/sec	1.3×10^{-2} cm/sec	8.0×10^{-5} cm/sec
Natural Water Contents (ω)	59.3%	6.25%	8.6%	69.17%	73.31%
Specific Gravity (Gs)	2.7458	2.7398	2.7562	2.7113	2.6273
Field Density (γt)	1.06 g/cm^3	1.50 g/cm^3	1.42 g/cm^3	0.81 g/cm^3	1.50 g/cm^3
Grain Size Distribution	6.25% 27.75% 20.75% 34.25% 11.00% (gravel, Coarse Sand, fine Sand, Silt, Clay)	7.75% 58.25% 17.75% 14.5% 1.75%	28.0% 44.5% 17.75% 8.75% 1.0%	3.0% 28.25% 15.0% 42.0% 11.75%	0.67% 9.43% 12.60% 58.10% 19.2%
Volume Ratio of Each Component					
Void Ratio ($e = \frac{Vv}{Vs}$)	3.13	1.08	1.11	4.66	2.0
Porosity ($n = \frac{Vv}{V} \times 100$)	75.6%	52.0%	52.6%	82.3%	66.7%
Saturation ($Sr = \frac{Vw}{Vv} \times 100$)	52.1%	16.4%	21.4%	40.2%	95.0%
Air Voids ($Va = \frac{Va}{V} \times 100$)	37.0%	43.5%	41.3%	49.2%	3.3%

4.3 DELINEATION OF GROUNDWATER SYSTEM

4.3.1 HYDROGEOLOGICAL EVALUATION OF LAYERS

(1) Hydrogeological Properties of Layers

Sequence of Strata related to K. Lengkong basin is given in Table-4.4 and its hydrogeological properties will be summarized here.

Table-4.4 Sequence of Strata related to K. Lengkong Basin

Age	Layer	Components
Quarternary Period	Riverbed deposits	Presently moving sand and gravels along river course.
	Younger Lahar deposits	Loose sand and gravels
	Pyroclastic deposits	Volcanic products directly issued from the crater, stationary
	Andesite lava	Andesite lava
	Older Lahar deposits	Well compacted sand and gravels
Tertiary Period	Tuff	Soft tuff, tufficious sandstone and tuff breccia. With thick weathered layer.
	Alternation of Andesite/Tuff Breccia	Alternation of hard, compact andesite and comparatively soft and porous tuff breccia

i) Alternation of Andesite/Tuff Breccia

The existence of alternation of andesite/tuff breccia in K. Lengkong Fan is estimated by electric sounding, found at around -60 to -80 m in depth. This layer becomes shallower toward west, finally being exposed on the riverbed of K. Lengkong near Pronojiwo Damsite. Toward east, this distribution goes deeper.
The deep fresh part can be considered to be impermeable, but some very porous zones may exist in tuff breccia.

ii) Tuff

Tuff layer distributed at the foot of the Tertiary mountains, and plateau-like hill, located west of the K. Lengkong fan, are composed of this layer. Also they are exposed at two spots in K. Lengkong Fan. This layer overlies the alternation of andesite/tuff breccia; its thickness is greatly varied and is partly missing while the thickness reaches as much as over 80 m on other parts.
Weathered surface part of this layer, very similar to loam, contains much silt and clay, but has high permeability due to soil fabric and pipe-like waterveins of which diameter is generally 1 to 3 cm. On the other hand, this weathered part, overlaid by other layers with enough thickness, will become compact and be regarded as aquitard or aquiclude.

iii) Older Lahar Deposits

Older Lahar deposits are composed of accumulation of very irregular tongue shaped stratum. These strata may consist of various layers from silty to very coarse. Autobrecciated lava, coarse and loose

Lahar or pyroclastic deposits, etc. are assumed to be intercalated in older Lahar deposits.

iv) Paddy Clay

Covering the older Lahar deposits, the distribution of paddy clay is limited to western part of K. Lengkong Fan. The maximum thickness of paddy clay is about 3 m. This paddy clay layer will be exported to act as aquitard.

v) Younger Lahar Deposits

Younger Lahar deposits distributed over K. Lengkong Fan were derived from Lahar of 1977 and 1978 and consist of silt, sand and gravels of low compaction. The maximum thickness of the layer is 4 to 5 m.

vi) Pyroclastic Deposits

Pyroclastic deposits consist of very loose volcanic ash, volcanic sand, pumice, lapili, angular boulders, etc. These deposits are distributed over the area over 800 m in elevation.

vii) Andesite Lava

Andesite lava is distributed in the northwest of Sumberbopang village in a strip about 2 km in width, about 6 km in length and 20 to 30 m in thickness. Inside of this lava is very hard and compact, but interstices are developed in the surface and bottom parts. Many springs are found at the lower tip of this lava and groundwater is supposed to flow down through interstitial zone at the bottom of lava.

(2) Hydrogeological Classification of Layers

Saturated bed, formation, or group of formation can be classified into three categories; aquifer, aquitard and aquiclude. From the viewpoint of groundwater resources, only aquifer has a sufficient quantity in yield. Aquitard and aquiclude yield inappreciable quantity of water compared to aquifer.

From the hydrogeological properties of layers, a tentative hydrogeological classification is given in Table-4.5.

Table-4.5 Tentative Hydrogeological Classification of Layers

Categories	Permeability	Layers
Aquifer	Middle to High ($K \geqq 10^{-4}$ cm/sec.)	- Andesite Lava - Pyroclastic Deposits - Younger Lahar Deposits - Porous Zones in Older Lahar Deposits
Aquitard	Low ($10^{-6} \leqq K \leqq 10^{-4}$ cm/sec.)	- Paddy Clay - Compact Older Lahar Deposits - Exposed Weathered Tuff - Some Parts of Alternation of Andesite/ Tuff Breccia
Aquiclude	Very Low ($K \leqq 10^{-6}$ cm/sec.)	- Tuff - Fresh Parts of Alternation of Andesite/ Tuff Breccia

4.3.2 GROUNDWATER BASIN STRUCTURE

(1) Geological Structure

K. Lengkong Fan was formed by deposits of volcanic products from Semeru volcano over the ancient mountains of Tertiary system. The base Tertiary formations may have small faults, but large faults which would substantially affect the groundwater movement are considered non-existent, taking account of the surrounding topography and geological structure. Also in the Tertiary formations, the bedding plane is roughly horizontal although there is local undulation.

(2) Bottom of Groundwater Basin

By the execution of drilling B-11 hole, core sampled at 55 to 60 m in depth shows enough impermeability as bottom of groundwater basin and are corresponding to the surface layer of highly weathered tuff of Tertiary system.

On the other hand, the surface layer of old volcanic products from Jambangan Volcanic Complex is assumed to be a thick layer of laterite rich in clay, due to a strong tropical weathering.

Therefore, the bottom of groundwater basin will be composed of: i) the surface layer of highly weathered tuff of Tertiary system and ii) the surface layer of highly weathered old volcanio products from Jambangan Volcanic Complex.

(3) Lateral Boundaries of Groundwater Basin

Lateral boundaries of groundwater basin can be generally configured by either watershed or groundwater divide. The area encircled by lateral boundaries represents a catchment area of groundwater. With regard to the K. Lengkong groundwater basin, the southern boundary is recognized as the watershed of tertiary mountains, and the others are roughly estimated by two radial lines of which center is the top of Mt. Semeru as shown in Fig.-4.5. The eastern boundary corresponds to the groundwater divide between K. Lengkong basin and that of K. Regali.

The western boundary is not clearly defined at present stage, but can be set, taking account of the hydrogeological conditions of the project site on K. Lengkong.

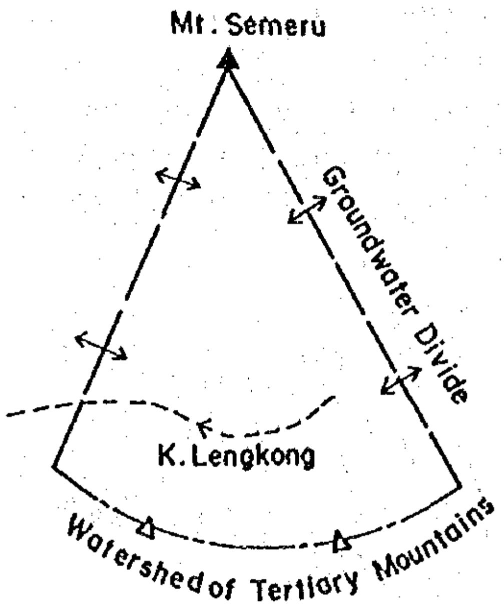


Fig.-4.5 Rough Sketch of K. Lengkong Groundwater Basin

4.3.3 GROUNDWATER FLOW REGIMES

(1) Groundwater Flow Regimes through Volcanic Products

Volcanic products of Mt. Semeru including older Lahar deposits are deposited largely in parallel with the slope of the present ground surface. Older Lahar deposits is considered to be main body of K. Lengkong groundwater basin.

Hydrogeological factors playing major roles on the groundwater flow are; i) water-vein system composed of autobrecciated lava, very loose and coarse Lahar or Pyroclastic deposits, etc. and ii) several aquitard beds formed by the tropical weathering.

From the field reconnaissance, the typical flow regimes through water-veins are recognized the following two types; flow regime through andesite interstices and flow regime through old channel (subsurface flow). These flow regimes are schematically given in Fig.-4.6.

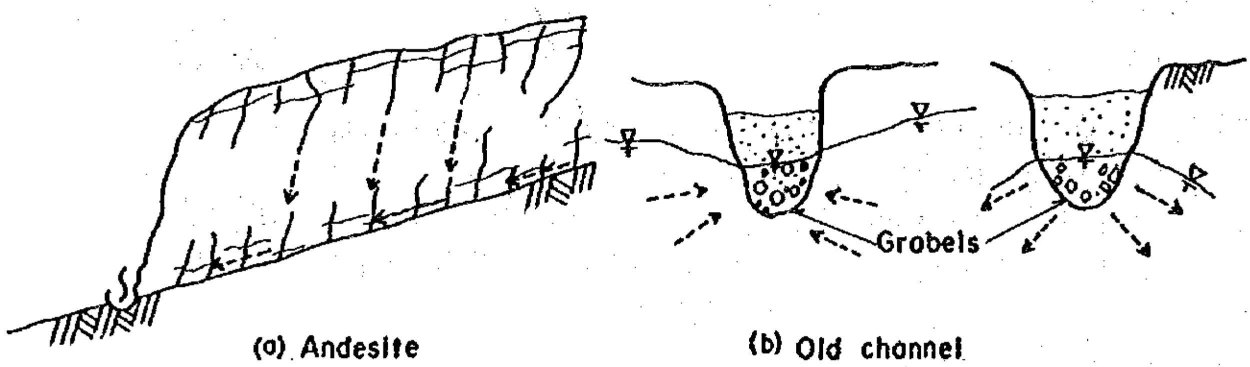


Fig-4.6 Typical Groundwater Flow Regimes

(2) Groundwater Flow Regime through Tertiary Formation

On the foot of the Tertiary mountains, many pipes, of which diameter varies 1 to 3 cm, can be observed in the weathered surface layer. These existence of pipes may play the major role of the underground flows.

In the Tertiary mountain area, vegetation is very rich and the thickness of weathered layer at the surface is generally thick. The important portion of rainfall water percolated into the weathered layer will be lost by evapo-transpiration, so that the portion of groundwater recharge in Tertiary mountain area will be not significant with regard to the groundwater recharge in Mt. Semeru area.

(3) Spring Distribution at near 800 m in Elevation

Springs are mainly found in the vicinity of contour line 800 m, corresponding to the inflection point of slope. Assumed that the piezometric surface is nearly parallel with the ground surface, discontinuity of underground flow appears at this inflection point. Furthermore, the permeability of the upper part is estimated to be higher than that of the lower. Consequently, groundwater table approachs to the surface and sometimes springs out.

4.3.4 GROUNDWATER MOVEMENT AND STORAGE CONDITION

(1) Groundwater Movement

Groundwater movement in K. Lengkong basin can be summarized as follows;

- As natural convection phenomena due to the heat source of Mt. Semeru are not observed up to the present, groundwater movement in shallow underground is almost governed by the water-vein system.

- Groundwater flow through shallow volcanic products is quantitatively governed by water-vein system developed in the stratified structure of Mt. Semeru. Flow directions are roughly estimated to be radial from the top of Mt. Semeru and are nearly similar to the estimated lines by the potential theory.

- Groundwater flow through the shallow layers of Tertiary mountains is quantitatively greater than that of deepers. From the results of field reconnaissance, these layers have a pipe network system. Flow direction will be similar to the maximum slope line.

- From the macroscopic viewpoint, groundwater movement can be discussed with the application of Darcy's law and are roughly estimated as shown in Fig.-4.7.

- Groundwater movement by water-vein system is compatible with the hydro-chemical results. Water quality of high velocity flow has less amount of dissolved solids than that of low velocity flow.

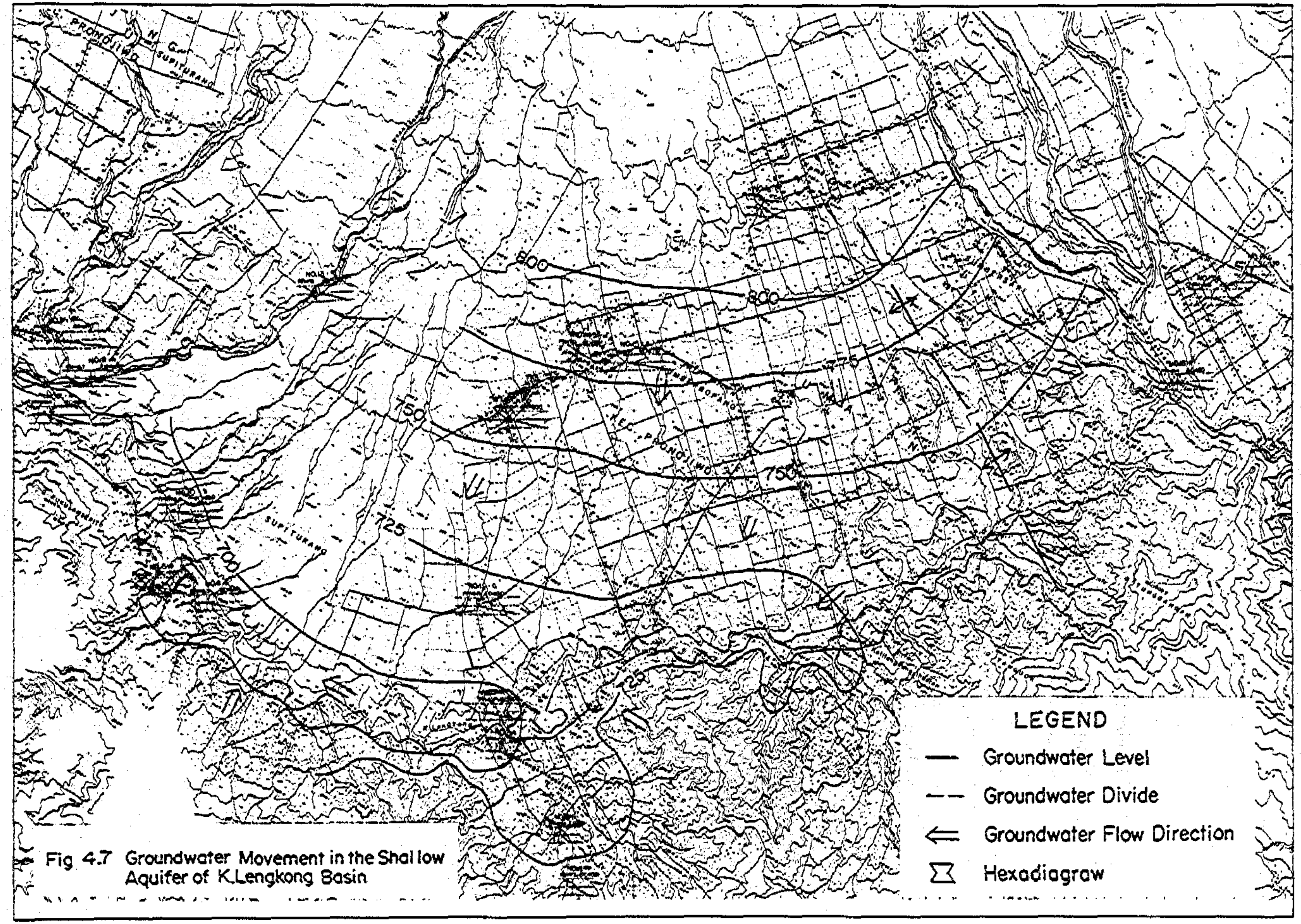


Fig 4.7 Groundwater Movement in the Shallow Aquifer of K.Lengkong Basin

(2) Groundwater Storage Condition

Groundwater storage condition of K. Lengkong basin can be summarized as follows;

- Main body of aquifer consist a number of discontinuous layers and its hydrogeological structure and properties are greatly varied. A vast distribution of thick sand and gravel layer are not recognized up to the present. The storage condition in older Lahar deposits will consist mainly of groundwater in water-vein system and that of its surroundings. As the quantity of the former is less than the later one, the groundwater storage amount will be roughly estimated from the multiplication of the volume of aquifer and the effective porosity of the later.

- Groundwater flows in K. Lengkong basin are strongly influenced with the water-vein system and its velocity will be particularly higher than that of estimation, derived from Darcy's law. Underground water movement between the water-vein system and its surroundings is estimated to be reciprocal, including some parts of unsaturated zone.

- In shallow water-veins, the response to rainfall is generally quick and those water are almost renewed by the rainfall of each year.

- As the piezometric pressure of deep layer is lower than that of shallow one, such as the observation results of water level in borehole (B-1 and B-11), leakage phenomena may be exist.

4.4 PANORAMA FOR GROUNDWATER DEVELOPMENT

4.4.1 GENERAL ASPECTS

As the conclusion of hydrogeological study, we will discuss about the prospect of groundwater development in K. Lengkong groundwater basin.
Hydrogeological characteristics can be summarized as follows;

- Groundwater movement is governed by water-vein system and its main channels will be thought to run in parallel with K. Lengkong.

- These main channels of the water-vein system is expected to have a sufficient groundwater recharge area and these discharges will be appreciable in quantity for a constant water supply.

- Expected depth of main channels will be shallower than the groundwater basin boundary such as the unconformity plane between older Lahar deposits and Tertiary formations.

- Water quality of water-vein system may represent some seasonal variation, but it will be expected to be suitable for agricultural purpose.

The future study themes on the groundwater development in K. Lengkong are recognized as follows:

- To find out the most appropriate solution of connection facilities between the main channels and the water conveyance facilities.

- To assure the compatibility with the erosion control works.

4.4.2 PROSPECTIVE PROJECT SITE

Electric sounding executed in K. Lengkong Fan shows an existence of long narrow ridge of Tertiary formations of which the weathered surface layer is thought to be impermeable layer and is identified as groundwater basin. The existence of this ridge is confirmated with the drilling work B-11.

This ridge, situated in the vicinity of Tumpak Nanas sabo dam site, extends from south to north and is partially exposed to the ground surface, as shown in Fig.-4.8. This impermeable ridge is considered to form a natural underground dam and main subsurface channels of water-vein system are expected to run the lower part of this ridge.

Furthermore, a diversion channel work from K. Rejali to K. Lengkong is being under consideration and the hinterland of Tumpak Nanas sabo dam will contribute to the augmentation of groundwater recharge amount by these construction of debris control facilities.

On the other hand, this site is advantageous to the distance of water conveyance, compared with Pronojiwo dam site.

Finally, it will be concluded that Tumpak Nanas sabo dam site has the most feasible site as groundwater development.

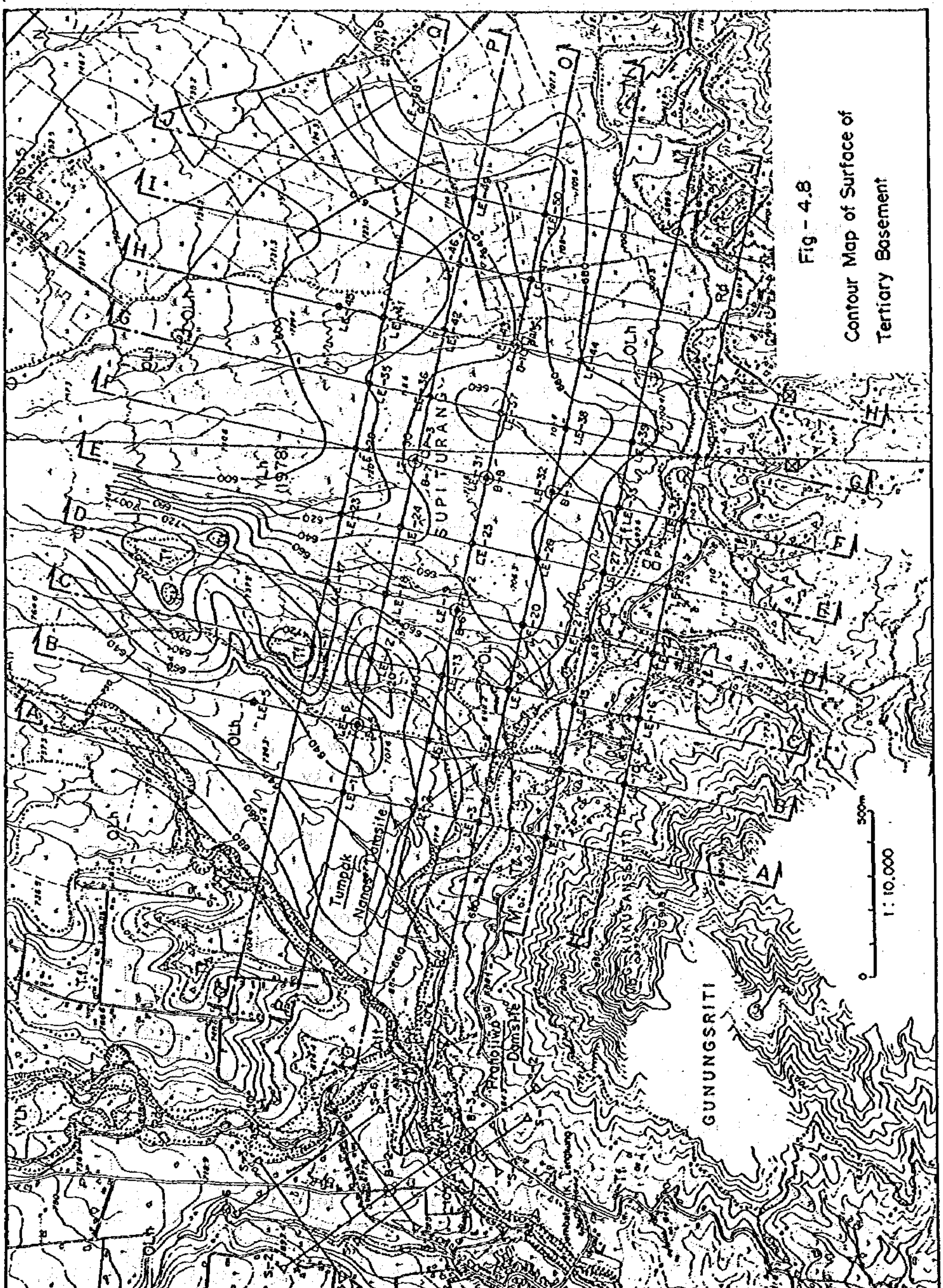


Fig - 4.8
Contour Map of Surface of Tertiary Basement

4.4.3 RESULTS OF DRILLING WORK B-11

The drilling work B-11 was carried out by Mt. Semeru Project Office in 1983 and its results are given as follows:

i) Location and Elevation

Location	:	LE-18 (Electric Sounding Point in K. Lengkong Fan)
Elevation	:	EL. 715.621 m

ii) Core Description

0 to -0.50 m	:	Black silty sand containing some gravels and many organic substances.
-0.50 to -3.85 m	:	Light gray to brown, loose, gravelly sand with silt (ash). Younger Lahar deposits
-3.85 to -8.0 m	:	Gray, relatively hard, sand and gravels, partly cemented. Core recovery is poor. Older Lahar deposits
-8.0 to -10.3 m	:	Brown, moderately stiff clay with some coarse sand. Older Lahar deposits
-10.3 to -12.1 m	:	Andesite boulders, between -11.2 to -11.70 m brown silty sand is intercalated. Older Lahar deposits
-12.1 to -13.05 m	:	Brown, hard, silty sand with fine gravels. Older Lahar deposits

-13.05 to -16.55 m:	Gray, hard, silty sand with fine gravels. Older Lahar deposits
-16.55 to -17.0 m :	Gray to grayish brown, stiff, silty to clay sand with fine gravels. Older Lahar deposits
-17.0 to -20.0 m :	Gray, hard, silty sand with fine gravels. Between -17.35 to 17.60 m andesite gravels are sampled. Older Lahar deposits
-20.0 to -21.5 m :	Yellowish brown to brown, stiff, sandy silt. Older Lahar deposits
-21.5 to -25.5 m :	Gray to brownish gray, hard, silty sand with fine gravels. Between -24.0 to -24.5 m andesite gravels is sampled. Older Lahar deposits
-25.5 to -27.7 m :	Brownish gray, stiff, sandy silt with fine gravels. Between -26.0 to -26.35 m andesite gravels are rich. Older Lahar deposits
-27.7 to -29.2 m :	Gray, partly brown, hard, gravelly sand with silt. Gravel rich. Older Lahar deposits
-29.2 to -29.7 m :	Brown, stiff, sandy silt with some gravels. Older Lahar deposits

-29.7 to -32.0 m : Dark gray, hard, silty sand with many gravels.
Older Lahar deposits

-32.0 to -32.5 m : Brown, stiff, sandy silt with few gravels. Older Lahar deposits

-32.5 to -33.2 m : Dark gray, hard, silty sand with fine gravels.
Older Lahar deposits

-33.2 to -33.5 m : Brown, stiff, sandy silt with few gravels. Older Lahar deposits

-33.5 to -38.5 m : Gray, hard, silty sand with fine gravels. Around -36.2 m andesite gravel of ø8 cm is contained.
Older Lahar deposits

-38.5 to -39.0 m : Brown, stiff, sandy silt with a few fine gravels.
Older Lahar deposits

-39.0 to -41.0 m : Gray to brown, hard, silty sand with fine gravels.
Older Lahar deposits

-41.0 to -55.2 m : Black, hard, coarse sand with gravels. Between -48.0 to -48.5 m gravels are very rich. Between -54.0 to -54.5 m only cutting materials are sampled.
Older Lahar deposits

-55.2 to -60.0 m : Black, weak, cohesive silty clay. This layer is presumed to be hardly weathered surface layer of tuff of Tertiary system.

iii) Water Level in Borehole

Please refer to Section 4.2.1(1) Water Level in Borehole.

iv) Geological Profiles

Geological profiles crossing the point of B-11 are given in Fig.-4.9.

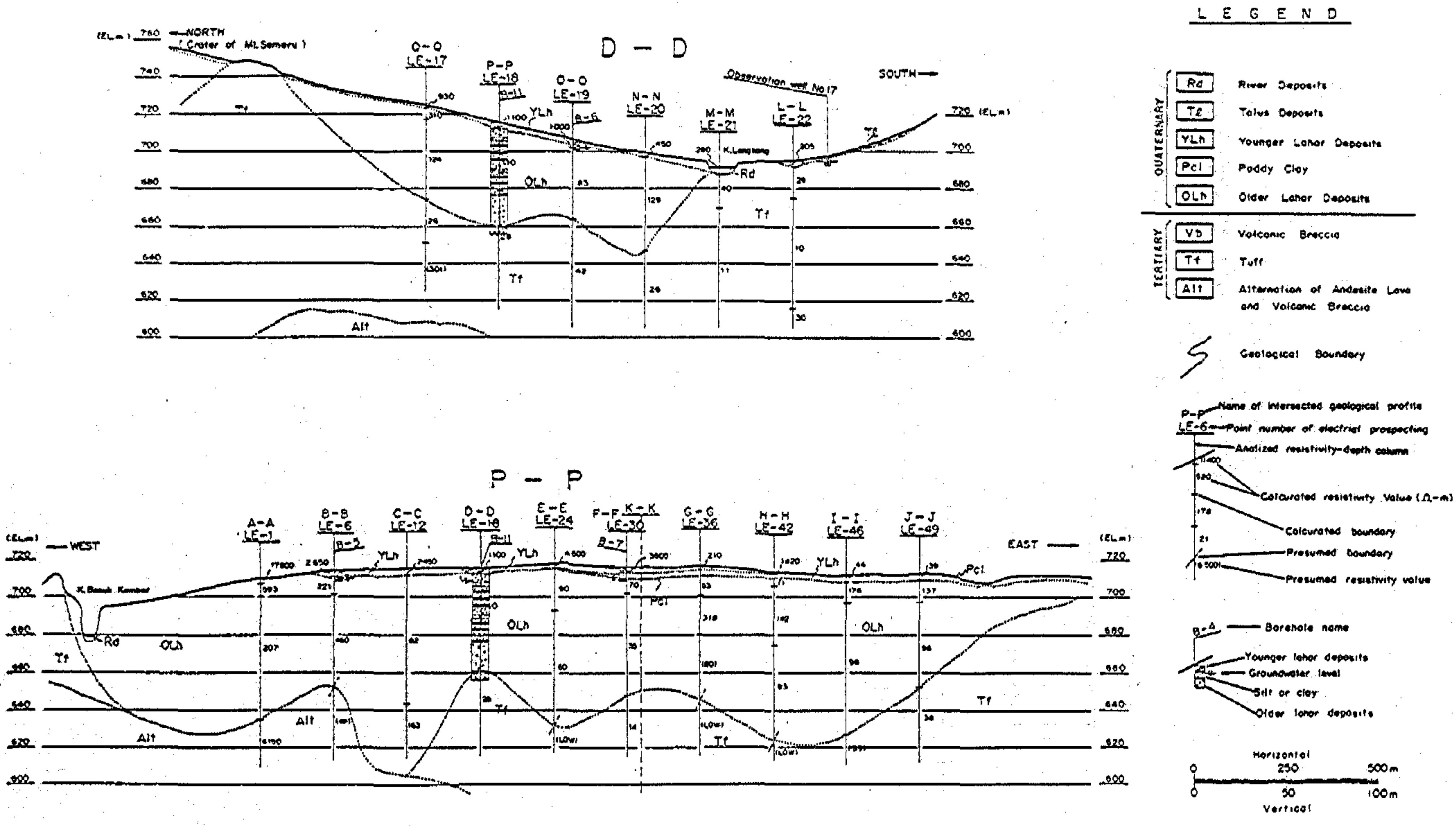


Fig-4.9 Geological Profile Crossing the Point of B-11

4.4.4 RECOMMENDATIONS

Hydrogeological study results carried out under the technical cooperation between the Government of Indonesia and JICA will be contributed to the future study on Groundwater Development; especially, Tumpak Nanas is expected to have the most advantageous hydrogeological features.

As groundwater is one of the continuous water movement in hydrological cycle caused by the solar radiation energy, the necessity of the more detail data collection related to hydrological water balance is well known and these parameters are as follows;

- Rainfall amount
- Actual areal evaporation or evapotranspiration amount
- Runoff amount including flood amount
- Groundwater flow amount

On the other hand, it will be necessary to obtain more detail information on the hydrogeological properties related to the water-vein system and the Tertiary ridge in the vicinity of Tumpak Nanas sabo dam-site.

In order to obtain necessary data in sufficient accuracy, we recommend that the Government of Indonesia will take into consideration;

- Continuous data collection and its data arrangement
- Construction of one climalotogical station in K. Lengkong for actual areal evaporation
- Hydrogeological investigation of Tumpak Nanas;

- Drilling works (2 3 holes ; ø = 8 10 inches)
- Geological logging
- Pumping test
- Lugeon test
- Grout test
- Measurement of water level in borehole by automatic water level gauge

APPENDIX C-1

Well Inventory

WELL INVENTORY CARD

WELL No. 1 : TEMPEH KIDUL I

Location: X : 113°10'39,90" E.
Y : 8°13'03,86" S.
Z : 72,284 meter

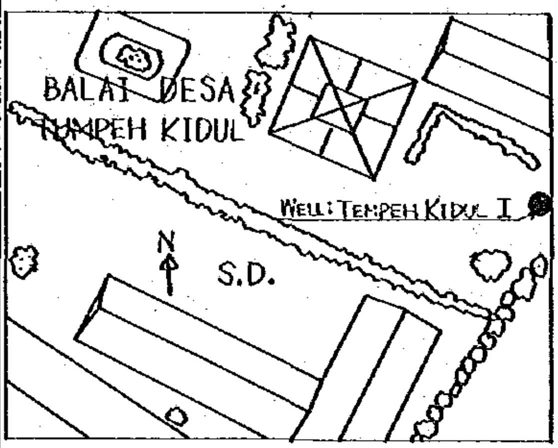
Well Type: Shallow dug well with handpump

Well Depth: 7.70 m, Bottom : 7.80 m

Owner's Name ; Pak Riyangkin

Address ; Tempeh Kidul Village Office, BALAI DESA, TEMPEH KIDUL

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 16 Feb. 82 To

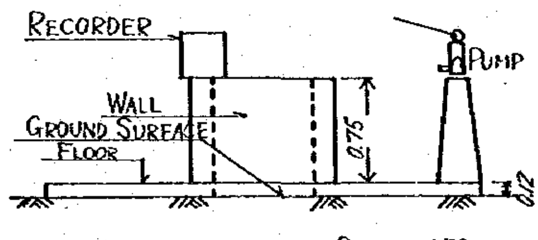
Observation Condition:

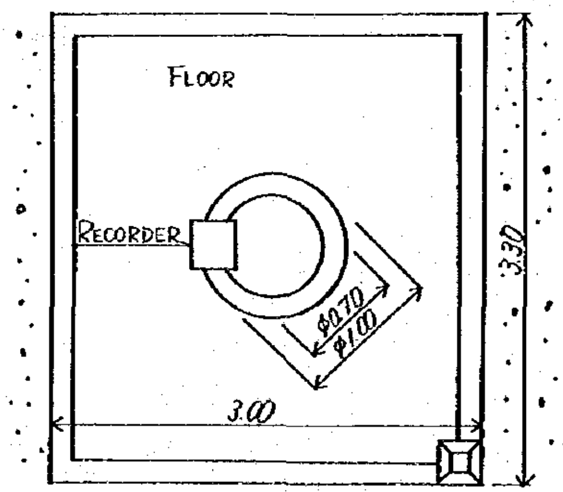
- Installation of Equipment : Good
- Land Condition : Town area
- Water Level Check : Executed

Variation Characteristic:

- High S.W.L. GL. - 5.40 m (16 Feb. 82)
- Low S.W.L. GL. - 9.60 m (23 Nov. 82)
- Correlation with Rainfall : Yes

WELL SKETCH





WATER USE

- O Drinking
- O Domestic
- Irrigation
- No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧ /cm)	Turb. (ppm)
3 May 83	5.4	28.0	2.5	500	5
4 Jul. 83	6.5	27.5	1.3	460	2
5 Sep. 83	4.5	28.0	4.7	380	0

WELL INVENTORY CARD

WELL No. 2 : TEMPEH KIDUL II

Location: X : 113°10'35,20" E.
Y : 8°13'16,29" S.
Z : 67,948 meter

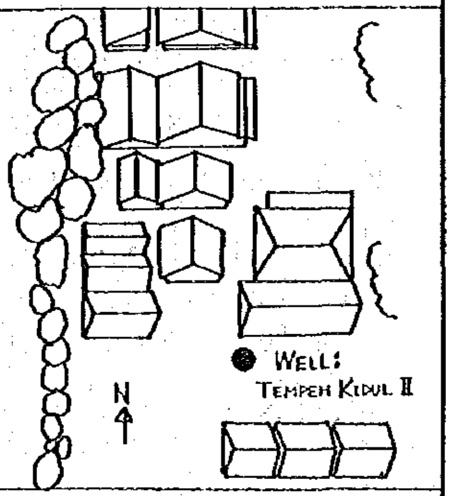
Well Type: Shallow dug well with pulley

Well Depth: 6.75 m, Bottom : 16.60 m

Owner's Name ; P. Dul Pangkat

Address ; RUMAH PAK DUL PANGKAT,
KAMPUNG POLISI NGEBRUK,
DESA TEMPEH KIDUL, TEMPEH

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 16 Feb. 82 To

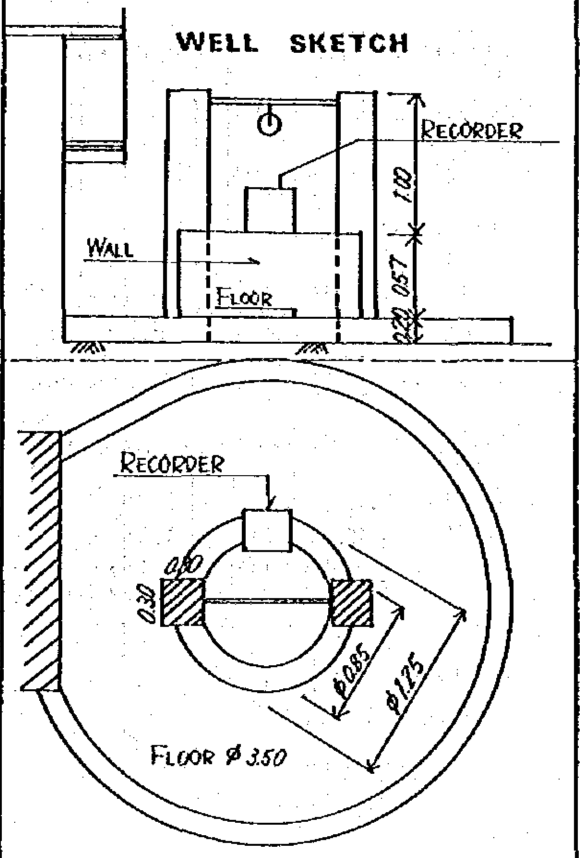
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Town area
- Water Level Check : Executed

Variation Characteristic:

- High S.W.L. GL. - 5.32 m (25 May 82)
- Low S.W.L. GL. - 7.68 m (16 Nov. 82)
- Correlation with Rainfall : Yes

WELL SKETCH



WATER USE

O Drinking
O Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧/cm)	Turb.(ppm)
3 May 83	7.0	29.0	2.5	500	6
4 Jul. 83	5.8	27.4	1.9	400	2
5 Sep. 83	3.1	30.0	4.8	380	1

WELL INVENTORY CARD

WELL No. 3 : KERTOSARI I

Location: X : 113°04'40,94" E.
Y : 8°08'15,12" S.
Z : 410,092 meter

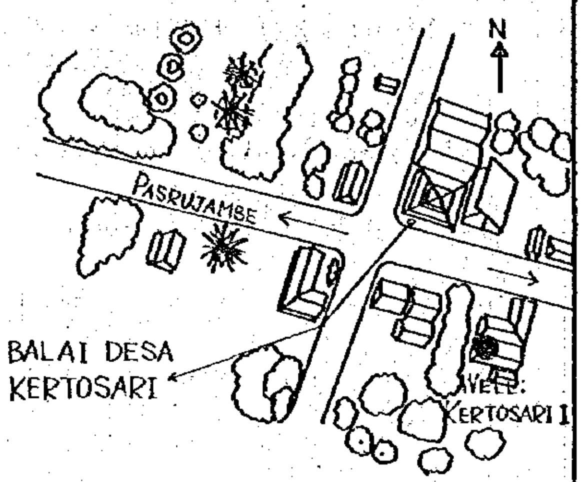
Well Type: Shallow dug well with pulley

Well Depth: 3,30 m, Bottom : 4 m

Owner's Name ; Pak Prio

Address ; TEMPAT PAK PRIYO,
DESA KERTOSARI, SENDURO

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 13 Feb. 82 To

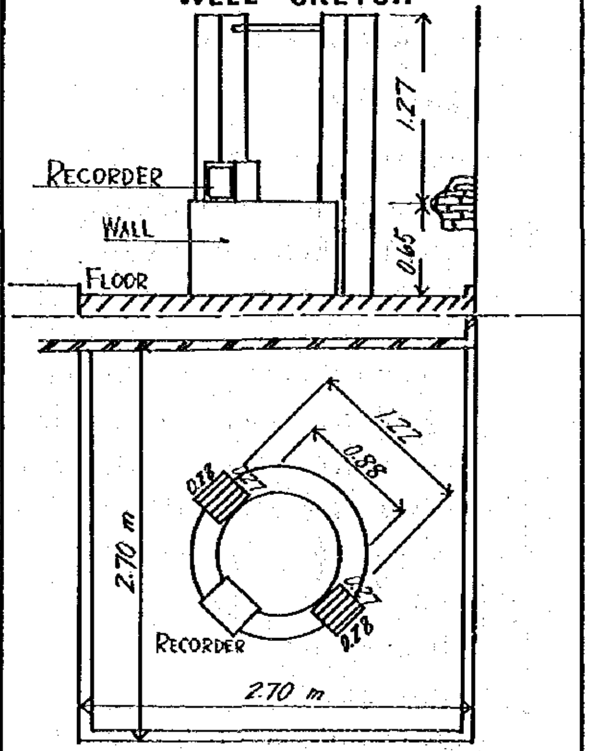
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Paddy field
- Water Level Check : Executed

Variation Characteristic:

- High S.W.L. GL. - 2.00 m (22 Feb. 82)
- Low S.W.L. GL. - 3.55 m (14 Dec. 82)
- Correlation with Rainfall : Not evident due to irrigation water

WELL SKETCH



WATER USE

O Drinking
O Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (Ʊ/cm)	Turb. (ppm)
25 Nov. 82	6.5	25.6	7.5	210	8
5 Jan. 83	6.7	25.5	4.7	180	2
3 May 83	7.1	26.2	5.0	280	4
4 Jul. 83	6.4	25.0	1.5	280	3

WELL INVENTORY CARD

WELL No. 4 : KERTOSARI II

Location: X : 113°04'35,19" E.
Y : 8°08'17,10" S.
Z : 414,808 meter

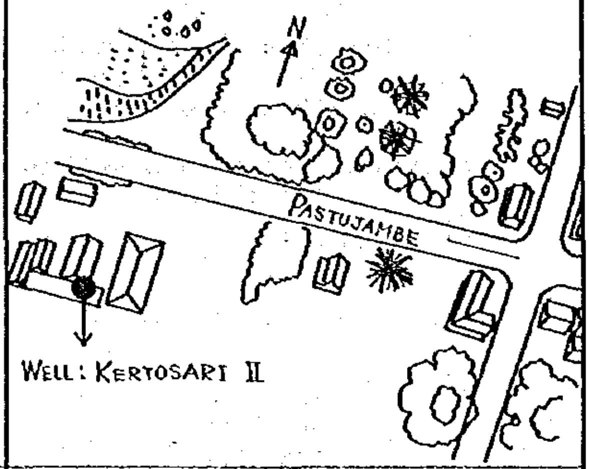
Well Type: Shallow dug well with pulley

Well Depth: 3.18 m, Bottom : 4 m

Owner's Name ; Haji Nur

Address ; TEMPAT PAK HAJI NUR.
DESA KERTOSARI, SENDURO

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

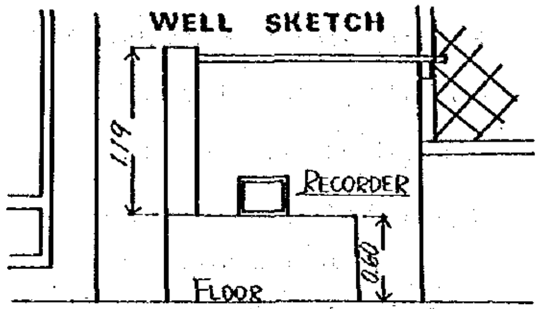
From 27 Feb. 82 To

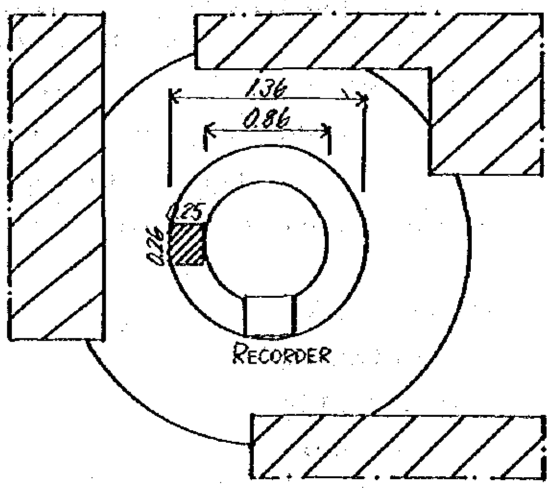
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Paddy field
- Water Level Check : Executed

Variation Characteristic:
- High S.W.L. GL. - 2.27 m (25 Oct. 83)
- Low S.W.L. GL. - 4.06 m (5 Apr. 83)
- Correlation with Rainfall : Not evident due to irrigation water

WELL SKETCH





WATER USE

Drinking
Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (ʊ/cm)	Turb. (ppm)
25 Nov. 82	6.0	25.0	7.0	200	8
5 Jan. 83	6.5	26.5	3.9	240	5
3 May 83	7.3	25.7	5.0	300	2
4 Jul. 83	6.3	24.8	1.6	300	6

WELL INVENTORY CARD

WELL No. 5 : SUMBER MUJUR I

Location: X : 113°01'05,60" E.
Y : 8°08'19,23" S.
Z : 677,057 meter

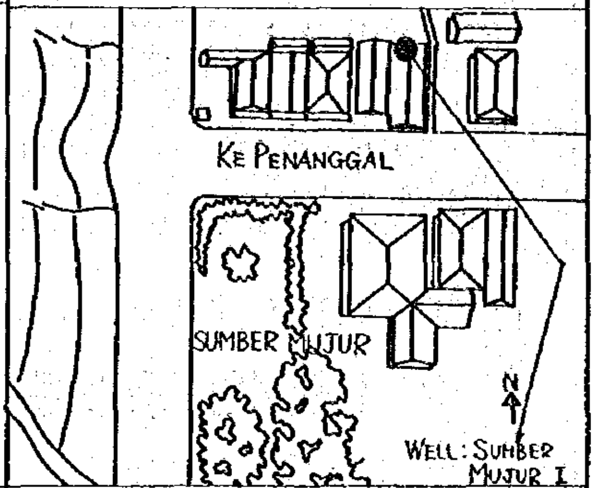
Well Type: Shallow dug well with pulley in the house

Well Depth: 1.20 m, Bottom : 2.25 m

Owner's Name ; P. Suroso

Address ; TEMPAT PAK SUROSO,
DESA SUMBER MUJUR,
CANDIPURO

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 28 Feb. 82 To

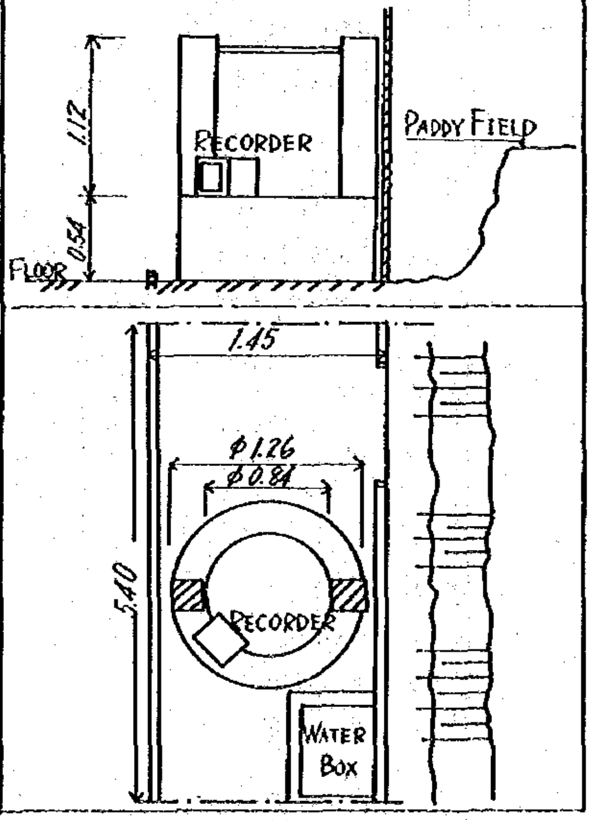
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Paddy field
- Water Level Check : Executed from Feb. 82 to Feb. 83

Variation Characteristic:

- High S.W.L. GL. - 0.90 m (1 Feb. 83)
- Low S.W.L. GL. - 2.13 m (30 Nov. 83)
- Correlation with Rainfall : Not evident

WELL SKETCH



WATER USE

Drinking
o Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧/cm)	Turb. (ppm)
6 Dec. 82	6.4	23.1	12.1	100	9
10 Jan. 83	7.2	23.3	3.8	120	11

WELL INVENTORY CARD

WELL No. 6 : SUMBER MUJUR II

Location: X : 113°01'03,10" E.
Y : 8°08'09,53" S.
Z : 688,72 meter

Well Type: Shallow dug well

Well Depth:

Owner's Name ;

Address ; TEMPAT PAK SULASTRI.
DESA SUMBER MUJUR,
CANDIPURO

LOCATION MAP

PIEZOMETRIC OBSERVATION

Observation Period:

From 3 Mar. 82 To 23 Sep. 82

Observation Condition:

- Installation of Equipment : Guide pipe was strongly inclined.
- Land Condition : Paddy field
- Observation interrupted from 23 Sep. 82

Variation Characteristic:

- Clogging of well wall was observed and water colour changed to white.
- S.W.L. of this well was estimated to have no connection with its surroundings.

WELL SKETCH

WATER USE

Drinking
Domestic
Irrigation
o No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (U /cm)	Turb. (ppm)
26 Aug. 82	6.6	22.2	2.5		9

WELL INVENTORY CARD

WELL No. 7 : CURAH KOBO'AN I

Location: X : 113°00'19,50" E.
Y : 8°10'20,55" S.
Z : 751,711 meter

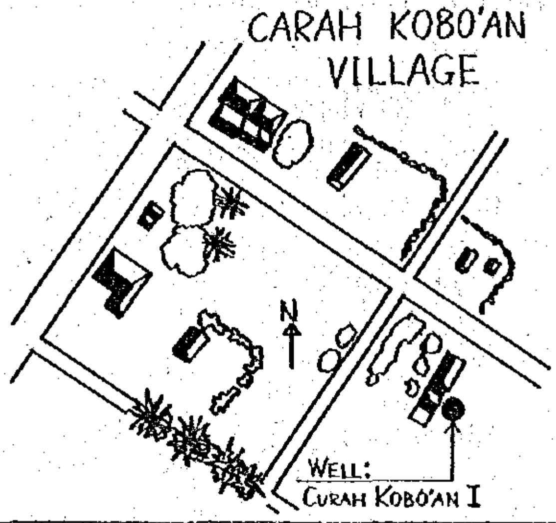
Well Type: Shallow dug well with pulley

Well Depth: 17.93 m, Bottom : 18.10 m

Owner's Name ; Pak Muji

Address ; PAK KAMPUNG,
CURAH KOBO'AN,
DESA SUPITURANG, PRONOJIWO

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 11 Feb. 82 To

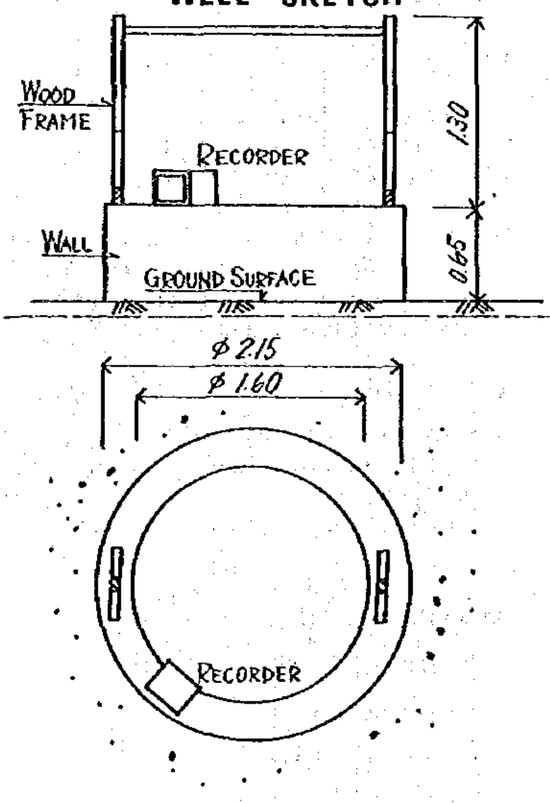
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Upstream of the Curah Cobo'an Valley
- Water Level Check : Continuously executed from Feb. 82 to Aug. 82

Variation Characteristic:

- High S.W.L. GL. - 12.89 m (18 Mar. 82)
- Low S.W.L. GL. - 17.93 m (26 Oct. 82)
- Correlation with Rainfall : An important fall of S.W.L. observed after rainy season

WELL SKETCH



WATER USE

O Drinking
O Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧ /cm)	Turb. (ppm)
6 Dec. 82	6.9	24.5	6.8	150	2
10 Jan. 83	6.8	23.7	6.7	100	3
4 May 83	6.9	23.5	5.0	200	6
5 Jul. 83	6.5	23.2	2.5	220	7

WELL INVENTORY CARD

WELL No. 8 : CURAH KOBO'AN II

Location: X : 113°00'28,50" E.
Y : 8°10'12,82" S.
Z : 741,607 meter

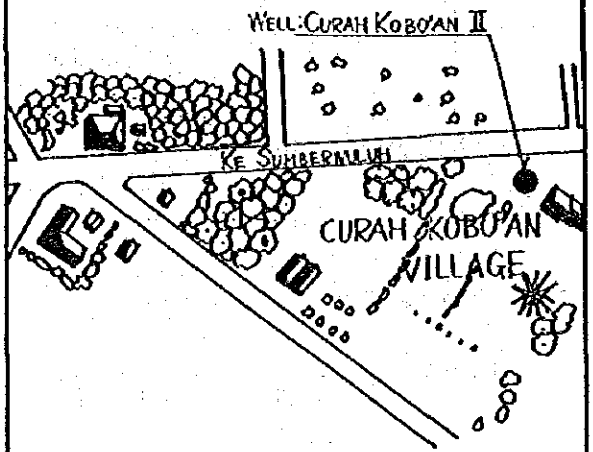
Well Type: Shallow dug well

Well Depth: 8.40 m, Bottom : 8.52 m

Owner's Name ; Pak Lawi

Address ; TEMPAT PAK LAWI,
CURAH KOBO'AN,
DESA SUPITURANG, PRONOJIWO

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 11 Feb. 82 To

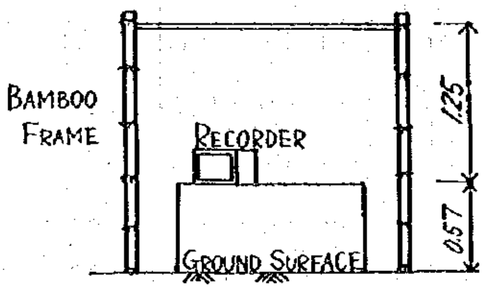
Observation Condition:

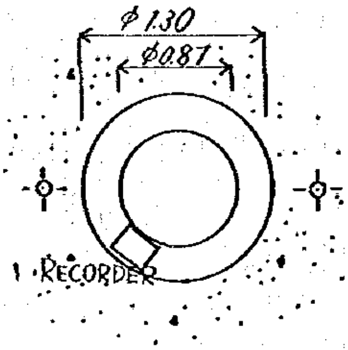
- Installation of Equipment : Good
- Land Condition : Upstream of the Curah Kobo'an Valley
- Water Level Check : Continuously executed from Feb. 82 to Aug. 82

Variation Characteristic:

- High S.W.L. GL. - 4.38 m (4 Mar. 82)
- Low S.W.L. GL. - 8.40 m (2 Nov. 82)
- Correlation with Rainfall: An important fall of S.W.L. observed after rainy season

WELL SKETCH





WATER USE

- o Drinking
- o Domestic
- Irrigation
- No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (U/cm)	Turb. (ppm)
6 Dec. 82	6.6	25.4	5.9	120	5
10 Jan. 83	6.9	24.3	4.8	50	2
4 May 83	7.4	23.7	5.0	140	6
5 Jul. 83	7.0	26.3	3.3	120	3

WELL INVENTORY CARD

WELL No. 9 : SUMBER WULUH I

Location: X : 113°02'27,70" E.
Y : 8°11'05,15" S.
Z : 428,055 meter

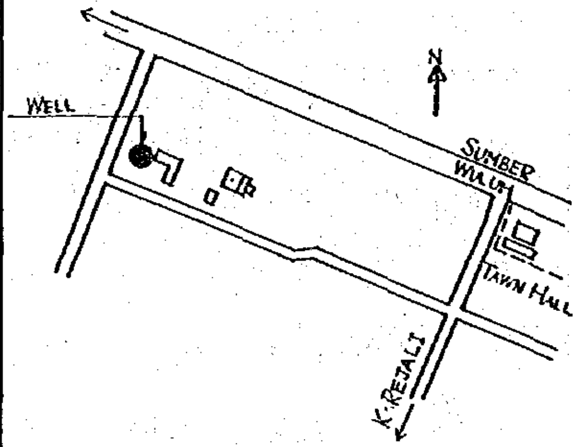
Well Type: Shallow dug well with pulley

Well Depth: 10.30 m, Bottom : 10.50 m

Owner's Name ; P. Lasman

Address ; TEMPAT PAK ASTRO,
DESA SUMBER WULUH,
CANDIPURO

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 10 Feb. 82 To

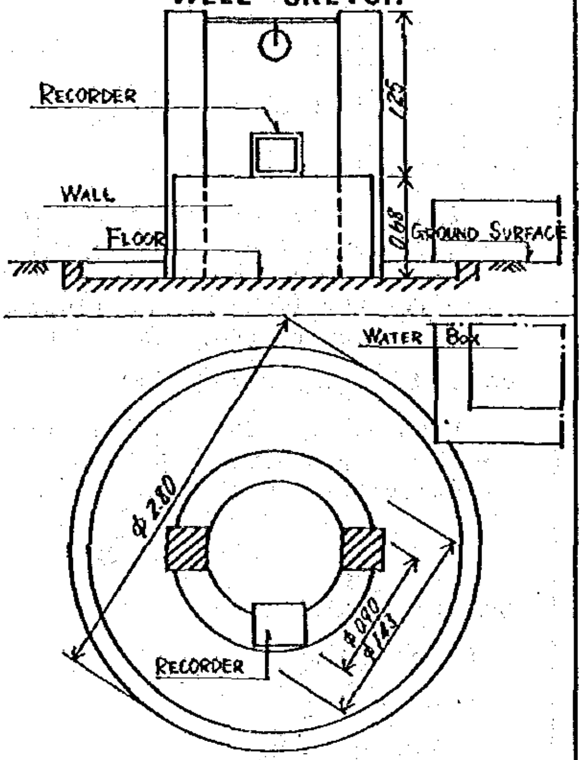
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Upstream of fan area
- Water Level Check ; Continuously executed from Feb. 82 to July 82

Variation Characteristic:

- High S.W.L. GL. - 7.50 m (18 Mar. 82)
- Dried out in dry season

WELL SKETCH



WATER USE

Drinking
Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧/cm)	Turb. (ppm)
6 Jul. 83	7.1	25.2	2.7	240	5
8 Sep. 83	6.3	25.9	4.4	240	1

WELL INVENTORY CARD

WELL No. 10 : SUMBER WULUH II

Location: X : 113°02'04,40" E.
Y : 8°11'04,33" S.
Z : 428,301 meter

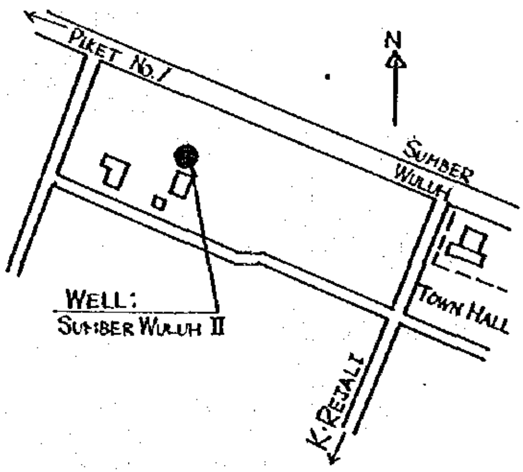
Well Type: Shallow dug well with pulley

Well Depth: 10.30 m, Bottom : 10.50 m

Owner's Name : P. Untung

Address : TEMPAT PAK UNTUNG,
DESA SUMBER WULUH,
CANDIPURO

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 1 Mar. 82 To

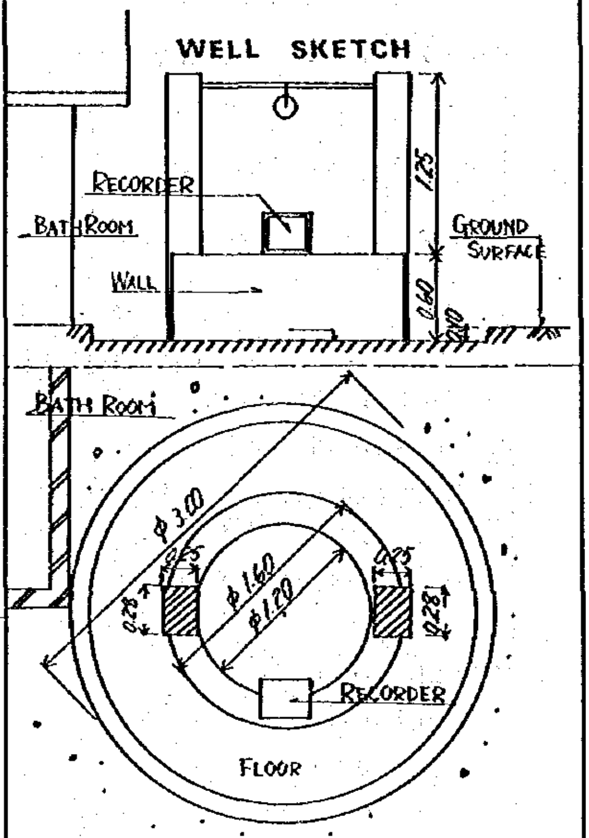
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Upstream of fan area
- Water Level Check : Continuously executed from Mar. 82 to Jul. 82

Variation Characteristic:

- High S.W.L. GL. - 7.23 m (3 Mar. 82)
- Dried out in dry season

WELL SKETCH



WATER USE

Drinking
Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧/cm)	Turb. (ppm)
5 May 83	6.8	26.4	3.5	220	8
6 Jul. 83	6.5	25.9	2.4	240	5
8 Sep. 83	6.1	25.5	4.8	180	1

WELL INVENTORY CARD

WELL No. 11 : SELOK AWAR-AWAR

Location: X : 113°08'50,20" E.
Y : 8°14'36,77" S.
Z : 68,502 meter

Well Type: Shallow dug well with pulley

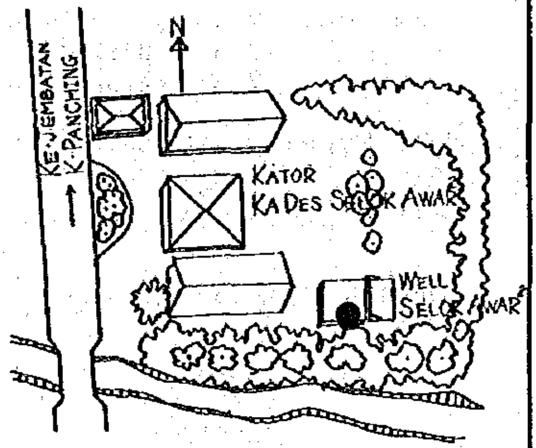
Well Depth: 16.50 m, Bottom : 16.60 m

Owner's Name ; P. Edy

Address ; Selok Awar² Village Office
BALAI DESA SELOK AWAR-AWAR, PASIRIAN

LOCATION MAP

SKETSA LOKASI



PIEZOMETRIC OBSERVATION

Observation Period:

From 11 Feb. 82 To

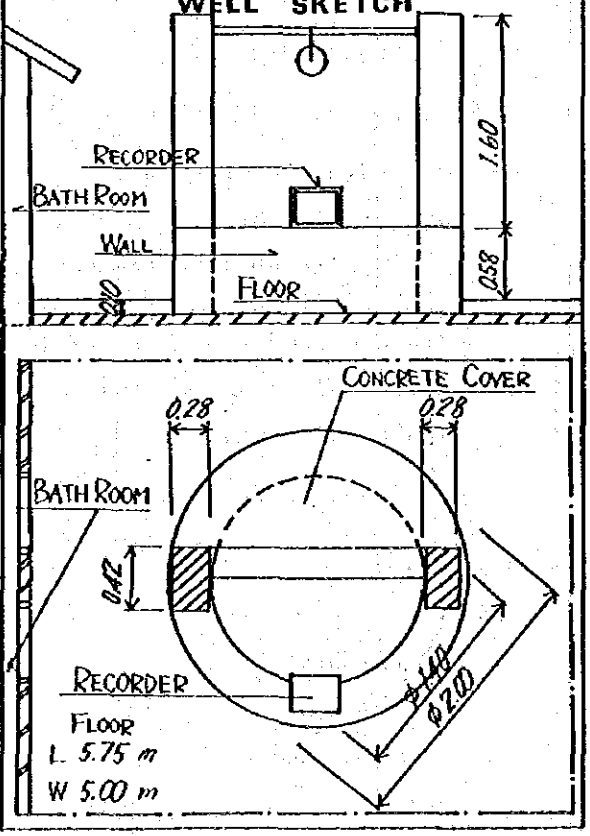
Observation Condition:

- Installation of Equipment : Transfer at new place on Jan. 83
- Land Condition : Periphery of fan
- Water Level Check : Executed

Variation Characteristic:

- High S.W.L. GL. - 14.23 m (1 Apr. 82)
- Low S.W.L. GL. - 16.50 m (23 Sep. 82)
- Correlation of Rainfall : Yes

WELL SKETCH



WATER USE

Drinking
Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧/cm)	Turb. (ppm)

WELL INVENTORY CARD

WELL No. 12 : TUMPENG

Location: X :
Y :
Z : 256,869 meter

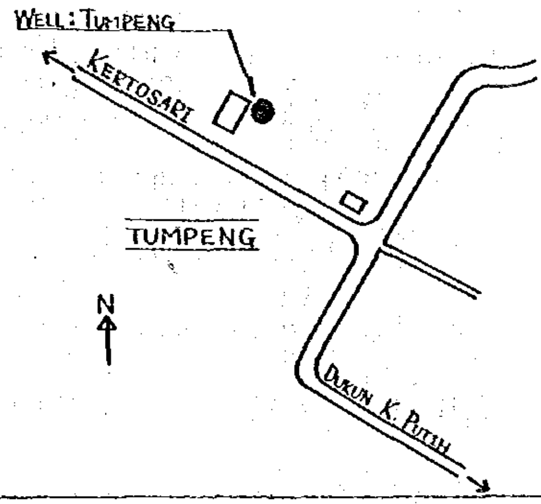
Well Type: Shallow dug well with pulley

Well Depth: 5.30 m, Bottom : 5.70 m

Owner's Name ; Pak Hartono

Address ; TUMPENG, CANDIPURO

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 29 Jun. 82 To

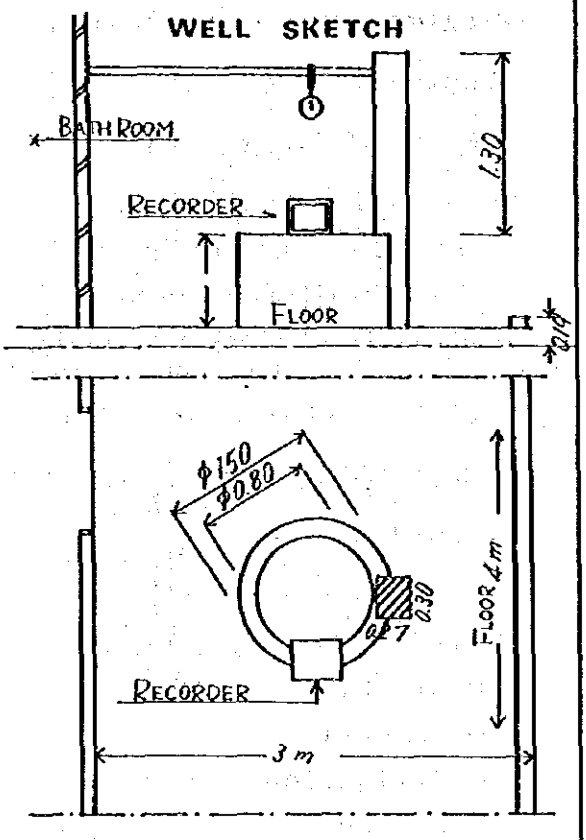
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Paddy field
- Water Level Check : Continuously executed from Nov. 82 to Jun. 83

Variation Characteristic:

- High S.W.L. GL. - 2.10 m (10 Feb. 83)
- Low S.W.L. GL. - 5.10 m (3 Dec. 82)
- Correlation with Rainfall : Yes

WELL SKETCH



WATER USE

O Drinking
O Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧/cm)	Turb. (ppm)
25 Nov. 82	6.7	27.6	3.6	410	8
5 Jan. 83	6.9	28.5	6.5	300	4
4 Jul. 83	6.4	27.3	1.3	400	5
5 Sep. 83	6.2	28.0	5.2	260	1

WELL INVENTORY CARD

WELL No. 13 : URANG GANTUNG I

Location: X : 113°04'45,79" E.
Y : 8°13'09,02" S.
Z : 206,098 meter

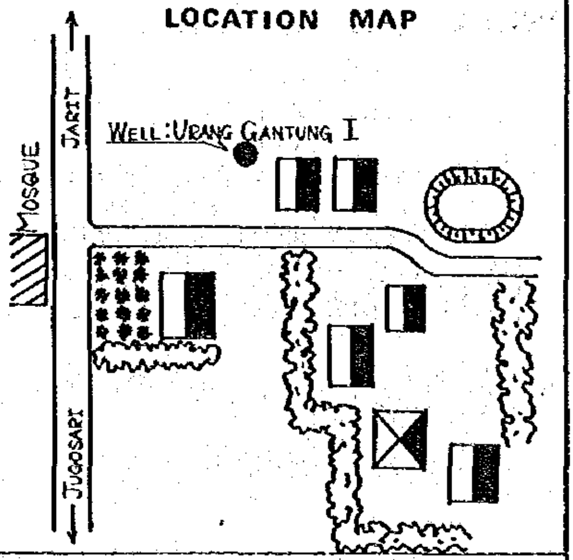
Well Type: Shallow dug well without well wall

Well Depth: 3.65 m, Bottom : 4 m

Owner's Name ; Pak Mardi

Address ; URANG GANTUNG, JARIT

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 18 Jul. 82 To

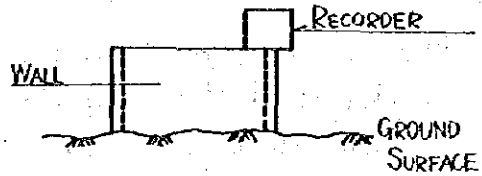
Observation Condition:

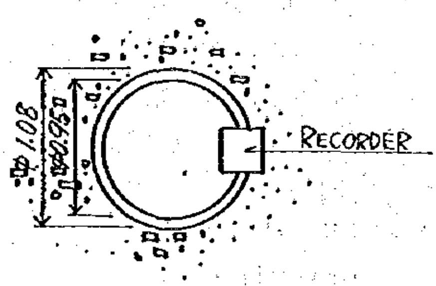
- Installation of Equipment :
- Land Condition : Fan area
- Water Level Check : Partially executed from Aug. 82 to Dec. 82

Variation Characteristic:

- High S.W.L. GL. - 2.12 m (9 Aug. 82)
- Dried out in dry season

WELL SKETCH





WATER USE

o Drinking
o Domestic
o Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧/cm)	Turb.(ppm)
10 Jan. 83	6.0	29.3	4.1	30	2

WELL INVENTORY CARD

WELL No. 14 : URANG GANTUNG II

Location: X : 113°04'46,99" E.
Y : 8°13'18,06" S.
Z : 206,228 meter

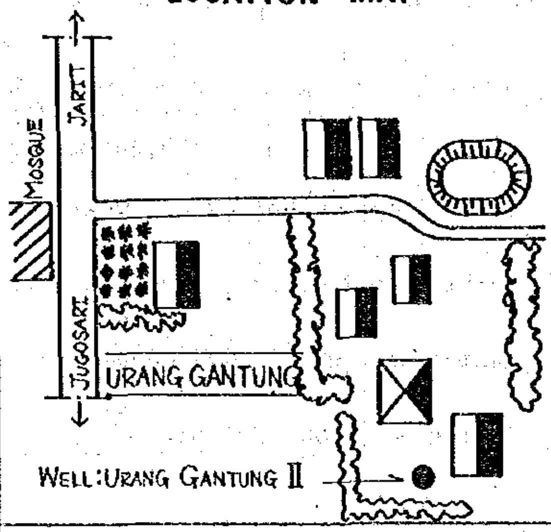
Well Type: Shallow dug well without well wall

Well Depth: 3.00 m, Bottom : 3.20 m

Owner's Name ; Pak Mardi

Address ; URANG GANTUNG, JARIT

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 25 Jun. 82 To

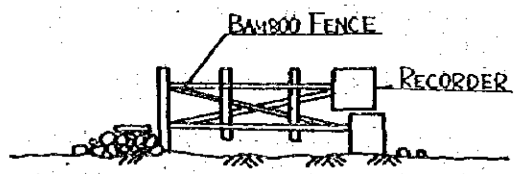
Observation Condition:

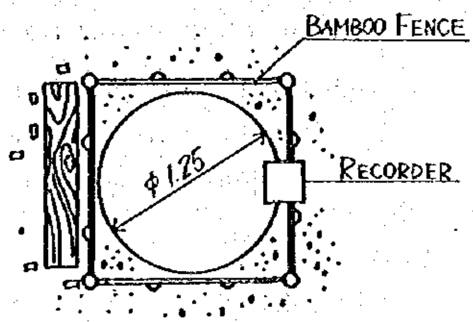
- Installation of Equipment : Good
- Land Condition : Fan area
- Water Level Check : Executed from Sep. 82

Variation Characteristic:

- High S.W.L. GL. - 2.10 m (11 Jun. 83)
- Low S.W.L. GL. - 3.70 m (9 Nov. 82)
- Correlation with Rainfall : Probable with time lag of about 3 weeks

WELL SKETCH





WATER USE

Drinking
Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (ʊ/cm)	Turb. (ppm)
6 Jul. 83	6.7	26.6	7.0	400	4
8 Sep. 83	6.4	27.7	1.8	400	1

WELL INVENTORY CARD

WELL No. 15 : SUMBER URIP KRAJAN

Location: X : 112°58'30,24" E.
Y : 8°12'15,72" S.
Z : 760,805 meter

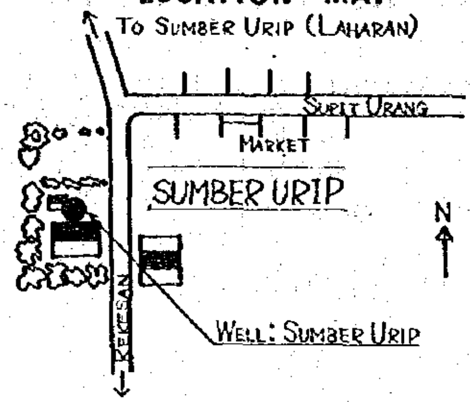
Well Type: Shallow dug well

Well Depth: 0.95 m, Bottom : 1.65 m

Owner's Name ; Haji Abdul Mukti

Address ; SUMBER URIP

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 25 Jun. 82 To

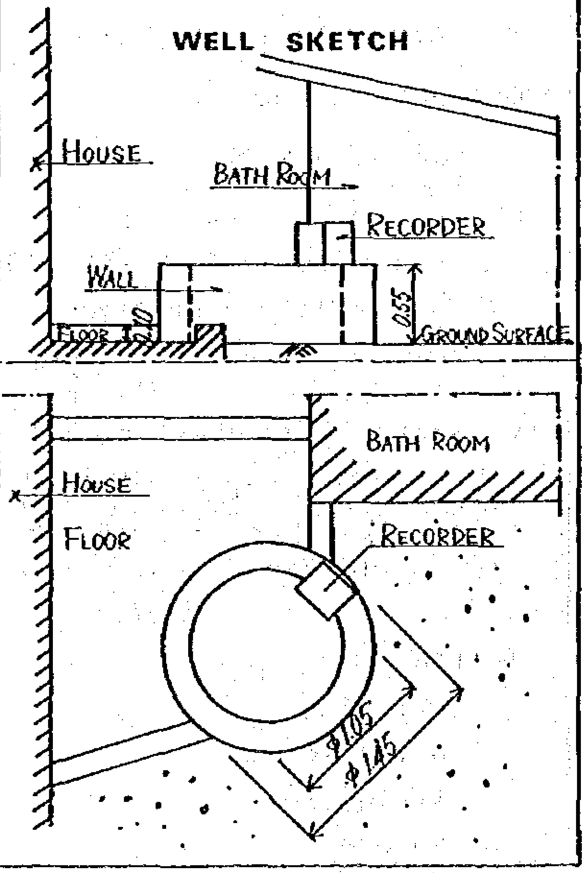
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Paddy field
- Water Level Check : Executed

Variation Characteristic:

- High S.W.L. GL. - 0.55 m (26 May 83)
- Low S.W.L. GL. - 1.40 m (3 Dec. 82)
- Correlation with Rainfall : Not evident

WELL SKETCH



WATER USE

o Drinking
o Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (μ/cm)	Turb. (ppm)
4 Dec. 82	6.1	24.0	2.0	260	2
8 Jan. 83	6.4	24.1	1.7	300	10
6 May 83	6.5	23.3	2.8	280	2
7 Jul. 83	6.2	22.1	1.3	240	3

WELL INVENTORY CARD

WELL No. 16 : REKESAN

Location: X : 112°58'39,07" E.
Y : 8°12'34,08" S.
Z : 206,228 meter

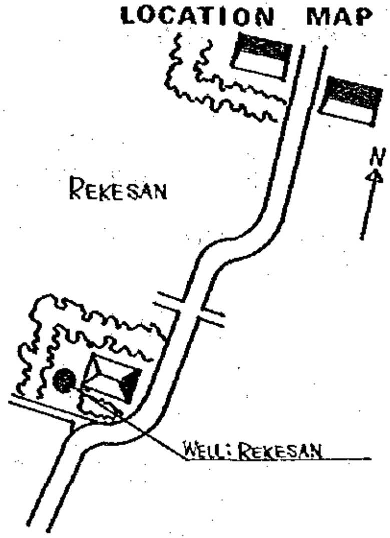
Well Type: Shallow dug well

Well Depth: 3.60 m, Bottom : 3.80 m

Owner's Name ; P. Asbih

Address ; REKESAN, SUMBER URIP

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 25 Jun. 82 To

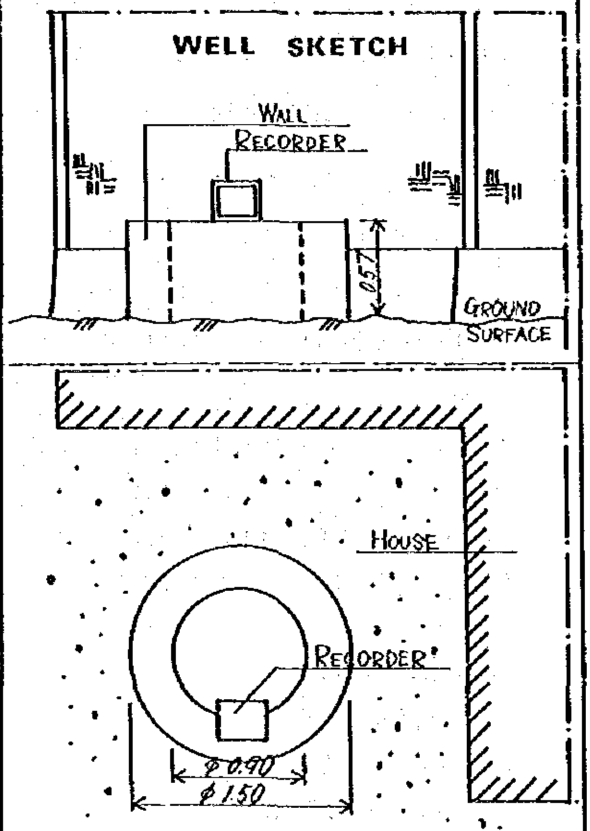
Observation Condition:

- Installation of Equipment : Good
- Land Condition : Paddy field
- Water Level Check : Executed

Variation Characteristic:

- High S.W.L. GL. - 1.24 m (11 Feb. 83)
- Low S.W.L. GL. - 4.20 m (10 Dec. 82)
- Correlation with Rainfall : Influence due to irrigation water

WELL SKETCH



WATER USE

o Drinking
o Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧/cm)	Turb. (ppm)
8 Jan. 83	6.1	24.6	4.9	100	9
6 May 83	6.5	24.1	3.9	260	1
7 Jul. 83	6.1	23.9	5.0	260	3
7 Sep. 83	6.6	23.2	2.0	220	5

WELL INVENTORY CARD

WELL No. 17 : TUMPAK NANAS

Location: X : 112°05' 54" E.
Y : 8°12'55,74" S.
Z : 696,759 meter

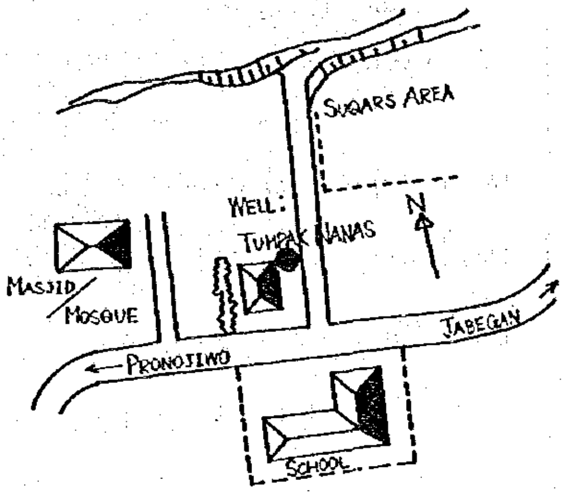
Well Type: Shallow dug well with pulley

Well Depth: 3,45 m, Bottom : 4.27 m

Owner's Name ; Pak Danum

Address ; TUMPAK NANAS, SUMBER URIP

LOCATION MAP



PIEZOMETRIC OBSERVATION

Observation Period:

From 25 Jun. 82 To

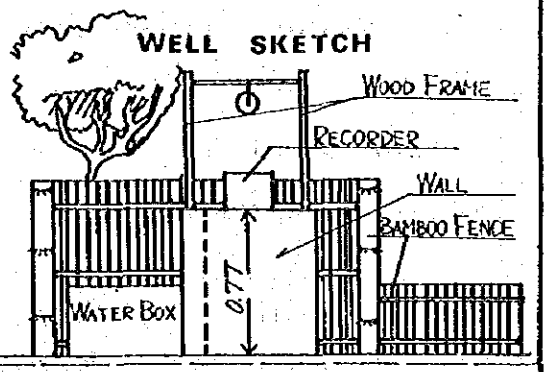
Observation Condition:

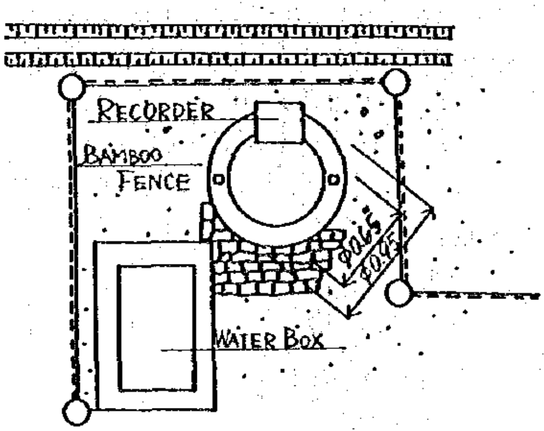
- Installation of Equipment : Good
- Land Condition : Foot of the Tertiary Mountains
- Water Level Check : Executed

Variation Characteristic:

- High S.W.L. GL. - 1.93 m (12 May 83)
- Low S.W.L. GL. - 3.52 m (13 Aug. 82)
- Correlation of Rainfall : Probable

WELL SKETCH





WATER USE

O Drinking
O Domestic
Irrigation
No Use

WATER QUALITY

Date	pH	T (°C)	DO (ppm)	EC (℧/cm)	Turb. (ppm)
26 Nov. 82	6.6	27.1	12.1	200	14
8 Jan. 83	6.2	26.6	2.4	180	5
5 May 83	5.2	24.5	4.7	200	4

APPENDIX C-2

Measurement Results of Simplified Water Quality Test

Table Measurement Results of Simplified Water Quality Test

No.	Location	Date	pH	T	Do	Ec	Turb.
1.	K. Lengkong(up.st)	26 Nov 82	6.5	30	12.1	140	15.2
2.	Oro-oro Ombo A	26 Nov 82	6.3	30	12.1	100	2.4
3.	Oro-oro Ombo B	26 Nov 82	6.5	30	12.1	51	15.2
4.	Oro-oro Ombo C	26 Nov 82	7.4	28.4	7.4	230	13
5.	N a n a s	26 Nov 82	6.6	27.1	12.1	200	14
6.	N a n a s sp.A	26 Nov 82	6.5	30	12.1	180	14.4
7.	K.Lengkong(Damsite)	23 Nov 82	8.3	23.1	7.7	260	2.5
8.	B. Kembar (Damsite)	23 Nov 82	7.9	27.8	8.2	275	4.01
9.	B. Bang (Damsite)	23 Nov 82	7.9	28	8.2	280	6
10.	N a n a s sp.B	2 Dec 82	6.8	24.6	2.7	220	8.7
11.	Rekesan	4 Dec 82	-	-	-	-	-
12.	Sumber Urip Krajan	4 Dec 82	6.1	24	2	260	2
13.	Sp. Kembar	4 Dec 82	7.6	24	12.7	230	0.6
14.	Sp. Raharan	6 Dec 82	7.5	22.7	6.6	120	2
15.	Oro-oro Ombo D	6 Dec 82	-	-	-	-	-
16.	Sp. Kamar A	6 Dec 82	6.8	22.5	7.3	70	0.6
17.	Curah Kobo'an I	6 Dec 82	6.9	24.5	6.8	150	2
18.	K.Besuk Kobo'an	6 Dec 82	-	-	-	-	-
19.	Curah Kobo'an II	6 Dec 82	6.6	25.4	5.9	120	0.5
20.	B. Semut	6 Dec 82	7.2	26	7.3	120	9
21.	K. Pancing (up)	6 Dec 82	7.9	25.2	9.6	180	0.2
22.	K. Mujur (up)	6 Dec 82	6.5	29.9	12.1	100	0.1
23.	S.U. Mujur I	6 Dec 82	6.4	23.1	12.1	100	9
24.	B. Sat (Kertosari)	6 Dec 82	7.5	30.2	4.7	250	2
25.	Kertosari II	25 Nov 82	6.0	25	7.0	200	8
26.	Kertosari I	25 Nov 82	6.5	25.6	7.5	210	8
27.	Sp. Gesang	25 Nov 82	-	-	-	-	-
28.	K. Mujur (Gesang)	25 Nov 82	8.1	31.4	7.30	340	40.8
29.	Gesang Streem	25 Nov 82	6.7	28.2	3.5	320	1.1
30.	Kedung Wringin	25 Nov 82	6.6	27.5	2.3	390	8
31.	Kali Putih	25 Nov 82	6.9	26.3	1.2	400	4.8
32.	Tumpeng	25 Nov 82	6.7	27.6	3.6	410	8
33.	Umbul Sari (Pulo)	25 Nov 82	5.6	28.5	2.4	380	8.5
34.	SB. Wuluh II	25 Nov 82	-	-	-	-	-
35.	SB. Wuluh I	25 Nov 82	-	-	-	-	-
36.	SB. Wuluh (sp)	29 Nov 82	5.4	26.8	5.9	140	7
37.	Urang Gatung II	6 Dec 82	-	-	-	-	-
38.	K. Leprak (Jugosari)	6 Dec 82	6.2	31.1	8.1	280	3.7
39.	Tempeh Kidul I	29 Nov 82	-	-	-	-	-
40.	Tempeh Kidul II	29 Nov 82	-	-	-	-	-
41.	Borehole B - 1	23 Nov 82	6.5	29.6	4.5	250	2
42.	Borehole B - 2	26 Nov 82	6.1	28	4.8	560	9.4
43.	Borehole B - 3	23 Nov 82	6.6	26.1	1.6	220	4.06
44.	Borehole B - 4	2 Dec 82	6.6	25.4	0.6	150	1
45.	Borehole B - 5	2 Dec 82	-	-	-	-	-
46.	Borehole B - 6	4 Dec 82	-	-	-	-	-
47.	Borehole B - 7	2 Dec 82	7.0	20.1	0.6	-	33.1
48.	Borehole B - 8	2 Dec 82	7.1	27.6	0.5	-	15
49.	Borehole B - 9	2 Dec 82	7.1	26.6	2.4	-	4.1
50.	Borehole B - 10	2 Dec 82	6.8	27.8	0.6	-	0

No.	Location	Date	pH	T	Do	Ec	Turb.
1.	K. Lengkong(up.st)	8 Jan 83	6.1	24.6	4.3	120	10
2.	Oro-oro Ombo A	8 Jan 83	5.9	24.6	1.2	100	2
3.	Oro-oro Ombo B	8 Jan 83	5.8	24	3.5	80	8
4.	Oro-oro Ombo C	8 Jan 83	7.3	26.4	6.5	200	1
5.	N a n a s	8 Jan 83	6.2	26.6	2.4	180	5
6.	N a n a s sp.A	8 Jan 83	6.0	28	2.7	130	2
7.	K.Lengkong(Damsite)	6 Jan 83	8.0	25.2	7.5	180	2.2
8.	B. Kembar (Damsite)	8 Jan 83	7.6	23.9	7.4	240	2
9.	B. Bang (Damsite)	6 Jan 83	7.9	27.9	6.7	620	6
10.	N a n a s sp.B	6 Jan 83	6.8	24.9	7.5	200	5
11.	Rekesan	8 Jan 83	6.1	24.6	4.9	100	9
12.	Sumber Urip Krajan	8 Jan 83	6.4	24.1	1.7	300	10
13.	Sp. Kembar	8 Jan 83	7.3	27.3	5.1	300	3
14.	Sp. Raharan	8 Jan 83	6.7	21.5	4.7	300	6
15.	Oro-oro Ombo D	-	-	-	-	-	-
16.	Sp. Kamar A	8 Jan 83	6.6	20	7.2	40	8
17.	Curah Kobo'an I	10 Jan 83	6.8	23.7	6.7	100	3
18.	K.Besuk Kobo'an	10 Jan 83	7.8	26.6	7.5	340	5
19.	Curah Kobo'an II	10 Jan 83	6.9	24.3	4.8	50	2
20.	B. Semut	10 Jan 83	7.8	26.6	7.5	340	5
21.	K. Pancing (up)	10 Jan 83	7.3	23.1	6.2	280	1
22.	K. Mujur (up)	10 Jan 83	7.4	23.7	7.7	320	8
23.	S.U. Mujur I	10 Jan 83	7.2	23.3	3.8	120	11
24.	B. Sat (Kertosari)	10 Jan 83	7.9	28.1	7.6	400	9
25.	Kertosari II	5 Jan 83	6.5	26.5	3.9	240	5
26.	Kertosari I	5 Jan 83	6.7	25.5	4.7	180	2
27.	Sp. Gesang	5 Jan 83	-	-	-	-	-
28.	K. Mujur (Gesang)	5 Jan 83	6.9	28.5	6.5	300	3.6
29.	Gesang Streem	5 Jan 83	6.7	28.6	3.7	340	2.4
30.	Kedung Wringin	5 Jan 83	6.7	27.5	2.5	480	4.2
31.	Kali Putih	5 Jan 83	6.5	27.1	0.4	420	20.1
32.	Tumpeng	5 Jan 83	6.9	28.5	6.5	300	4
33.	Umbul Sari (Pulo)	5 Jan 83	6.4	27.2	1.4	320	7.4
34.	SB. Wuluh II	-	-	-	-	-	-
35.	SB. Wuluh I	-	-	-	-	-	-
36.	SB. Wuluh (sp)	8 Jan 83	6.7	25	6.7	80	8
37.	Urang Gatung II	10 Jan 83	-	-	-	-	-
38.	K. Leprak (Jugosari)	10 Jan 83	8.1	28.8	8.3	60	6
39.	Tempeh Kidul I	5 Jan 83	-	-	-	-	-
40.	Tempeh Kidul II	5 Jan 83	-	-	-	-	-
41.	Borehole B - 1	6 Jan 83	-	-	-	-	-
42.	Borehole B - 2	6 Jan 83	-	-	-	-	-
43.	Borehole B - 3	6 Jan 83	6.5	28	4.8	500	4.2
44.	Borehole B - 4	6 Jan 83	6.7	24.8	1.1	220	5
45.	Borehole B - 5	6 Jan 83	6.7	26.8	2.3	400	8.2
46.	Borehole B - 6	6 Jan 83	6.7	27	9	300	3.6
47.	Borehole B - 7	6 Jan 83	6.1	27	1.3	140	13
48.	Borehole B - 8	6 Jan 83	7.2	28.7	1.1	200	7.1
49.	Borehole B - 9	6 Jan 83	7.3	27.9	2.5	180	17.6
50.	Borehole B - 10	6 Jan 83	6.8	28	1.4	120	8.4

No.	Location	Date	pH	T	Do	Ec	Turb.
1.	K. Lengkong(up.st)	5 May 83	6.5	24	5	145	9
2.	Oro-oro Ombo A	5 May 83	5.6	23.8	6.1	110	4
3.	Oro-oro Ombo B	5 May 83	6.9	24.6	8	100	6
4.	Oro-oro Ombo C	7 May 83	7.6	26.5	6.6	200	110
5.	N a n a s	5 May 83	5.2	24.5	4.7	200	4
6.	N a n a s sp.A	-	-	-	-	-	-
7.	K. Lengkong(Damsite)	7 May 83	7.3	27.2	7.8	200	26
8.	B. Kembar (Damsite)	7 May 83	7.6	27.3	7.4	260	130
9.	B. Bang (Damsite)	7 May 83	8.0	29.5	7.4	400	377
10.	N a n a s sp.B	7 May 83	-	-	-	-	-
11.	Rekesan	6 May 83	6.5	24.1	3.9	260	1
12.	Sumber Urip Krajan	6 May 83	6.5	23.3	2.8	280	2
13.	Sp. Kembar	6 May 83	-	-	-	-	-
14.	Sp. Raharan	-	-	-	-	-	-
15.	Oro-oro Ombo D	6 May 83	6.6	23.6	6.5	240	1
16.	Sp. Kamar A	6 May 83	7.0	21.9	9.6	180	1
17.	Curah Kobo'an I	4 May 83	6.9	23.5	5.0	200	6
18.	K.Besuk Kobo'an	4 May 83	8.2	27.6	7.0	200	298
19.	Curah Kobo'an II	4 May 83	7.4	23.7	5.0	140	6
20.	B. Semut	4 May 83	7.9	24.9	7.0	200	1
21.	K. Pancing (up)	4 May 83	8.0	25.0	7.0	140	2
22.	K. Mujur (up)	4 May 83	8.2	23.9	7.0	160	4
23.	S.U. Mujur I	4 May 83	7.5	24.0	5.0	160	6
24.	B. Sat (Kertosari)	3 May 83	8.4	29.9	9.0	240	188
25.	Kertosari II	3 May 83	7.3	25.7	5.0	300	2
26.	Kertosari I	3 May 83	7.1	26.2	5.0	280	4
27.	Sp. Gesang	-	-	-	-	-	-
28.	K. Mujur (Gesang)	3 May 83	9.7	28.5	1.7	260	203
29.	Gesang Streem	-	-	-	-	-	-
30.	Kedung Wringin	3 May 83	7.2	27.1	4.0	640	3
31.	Kali Putih	3 May 83	7.7	27.8	2.1	440	1
32.	Tumpeng	-	-	-	-	-	-
33.	Umbul Sari (Pulo)	3 May 83	6.3	28.1	2.3	400	44
34.	SB. Wuluh II	5 May 83	6.8	26.4	3.5	220	8
35.	SB. Wuluh I	-	-	-	-	-	-
36.	SB. Wuluh (sp)	5 May 83	6.9	25.2	5.8	220	9
37.	Urang Gatung II	5 May 83	-	-	-	-	-
38.	K. Leprak (Jugosari)	5 May 83	8.8	29.5	4.4	240	521
39.	Tempeh Kidul I	3 May 83	5.4	28.0	2.5	500	5
40.	Tempeh Kidul II	3 May 83	7.0	29.0	2.5	500	6
41.	Borehole B - 1	7 May 83	-	-	-	-	-
42.	Borehole B - 2	7 May 83	-	-	-	-	-
43.	Borehole B - 3	7 May 83	-	-	-	-	-
44.	Borehole B - 4	7 May 83	6.8	25.7	10	300	16
45.	Borehole B - 5	7 May 83	-	-	-	-	-
46.	Borehole B - 6	7 May 83	6.3	27.9	1.9	300	43
47.	Borehole B - 7	7 May 83	-	-	-	-	-
48.	Borehole B - 8	7 May 83	7.7	26.6	6.5	220	3
49.	Borehole B - 9	7 May 83	-	-	-	-	-
50.	Borehole B - 10	7 May 83	-	-	-	-	-

No.	Location	Date	pH	T	Do	Ec	Turb.
1.	K. Lengkong(up.st)	6 Jul 83	6.6	23.2	1.6	100	2
2.	Oro-oro Ombo A	6 Jul 83	5.6	23.3	2.5	200	3
3.	Oro-oro Ombo B	6 Jul 83	7.1	23.7	1.2	80	7
4.	Oro-oro Ombo C	6 Jul 83	5.6	22.5	2.4	160	34
5.	N a n a s	-	-	-	-	-	-
6.	N a n a s sp.A	-	-	-	-	-	-
7.	K. Lengkong(Damsite)	7 Jul 83	8.2	25.4	6.3	200	82
8.	B. Kembar (Damsite)	-	-	-	-	-	-
9.	B. Bang (Damsite)	7 Jul 83	7.9	26.6	6.2	340	199
10.	N a n a s sp.B	7 Jul 83	6.6	24.7	3.7	200	2
11.	Rekesan	7 Jul 83	6.1	23.9	5	260	3
12.	Sumber Urip Krajan	7 Jul 83	6.2	22.1	1.3	240	3
13.	Sp. Kembar	7 Jul 83	-	-	-	-	-
14.	Sp. Raharan	7 Jul 83	6.4	23	2	160	3
15.	Oro-oro Ombo D	7 Jul 83	8.1	23.2	1.8	200	2
16.	Sp. Kamar A	7 Jul 83	6.4	22.3	2.2	180	31
17.	Curah Kobo'an I	5 Jul 83	6.5	23.2	2.5	220	7
18.	K. Besuk Kobo'an	5 Jul 83	7.6	26	2.7	200	29
19.	Curah Kobo'an II	5 Jul 83	7.0	26.3	3.3	120	3
20.	B. Semut	5 Jul 83	7.4	23.9	2.6	200	4
21.	K. Pancing (up)	5 Jul 83	7.1	24.1	2.9	140	7
22.	K. Mujur (up)	5 Jul 83	6.6	23.2	4.7	180	1
23.	S.U. Mujur I	5 Jul 83	7.2	21.5	1.4	160	1
24.	B. Sat (Kertosari)	5 Jul 83	6.7	22.4	5.4	400	3
25.	Kertosari II	4 Jul 83	6.3	24.8	1.6	300	6
26.	Kertosari I	4 Jul 83	6.4	25	1.5	280	3
27.	Sp. Gesang	-	-	-	-	-	-
28.	K. Mujur (Gesang)	4 Jul 83	7.5	25.8	2.6	280	21
29.	Gesang Streem	4 Jul 83	6.6	27	1.4	400	4
30.	Kedung Wringin	4 Jul 83	4.8	26.4	3.2	600	1
31.	Kali Putih	4 Jul 83	6.1	26.3	1.4	520	1
32.	Tumpeng	4 Jul 83	6.4	27.3	1.3	400	5
33.	Umbul Sari (Pulo)	4 Jul 83	6.8	27.6	1	420	2
34.	SB. Wuluh II	6 Jul 83	6.5	25.9	2.4	240	5
35.	SB. Wuluh I	6 Jul 83	7.1	25.2	2.7	240	5
36.	SB. Wuluh (sp)	6 Jul 83	6.4	25.2	2.1	220	3
37.	Urang Gatung II	6 Jul 83	6.7	26.6	7	400	4
38.	K. Leprak (Jugosari)	6 Jul 83	7.9	23.3	2.6	160	220
39.	Tempeh Kidul I	4 Jul 83	6.5	27.5	1.3	460	2
40.	Tempeh Kidul II	4 Jul 83	5.8	27.4	1.9	400	2
41.	Borehole B - 1	8 Jul 83	-	-	-	-	-
42.	Borehole B - 2	8 Jul 83	-	-	-	-	-
43.	Borehole B - 3	8 Jul 83	-	-	-	-	-
44.	Borehole B - 4	8 Jul 83	-	-	-	-	-
45.	Borehole B - 5	8 Jul 83	6.6	27.3	1.2	200	149
46.	Borehole B - 6	8 Jul 83	7.0	25.7	1.1	7	340
47.	Borehole B - 7	8 Jul 83	7.7	25.7	1.2	100	190
48.	Borehole B - 8	8 Jul 83	-	-	-	-	-
49.	Borehole B - 9	8 Jul 83	-	-	-	-	-
50.	Borehole B - 10	8 Jul 83	-	-	-	-	-

No.	Location	Date	pH	T	Do	Ec	Turb.
1.	K. Lengkong(up.st)	7 Sep 83	6.4	22.3	6	60	6
2.	Oro-oro Ombo A	7 Sep 83	5.8	23.4	2.8	120	5
3.	Oro-oro Ombo B	7 Sep 83	5.7	24	3	80	2
4.	Oro-oro Ombo C	7 Sep 83	6.7	21.9	5.6	220	6
5.	N a n a s	-	-	-	-	-	-
6.	N a n a s sp.A	-	-	-	-	-	-
7.	K. Lengkong(Damsite)	8 Sep 83	8.2	27.1	4.7	250	9
8.	B. Kembar (Damsite)	9 Sep 83	7.9	26.8	4.7	320	5
9.	B. Bang (Damsite)	8 Sep 83	7.9	26.3	4.7	380	4
10.	N a n a s sp.B	8 Sep 83	7.1	29.2	1.1	200	14
11.	Rekesan	7 Sep 83	6.6	23.2	2	220	5
12.	Sumber Urip Krajan	7 Sep 83	6.1	22.3	9	260	3
13.	Sp. Kembar	-	-	-	-	-	-
14.	Sp. Raharan	7 Sep 83	6.6	21.6	5.2	60	1
15.	Oro-oro Ombo D	7 Sep 83	7.0	23	1.6	200	1
16.	Sp. Kamar A	7 Sep 83	6.7	21.9	4.8	80	1
17.	Curah Kobo'an I	6 Sep 83	6.4	24	4.8	240	1
18.	K. Besuk Kobo'an	6 Sep 83	7.8	27	5.1	220	1
19.	Curah Kobo'an II	6 Sep 83	6.4	24	5	180	1
20.	B. Semut	6 Sep 83	5.4	25	5.4	200	2
21.	K. Pancing (up)	6 Sep 83	4.9	26	5.4	160	2
22.	K. Mujur (up)	6 Sep 83	6.5	25	5.5	180	1
23.	S.U. Mujur I	6 Sep 83	1.7	23	5.1	200	2
24.	B. Sat (Kertosari)	6 Sep 83	3.5	30	4.7	380	1
25.	Kertosari II	5 Sep 83	6.1	26	5.2	220	1
26.	Kertosari I	5 Sep 83	6.4	26	5.3	260	1
27.	Sp. Gesang	-	-	-	-	-	-
28.	K. Mujur (Gesang)	5 Sep 83	6.1	29	5.4	220	1
29.	Gesang Streem	5 Sep 83	6.1	28	4.9	200	4
30.	Kedung Wringin	5 Sep 83	6.0	27	4.9	200	2
31.	Kali Putih	5 Sep 83	6.3	27	5.4	240	0
32.	Tumpeng	5 Sep 83	6.2	28	5.2	260	1
33.	Umbul Sari (Pulo)	5 Sep 83	5.6	28	4.9	120	2
34.	SB. Wuluh II	8 Sep 83	6.1	25.5	4.8	180	1
35.	SB. Wuluh I	8 Sep 83	6.3	25.9	4.4	240	1
36.	SB. Wuluh (sp)	8 Sep 83	6.5	25.3	4.2	200	1
37.	Urang Gatung II	8 Sep 83	6.4	27.7	1.8	400	1
38.	K. Leprak (Jugosari)	8 Sep 83	7.7	27	5	200	1
39.	Tempeh Kidul I	5 Sep 83	4.5	28	4.7	380	0
40.	Tempeh Kidul II	5 Sep 83	3.1	30	4.8	380	1
41.	Borehole B - 1	9 Sep 83	-	-	-	-	-
42.	Borehole B - 2	9 Sep 83	-	-	-	-	-
43.	Borehole B - 3	9 Sep 83	-	-	-	-	-
44.	Borehole B - 4	9 Sep 83	-	-	-	-	-
45.	Borehole B - 5	9 Sep 83	7	27	2	400	9
46.	Borehole B - 6	9 Sep 83	-	-	-	-	-
47.	Borehole B - 7	9 Sep 83	-	-	-	-	-
48.	Borehole B - 8	9 Sep 83	-	-	-	-	-
49.	Borehole B - 9	9 Sep 83	-	-	-	-	-
50.	Borehole B - 10	9 Sep 83	-	-	-	-	-

APPENDIX C-3

Hydrochemical Charts

Chemical Analysis Chart

Well Number / Sampling Date	T.D.S. (ppm)	Unit	Total Content in one liter of Water in ppm, epm, %epm — Cations: Na	K	Mg	Ca	Total	Anions: Cl	SO4	HCO3	Total	Hydrochemical Formula
No. 1 : P K.Leng Kong (Upstream)	208	ppm	11.59	3.59	8.04	19.84		6.34	0.57	146.52		$M\ 0.21\ \frac{Cl_{7}\ SO4_{0}\ HCO3_{93}}{(Na+K)_{27}\ Mg_{29}\ Ca_{44}}$
		epm	0.504	0.092	0.661	0.990	2.247	0.179	0.012	2.402	2.593	
1 sep. 1982		%epm	22.4	4.1	29.4	44.1	100.0	6.9	0.5	92.6	100.0	
No. 2 : G Oro-oro Ombo A	112	ppm	4.23	1.17	2.81	9.92		8.24	0.77	54.14		$M\ 0.11\ \frac{Cl_{20}\ SO4_{2}\ HCO3_{78}}{(Na+K)_{23}\ Mg_{24}\ Ca_{53}}$
		epm	0.184	0.030	0.231	0.495	0.940	0.232	0.016	0.887	1.136	
1 Sep. 1982		%epm	19.6	3.2	24.6	52.6	100.1	20.4	1.4	78.2	100.0	
No. 3 : G Oro-oro Ombo B	107	ppm	4.05	0.86	3.20	5.29		6.66	7.5	42.10		$M\ 0.11\ \frac{Cl_{18}\ SO4_{15}\ HCO3_{67}}{(Na+K)_{27}\ Mg_{36}\ Ca_{37}}$
		epm	0.176	0.022	0.263	0.264	0.725	0.188	0.156	0.690	1.034	
1 Sep. 1982		%epm	24.3	3.0	36.3	36.4	100.0	18.2	15.1	66.7	100.0	
No. 4 : R Oro-oro Ombo C	116	ppm	5.52	0.94	3.22	10.58		5.07	1.95	67.28		$M\ 0.12\ \frac{Cl_{11}\ SO4_{3}\ HCO3_{86}}{(Na+K)_{25}\ Mg_{25}\ Ca_{50}}$
		epm	0.240	0.024	0.265	0.528	1.057	0.143	0.041	1.103	1.287	
1 Sep. 1982		%epm	22.7	2.3	25.1	49.9	100.0	11.1	3.2	85.7	100.0	
No. 5 : G Tumpak Nanas	203	ppm	0.10	2.18	8.035	21.16		10.14	1.07	127.94		$M\ 0.20\ \frac{Cl_{12}\ SO4_{1}\ HCO3_{87}}{(Na+K)_{4}\ Mg_{37}\ Ca_{59}}$
		epm	0.004	0.056	0.661	1.056	1.777	0.286	0.022	2.097	2.405	
1 Sep. 1982		%epm	0.2	3.2	37.2	59.4	100.0	11.9	0.9	87.2	100.0	
No. 6 : S Sb.Tumpak Nanas (Left B.)	219	ppm	9.94	0.62	13.67	13.23		6.97	4.39	131.04		$M\ 0.22\ \frac{Cl_{8}\ SO4_{4}\ HCO3_{88}}{(Na+K)_{20}\ Mg_{50}\ Ca_{30}}$
		epm	0.432	0.016	1.124	0.660	2.232	0.197	0.091	2.148	2.436	
1 Sep. 1982		%epm	19.3	0.7	50.4	29.6	100.0	8.1	3.7	88.2	100.0	
No. 7 : R K. Leng Kong (Dam site)	216	ppm	13.43	4.84	9.64	20.50		7.29	1.17	144.08		$M\ 0.22\ \frac{Cl_{8}\ SO4_{1}\ HCO3_{91}}{(Na+K)_{28}\ Mg_{31}\ Ca_{41}}$
		epm	0.584	0.124	0.773	1.023	2.503	0.206	0.024	2.362	2.592	
1 Sep. 1982		%epm	23.3	4.1	31.7	40.9	100.0	8.0	0.9	91.1	100.0	
No. 8 : R B. Kembar (Dam site)	242	ppm	19.32	4.37	12.05	21.16		10.46	16.98	158.49		$M\ 0.24\ \frac{Cl_{9}\ SO4_{11}\ HCO3_{80}}{(Na+K)_{32}\ Mg_{33}\ Ca_{35}}$
		epm	0.840	0.112	0.991	1.056	2.999	0.295	0.354	2.598	3.247	
1 Sep. 1982		%epm	28.0	3.8	33.0	35.2	100.0	9.1	10.9	80.0	100.0	

Chemical Analysis Chart

Well Number Sampling Date	T.D.S. (ppm)	Unit	Total Content in one liter of Water in ppm, epm, %epm: Cations: Na	K	Mg	Ca	Total	Anions: Cl	SO4	HCO3	Total	Hydrochemical Formula
No. 9 : R		ppm	28.34	8.74	18.88	26.45		14.89	20.88	230.53		
B. Kobo'an (Dam site)	236	epm	1.232	0.224	1.553	1.320	4.329	0.420	0.435	3.779	4.634	$M_{0.24} \frac{Cl_{9}\ SO4_{9}\ HCO3_{82}}{(Na+K)_{34}\ Mg_{36}\ Ca_{30}}$
1 Sep. 1982		%epm	28.4	5.2	35.9	30.5	100.0	9.1	9.4	81.5	100.0	
No. 10 : S		ppm	15.27	3.51	9.24	21.16		6.02	0.98	165.84		
Sb. Tumpak Nonas (Right B.)	271	epm	0.664	0.090	0.760	1.056	2.570	0.170	0.020	2.718	2.908	$M_{0.27} \frac{Cl_{6}\ SO4_{1}\ HCO3_{93}}{(Na+K)_{29}\ Mg_{30}\ Ca_{41}}$
1 Sep. 1982		%epm	25.8	3.5	29.6	41.1	100.0	5.8	0.7	93.5	100.0	
No. 11 : G		ppm	11.96	6.40	9.25	21.16		6.02	0.89	148.97		
Rekasan	214	epm	0.520	0.164	0.761	1.056	2.501	0.170	0.019	2.442	2.631	$M_{0.21} \frac{Cl_{6}\ SO4_{1}\ HCO3_{93}}{(Na+K)_{28}\ Mg_{30}\ Ca_{42}}$
2 Sep. 1982		%epm	20.8	6.6	30.4	42.2	100.0	6.5	0.7	92.8	100.0	
No. 12 : G		ppm	15.27	7.33	0.46	17.86		10.46	1.78	130.97		
Sb. Urip Krajan	218	epm	0.664	0.187	0.038	0.891	1.780	0.295	0.037	2.147	2.479	$M_{0.22} \frac{Cl_{12}\ SO4_{2}\ HCO3_{86}}{(Na+K)_{48}\ Mg_{2}\ Ca_{50}}$
2 Sep. 1982		%epm	37.3	10.5	2.1	50.1	100.0	11.9	1.5	86.6	100.0	
No. 13 : S		ppm	15.46	4.13	0.34	21.82		7.92	14.06	126.72		
Sb. Kembar	214	epm	0.672	0.106	0.028	1.089	1.895	0.223	0.293	2.077	2.593	$M_{0.21} \frac{Cl_{9}\ SO4_{11}\ HCO3_{80}}{(Na+K)_{38}\ Mg_{2}\ Ca_{60}}$
2 Sep. 1982		%epm	35.5	5.6	1.5	57.4	100.0	8.6	11.3	80.1	100.0	
No. 14 : S		ppm	9.75	3.20	0.10	10.58		5.71	1.68	81.70		
Sb. Raharan	132	epm	0.424	0.082	0.008	0.528	1.042	0.161	0.035	1.339	1.535	$M_{0.13} \frac{Cl_{11}\ SO4_{2}\ HCO3_{87}}{(Na+K)_{48}\ Mg_{1}\ Ca_{51}}$
2 Sep. 1982		%epm	40.7	7.9	0.8	50.7	100.1	10.5	2.3	87.2	100.0	
No. 15 : G		ppm	12.51	3.59	0.08	27.78		5.71	1.58	175.80		
Oro-oro Ombo D	272	epm	0.544	0.092	0.007	1.386	2.029	0.161	0.033	2.881	3.075	$M_{0.27} \frac{Cl_{5}\ SO4_{1}\ HCO3_{94}}{(Na+K)_{31}\ Mg_{1}\ Ca_{68}}$
2 Sep. 1982		%epm	26.8	4.5	0.4	68.3	100.0	5.2	1.1	93.7	100.0	
No. 16 : S		ppm	9.75	2.96	0.15	9.20		6.66	3.27	72.67		
Sb. Kamar A	127	epm	0.424	0.076	0.012	0.459	0.971	0.188	0.068	1.191	1.447	$M_{0.13} \frac{Cl_{13}\ SO4_{5}\ HCO3_{82}}{(Na+K)_{52}\ Mg_{1}\ Ca_{47}}$
2 Sep. 1982		%epm	43.7	7.8	1.2	47.3	100.0	13.0	4.7	82.3	100.0	

Chemical Analysis Chart

Well Number Sampling Date	T.D.S. (ppm)	Unit	Total Content in one liter of Water in ppm.epm.%epm									Hydrochemical Formula
			Cations					Anions				
			Na	K	Mg	Ca	Total	Cl	SO4	HCO3	Total	
No. 17 : G		ppm	9.38	4.13	3.41	21.16		8.87	1.58	104.53		
Curah. Kobo'an I	186	epm	0.408	0.106	0.280	1.056	1.850	0.250	0.033	1.713	1.996	$M_{0.19} \frac{Cl_{12}\ SO4_{2}\ HCO3_{66}}{(Na+K)_{28}\ Mg_{15}\ Ca_{57}}$
2 Sep. 1982		%epm	22.1	5.7	15.1	57.1	100.0	12.5	1.7	85.8	100.0	
No. 18 : R		ppm	11.41	3.74	5.83	19.18		6.02	2.28	122.47		
K. Busuk Kobo'an	178	epm	0.496	0.096	0.479	0.957	2.028	0.170	0.047	2.007	2.224	$M_{0.18} \frac{Cl_{8}\ SO4_{2}\ HCO3_{90}}{(Na+K)_{29}\ Mg_{24}\ Ca_{47}}$
2 Sep. 1982		%epm	24.5	4.7	23.6	47.2	100.0	7.7	2.1	90.2	100.0	
No. 19 : G		ppm	7.36	2.89	3.62	13.89		5.71	3.27	75.10		
Carah Kobo'an II	180	epm	0.320	0.074	0.298	0.693	1.097	0.161	0.068	1.231	1.460	$M_{0.18} \frac{Cl_{11}\ SO4_{5}\ HCO3_{84}}{(Na+K)_{28}\ Mg_{22}\ Ca_{50}}$
2 Sep. 1982		%epm		6.7	27.2	63.2	100.0	11.0	4.7	84.3	100.0	
No. 20 : R		ppm	18.40	3.90	5.22	13.89		6.34	3.96	116.49		
Besuk semust	171	epm	0.80	0.100	0.429	0.693	1.302	0.179	0.082	1.909	2.170	$M_{0.17} \frac{Cl_{8}\ SO4_{4}\ HCO3_{88}}{(Na+K)_{33}\ Mg_{26}\ Ca_{41}}$
2 Sep. 1982		%epm	6.2	7.7	32.9	53.2	100.0	8.2	3.8	88.0	100.0	
No. 21 : R K. Panching		ppm	9.02	3.04	2.40	11.93		5.71	0.39	86.48		
(Upstream)	127	epm	0.392	0.078	0.197	0.595	1.232	0.161	0.008	1.417	1.586	$M_{0.13} \frac{Cl_{10}\ SO4_{1}\ HCO3_{89}}{(Na+K)_{36}\ Mg_{16}\ Ca_{48}}$
2. Sep. 1982		%epm	31.1	6.2	15.6	47.1	100.0	10.2	0.5	89.3	100.0	
No. 22 : R K. Mujur		ppm	9.02	2.89	3.62	14.55		5.71	0.20	90.73		
(Upstream)	136	epm	0.392	0.074	0.298	0.726	1.490	0.161	0.004	1.487	1.652	$M_{0.14} \frac{Cl_{10}\ SO4_{0}\ HCO3_{90}}{(Na+K)_{30}\ Mg_{20}\ Ca_{50}}$
2 Sep. 1982		%epm	26.3	5.0	20.0	48.7	100.0	9.8	0.2	90.0	99.9	
No. 23 : G		ppm	9.75	4.37	2.80	13.87		6.34	3.12	84.67		
Sumber Mujur I	140	epm	0.424	0.112	0.230	0.692	1.458	0.179	0.065	1.388	1.632	$M_{0.14} \frac{Cl_{11}\ SO4_{4}\ HCO3_{85}}{(Na+K)_{37}\ Mg_{16}\ Ca_{47}}$
2 Sep. 1982		%epm	29.1	7.7	15.8	47.4	100.0	11.0	4.0	85.0	100.0	
No. 24 : R B. Sat		ppm	11.22	3.90	8.84	19.18		7.29	0.39	135.11		
(Kertosari)	202	epm	0.488	0.100	0.727	0.957	2.272	0.206	0.008	2.215	2.429	$M_{0.20} \frac{Cl_{9}\ SO4_{0}\ HCO3_{91}}{(Na+K)_{26}\ Mg_{32}\ Ca_{42}}$
2 Sep. 1982		%epm	21.5	4.4	32.0	42.1	100.0	8.5	0.3	91.2	100.0	

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 (5)

PART - D
GEOLOGY

FEBRUARY, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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ABSTRACT

Geological investigation is divided into three catergories.

Firstly, there is a general geological survey to understand the geological situation of the wide area.

Secondly, there is a land condition survey to understand the hydrogeological as well as geotechnical situation at each planned site for the main Sabo facility and for water conservation.

Lastly, there is a geophysical sounding to analyse measured data of geophysical sounding at the above-mentioned sites.

A summary of survey results is given below.

(1) General Geological Survey

Geology of the investigated area is largely divided into two systems: (i) Quaternary volcanic products of the Sunda Quaternary Volcanic Arc which forms the backbone of Java Island, and (ii) Tertiary volcanic rocks which form the base of Quaternary volcanic products. Tertiary volcanic rocks form a steep mountains in the south-west of the study area. Quaternary volcanic products are classified into relatively young and loose volcanic products from Mt. Semeru and relatively old and compact older volcanic products, eroded to a certain extent, which are the basement of the younger volcanic products and consist of volcanic products from the Jambangan volcanic complex.

Characteristics of the volcanic activities of Mt. Semeru are: (i) Lahar and Nuée Ardente are concentrated in the south-east slope; (ii) No large-scale erruption is presumed to happen in the past; (iii) An active period and a dormant period repeat regularly; (iv) Location of a crater is slowly shifting to the south.

(2) Land Condition Survey and Geophysical Sounding

Geological conditions discovered by the investigations at the planned sites for the main Sabo facility and water conservation are as follows:

i) Pronojiwo Damsite

Very hard and strong Tertiary andesite lava (10 m in thickness) is distributed at the riverbed, its P wave propagation velocity is 4 km/s. and the shear strength is estimated to be about $\tau o = 120$ ton/m . A weak layer of Volcanic breccia lies under the andesite lava, and its shear strength is assumed to be $\tau o = 30 - 50$ ton/m .

The right-bank mountain is formed by the older Lahar deposits of Quaternary and its topographical capacity is small. Its P wave propagation velocity is 1.3 to 1.8 km/s.

The permeability of Tertiary Volcanic breccia and andesite lava, which form the baserock of the damsite, is small at under 5 Lu at 10 m or deeper.

The left-bank mountain is formed by the Tertiary tuff and tuff breccia.

Based on these findings, it appears possible to build an approximately 30 m high gravity type dam, in spite of some difficulties.

ii) K. Lengkong Fan

As the hydrogeological structure of K. Lengkong Fan, the fan consists of impervious layers of Tertiary volcanic rocks and Quaternary Older volcanic products as basement, and of a pervious layer of younger volcanic products from Mt. Semeru as overburden.

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 the further west of the fan.

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

The electric sounding, however, suggests that various layers of high permeability such as autobrecciated lava and pyroclastic materials, 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 $K = 10^{-4}$ cm/s.

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

1. GENERAL GEOLOGY

1.1 INTRODUCTION

Chapter 1 gives the results of regional geological survey in the southeastern slope of Mt. Semeru as part of Feasibility Study on the Volcanic Debris Control and Water Conservation Project in the Southeastern Slope of Mt. Semeru in the Republic of Indonesia.

Outlines of this survey are given below.

(1) Purpose of the Survey

The purpose of this survey is to carry out a regional geological survey of the southeastern slope of Mt. Semeru and to determine the geological situation of planned site of major Sabo facilities and water conservation project as well as to formulate the future plans for subsequent various geological investigation works based on the results of regional geological survey.

(2) Study Area and Methodology

The study area is about 730 km^2. The method of the survey chiefly consists of the route survey of main rivers and roads but somewhat more detailed investigation was carried out around the planned site of important sabo facilities.

Generally, 1/50,000 topographical map was used but occasionally 1/10,000 topographical map was used for K. Lengkong Fan and 1/5,000 topographical map for K. Mujur, K.B. Tunggeng and K. Rejali.

(3) Period of Survey

The survey period took 2 months from May 11, 1982 to July 10, 1982.

(4) Persons in Charge

Geological reconnaissance was carried out by Mr. Nobuhiko Uchiseto and Mr. Yosuke Sakaki of JICA Study Team, and was accompanied by Mr. SUMARTONO of the Department of Public Works and Mr. SURYO of the Geological Survey of Indonesia for the field survey.

1.2 OUTLINES OF THE STUDY RESULTS

(1) Topography and Geology of the Survey Area

-: Topography

The study area covers the southeastern slope of Mt. Semeru (EL. 3,676 m) in the eastern part of Java Island. Mt. Semeru is the highest mountain in Java Island and an active stratovolcano. Mt. Semeru is located in the east of long and large Quaternary volcanic arc running from east to west in the center of Java Island called Solo Zone or Sunda Quaternary Volcanic Arc, and belongs to Tengger-Semeru Volcanic complex extending from north to south taht is one of the volcanic complexes forming Solo Zone.

Tengger-Semeru volcanic complexes are morphologically classified into the following 3 units. (A. SAKAI, I. SURYO, 1980)

- Tengger mountain range
- Jambangan volcanic complex
- Semeru volcano

Among them Mt. Semeru is the youngest and is formed on the southern slope of the Jambangan volcanic complex which is the oldest among the 3 units.

To the south of Solo Zone in the study area, the mountain range called Southern Mountains comprising the Tertiary system runs from east to west in parallel with Solo Zone.

The study area covers both Solo Zone and Southern Mountains and is roughly classified into the following 4 areas according to the geomorphological characteristics.

Semeru Volcano	a. Main part of volcanic cone (EL. 1,500 m to top) b. Volcanic fan (EL. 150 to 1,500 m) c. Volcanic piedmont periphery (EL. 0 to 150 m)
Southern Mountains	d. Mountains and hills

-: Geology

Geology of the study area is largely divided into Tertiary system and Quaternary system. Quaternary system forms volcanic ranges including Mt. Semeru on the north side of the study area and Tertiary system forms steep mountains on the south side of the study area.

The Tertiary system of the study area comprises various volcanic rocks such as andesite, tuff and tuff breccia. The lowest layer is composed of green tuff etc. The green tuff is called Old Andesite in Indonesia which was turned into green by hydrothermal alteration. There seems to be unconformity between these green tuff, etc. and the volcanic rocks lying over the former.

The Quaternary system of the study area is largely classified into older volcanic products, which are volcanic products of Jambangan volcanic complex, and younger volcanic products which are from Mt. Semeru. Most of the study area is covered with younger volcanic products. The younger volcanic products can be also classified into the following 4 types according to the composite material, mode of occurrence and compactness.

a. Primary volcanic products

Secondary volcanic products
(Epiclastic volcaniclastic deposits):

b. Younger Lahar deposits
c. Older Lahar deposits
d. Alluvium

Primary volcanic products are composed of those directly from the center crater or parasitic volcanos. They have not moved from the original place in spite of rain, etc. Most of them are distributed over the area above EL. 800 m.

Secondary volcanic products (epiclastic volcaniclastic deposits in terms of volcanology) are those of the primary volcanic products which are moved with water and redeposited. They are included in debris flow and mud flow deposits in the study of mud flow. In this report debris flow and mud flow deposits are collectively called Lahar deposits. Lahar deposits are distributed over the area from EL. 800 to 150 m. Lahar deposit can be classified into loose younger Lahar deposits and well compacted older Lahar deposits according to the degree of compactness. Older Lahar deposits form an old volcanic fan such as K. Poh Fan and younger Lahar deposits form a new volcanic fan covering the old volcanic fan.

The stratified alluvium is distributed in the Volcanic piedmont periphery which surrounds the Volcanic fan and comprises round pebbles, sub angular pebbles, sands, silt and clay.

(2) Characteristics of Volcanic Activities of Semeru Volcano

Characteristics of volcanic activities of Semeru volcano are given below.

-: Nuée Ardente and Lahar are concentrated on the southeastern slope.

-: Judging from distribution of volcanic ejectaments (ex. ash falls, bomb, etc.), there seems to have been no large-scale eruptions in the past.

-: Cycle of the active period and dormant period had been repeated many times.

-: The crater is gradually shifting toward south.

(3) Planned Site of Major Sabo Facilities and Water Conservation

Planned sites of major Sabo facilities and water conservation are shown in Fig.-1.5.1, Geological Map of the Study Area.

-: Pronojiwo Damsite

It comprises the west bank to the riverbed with Tertiary volcanic rocks (alternating layers of andesite and Volcanic breccia), but the west bank is composed of older Lahar deposits of sand and gravels from Mt. Semeru but its topographic capacity is slight.

On the riverbed an andesite lava of about 10 m in thickness is distributed, underlain by a weak Volcanic breccia layer.

Considering the topographical and geological conditions described above, it seems possible to construct a concrete dam of 30 to 40 m in height at Pronojiwo damsite in spite of some difficulties.

For use as aggregates, Lahar deposits whose quality is not so poor can easily be collected.

For use as soil material, highly weathered part of tuff layer of Tertiary period was considered but the quality was found to be not so suitable.

-: K. Lengkong Fan

K. Lengkong Fan abounds in spring, and on the impervious Tertiary basement the relatively pervious layer of volcanic products lies disconcordantly. The stratostructure of Semeru Volcano is thought to be as a hydrogeological structure of relatively pervious volcanic products.

-: Diversion Channel

Around the route of Diversion Channel, older Lahar deposits are predominant and there exists no large-scale lava flow.

-: Curah Kobo'an Check Dam

Andesite lava is distributed widely over the riverbed but it is as thin as about 3 m and underlain with soft mudstone.

The right bank is composed of soft, highly weathered alternating layers of tuff/tufficious mudstone and its topography shows a narrow ridge.

On the left bank, older Lahar deposits of compacted sand and gravels are thickly distributed. For the above reason, it would be very difficult to construct a large dam (over 40 m high) at this damsite.

-: Site of Sabo Facilities along K. Mujur and K.B. Tunggeng

At 3 points along Gesang, Kloposawit and Kertosari, older Lahar deposits lie as a base, on which younger Lahar deposits and riverbed deposits are thinly distributed. At all these 3 points, the ground water level is high and ground water out-permeates from both banks.

1.3 LOCATION

The study area is located at Lumajang city in the eastern province of Java, about 150 km south of Surabaya. By car it takes two hours to reach Lumajang city from Surabaya via Pasuluan and Probolingo. From Lumajang to Pronojiwo, the western end of the study area, it is a distance of one hour and a half by car. Mt. Semeru is located between Lumajang city and Malan city with its southeastern slope facing Indonesian Ocean.

1.4 OUTLINES OF TOPOGRAPHY AND GEOLOGY OF THE EASTERN PART OF JAVA ISLAND.

1.4.1 TOPOGRAPHY OF EASTERN PART OF JAVA ISLAND

Semeru Volcano belongs to Sunda Quaternary Volcanic Arc which runs from east to west through Sumatra Island and the center of Java Island reaching Bali Island and Sunbawa Island. Semeru volcano is an active stratovolcano and the highest mountain in Java Island at El. 3,675.6 m. There is another smaller volcanic row named Tengger-Semeru Volcanic Row running from south to north at a right angle to Sunda Quaternary Volcanic Arc in the eastern Java. Semeru Volcano is located at the south end of this Smaller volcanic row as shown in Fig.-1.4.1.

This volcanic row extending from south to north can be classified into the following 3 geomorphological units according to Sakai & Suryo (1980). (See Fig.-1.4.1)

i) Tengger Mountain Range

ii) Jambangan Volcanic Complex

iii) Semeru Volcano

The oldest unit is Jambangan Volcanic Complex and Semeru Volcano is the youngest of the three.

Semeru Volcano is called Mahameru (meaning sacred) mountains. Semeru means the sole sacred mountain.

(1) Tengger Mountain Range

To the west of Tengger Mountain Range, non-volcanic deposits are distributed as the basement . Volcanic deposits cover this basement on the east. Bromo Volcano

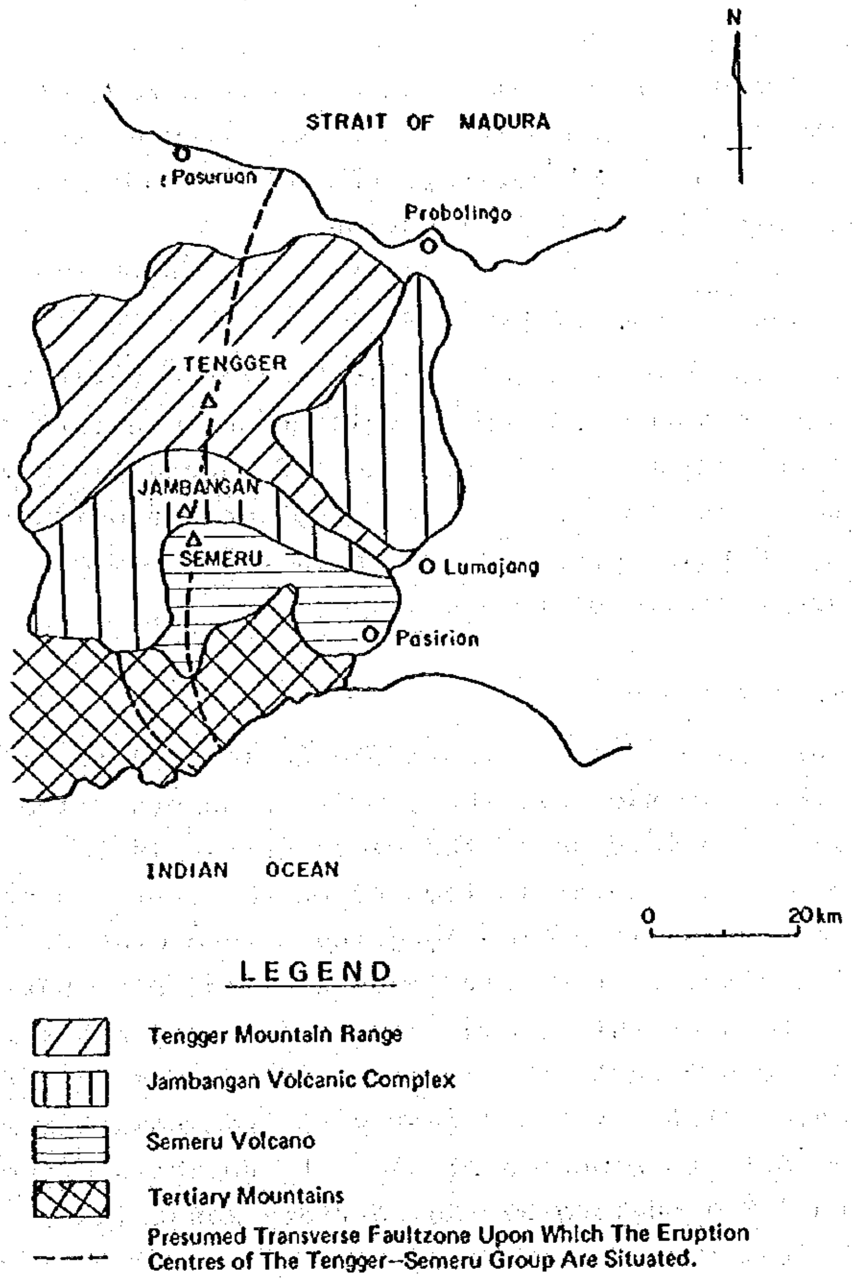


Fig.- 1.4.1 Schematic Geomorphological Unit Map of Tengger – Semeru Volcanic Row is located on the west of the mountain range and is the only active volcano in this unit. Tengger Mountain Range is located at the northern end of the volcanic row extending in the N-S direction.

(2) Jambangan Volcanic Complex

Jambangan Volcanic Complex is located between Tengger Mountain Range and Semeru Volcano and consists of Ayegayeg Volcano, Ranu Kembolo Volcano and Gunung Kepla Volcano. Since these volcanos ceased eruptions, erosion is progressing, cutting deep valleys which represent a characteristic of this unit.

(3) Semeru Volcano

Semeru Volcano is a stratovolcano located at the south end of the volcanic row, the summit of Semeru Volcano is called Mahameru where the older crater is located, while the present crater is located on the southeastern side of Mahameru and is called Joggring Seleko Crater. Joggring Seleko Crater presently faces K. Besuk Bang but the direction of this crater had changed several times in the past according to the existing data. The eastern slope of Semeru Volcano extends gently towards Lumajang Plain and the southern slope is blocked its southern expansion beyond K. Lengkong by the Tertiary mountains extending in arc from east to west.

From geomorphological point of view, the southeastern slope of Semeru Volcano can be said to be younger than the slopes on the northern and western side. In other words, this is because the slope to the west of K. Glidik belongs to the aforesaid Jambangan Volcanic Complex and the slope to the north of K. Besuk Sat belongs to Tengger Mountain

Range and Jambangan Volcanic Complex. The study area of this project is the youngest slope of Semeru Volcano from a geomorphological point of view.

1.4.2 GEOLOGY OF EASTERN PART OF JAVA ISLAND

Geology of the eastern part of Java Island, as shown in Fig.-1.4.2 has distribution of several geological provinces extending to E-W in a band shape, which are arranged from south to the north in the following order.

i) Tertiary volcanic rocks, limestone, etc.

ii) Quaternary volcanic Facies

iii) Miocene-Pliocene Sedimentary Facies

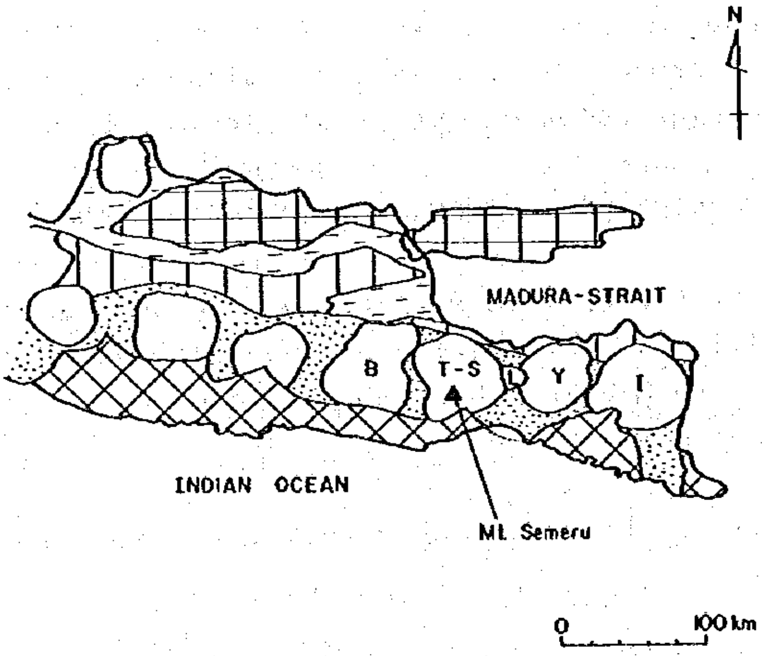
iv) Quaternary sedimentary Facies

v) Miocene-Pliocene Sedimentary Facies

The above geological facies are explained in the order listed.

(1) Tertiary Volcanic Rocks, Limestone, etc.

Southern mountains shown in Fig.-1.4.2 are composed of Tertiary "Old Andesite" and limestone, etc. According to Katili in 1973, since volcanic activities were prominent when these layers were formed, Southern Mountains are called Sunda Tertiary Magmatic Arc. To the east of Jember, granite is observed intruded into Tertiary system. Because of this, alteration is observed in the lower part of Tertiary system. In Tertiary system, extending to the south of Semeru Volcano, a little greenish and clay-turned Tertiary system due to alteration is observed. The acidic welded tuff assumed to be cognate with the granite is also observed in the study area.



LEGEND

Quaternary Volcanoes

Alluvial Plains of Nothern Java

Rembang – Madura Anticlinorium (Miocene – Pliocene Sedimentary Facies)

Boger –, North-Seraju –, and Kendung – Anticlinolium (Ditto)

Central Depression Zone of Java (Alluvium)

Southern Mountains (Miocene Volcanic and Limestone Facies)

I	Ijen Volcanic Complex
Y	Iyang Volcanic Complex
L	Lamongan Volcanic Complex
T–S	Tengger – Semeru Volcanic Complex
B	Butak Volcanic Complex

Fig.-1.4.2 Physiographic Map of East Java
(From GEOLOGY OF INDONESIA VOL I A, VAN BEMMELEN, 1950)

(2) Quaternary Volcanic Rocks

The quaternary volcanic arc running through the center of Java Island is called Sunda Quaternary Volcanic Arc. It is a very long and large volcanic zone extending to the Andaman Islands in the north and to Celebes Island in the east. In Java, this volcanic arc is called Solo Zone. In so called Solo Zone, Tertiary system, limestone, etc. are overlain with thick volcanic products from Quaternary volcanos. The start of a volcanic activism of Quaternary period goes as far back as the middle to the latter pleistocene. Solo Zone on east Java as shown in Fig.-1.4.2 consists of several volcanic complexes. These are listed from east to west around Semeru Volcano.

i) Ijen volcanic complex

ii) Iyang volcanic complex

iii) Lamongan volcanic complex

iv) Tengger-Semeru volcanic complex

v) Butak volcanic complex

With regard to topography and geology of (iv) Tengger-Semeru complex where the study area is located, please refer to 1.4.1 Topography of the Eastern Part of Java Island. The characterisitc of geological structure of Tengger Semeru complex, as shown in Fig.-1.4.1, shows arrangement of several craters in N-S direction, crossing Sunda Quaternary volcanic Arc at a right angle. This indicates existence of transverse fault zone of Java Island along the craters in N-S direction. This fault is also considered to border the western edge of the depression zone expanding in Lumajang Plain with Lamongan volcanic complex in the center (Van Bemmelen, 1950).

(3) Northern Zone of Eastern Java

Deposits covered with alluvium, miocene and pliocene are distributed on the north of Sunda Quaternary Volcanic Arc. Deposits from Miocene to Pliocene are mostly composed of limy detrital sediments which are folded. As a geological structure of the northern zone of Eastern Part of Java, as is shown in Fig.-1.4.2, the follwoing anticline and syncline exist in parallel with Java Island: These are from south to north Boger-North-Seraju- and Kenduna anticlinorium, Randublatung syncline and Dembang-Madura anticlinorium with alluvium thickly covering Randublatung syncline.

1.4.3 *EARTHQUAKE*

Along the Sunda Islands from Sumatra and Java Islands to Timore Island, the epicenter is distributed in an arc shape. Such a seismic activity in Indonesia is explained by Plate Tectonics Theory as follows. As a result of gushing action at southern Indian ocean Ridge and Carlsberg Ridge, stress is accumulated by a moving mass of Indian Ocean - Australian Plate getting underneath the Southeastern Asia Plate. This is the reason for earthquakes along the Sunda Islands. Around Semeru volcano, both the structural earthquakes caused by entrance of the plate as is above described and volcanic earthquakes frequently occur but the frequency of volcanic earthquakes is especially higher. However, seismic intensity of these earthquakes is generally weak and little damage by earthquake was reported in the record since 1900. The largest acceleration was less than 0.05 g, although Isosismo map using Kawasumi formula of Weather Bureau of Indonesia shows that the area surrounding Semeru Volcano is a possible area of earthquake of maximum acceleration of 0.15 - 0.3 g.

1.5 TOPOGRAPHY AND GEOLOGY OF THE STUDY AREA

1.5.1 TOPOGRAPHY OF THE STUDY AREA

The southeastern part of Semeru Volcano, a subject area of the current study, can be divided into the following 4 geomorphological units. For further details of the topography of the survey area, please refer to Supporting Report (5) Part H, Topography and Natural Disaster.

i) Main part of the volcanic cone

ii) Volcanic fan

iii) Volcanic piedmont periphery

iv) Tertiary mountains and hills

(1) Main part of the volcanic cone is over EL. 1,500 m, where volcanic activity of Semeru Volcano directly affects.

Pyroclastic flow, ash fall, lapilli, volcanic bomb and lava etc. spewed directly from the crater, are distributed over this area and its inclination is very steep at 27 degree.

(2) The volcanic fan is the slope between EL. 150 and 1,500 m, where Lahar and Ladu disasters mostly concentrate. The volcanic fan is largely divided into two areas, i.e.: Ladu fan where lava flow and pyroclastic flow deposits and Lahar deposits are distributed in mixture, at EL. 800 to 1,500 m Lahar fan where lava flow and pyroclastic flow deposits are not distributed but consist only of Lahar deposits at EL. 600 to 150 m. Lahar fan can be further divided into two at around EL. 200 m, i.e.: Lahar fan-A which is a steep sloped fan at EL. 250 to 800 m and Lahar fan-B which is a slow sloped fan at EL. 150 to 250 m.

The above is summarized as follows.

i) Ladu type fan (EL. 800 to 1,500 m)
Lahar type fan ii) Lahar fan-A (EL. 250 to 600 m)
iii) Lahar fan-B (EL. 150 to 250 m)

(3) Volcanic piedmont periphery is a very slow sloped flat ground formed outside of the volcanic fan. In this area, exists an overflow deposit comprising sand, subangular pebbles, silt and clay. Further outside of this terrain, the alluvial plain and the coastal plain are formed.

(4) In the southwestern part of the study area lie steep mountains of Mature stage of max. EL. 1,000 m consisting of Tertiary volcanic rocks. In the north of these mountains near the boundary between Semeru Volcano and the mountains, a mountain range extends east to west in arcs, which blocks the extension of the foot of Semeru Volcano to the south. The slope of the mountains is very steep and dissected with many small valleys. To the south of Pasirian, two isolated hills consisting of the Tertiary Volcanic breccia stand out in the Volcanic fan.

There are many small hills at a relative height less than 10 m scattered in the volcanic piedmont periphery to the south of Pasirian. In these small hills, huge angular boulders of andesite dia. 2 - 3 m are irregularly mixed in the weathered and lateritized sand and silt. The area where these small hills distributed elongate NW - SE direction and their distribution area presents a slender fan opening toward SE direction. These hills show the relic of a very large scale volcanic mudflow and can be considered as so called mudflow hills. Judging from weathered condition of these hills, the deposits may be older than those from Semeru volcano but the origin of these hills can not be confirmed in this study.