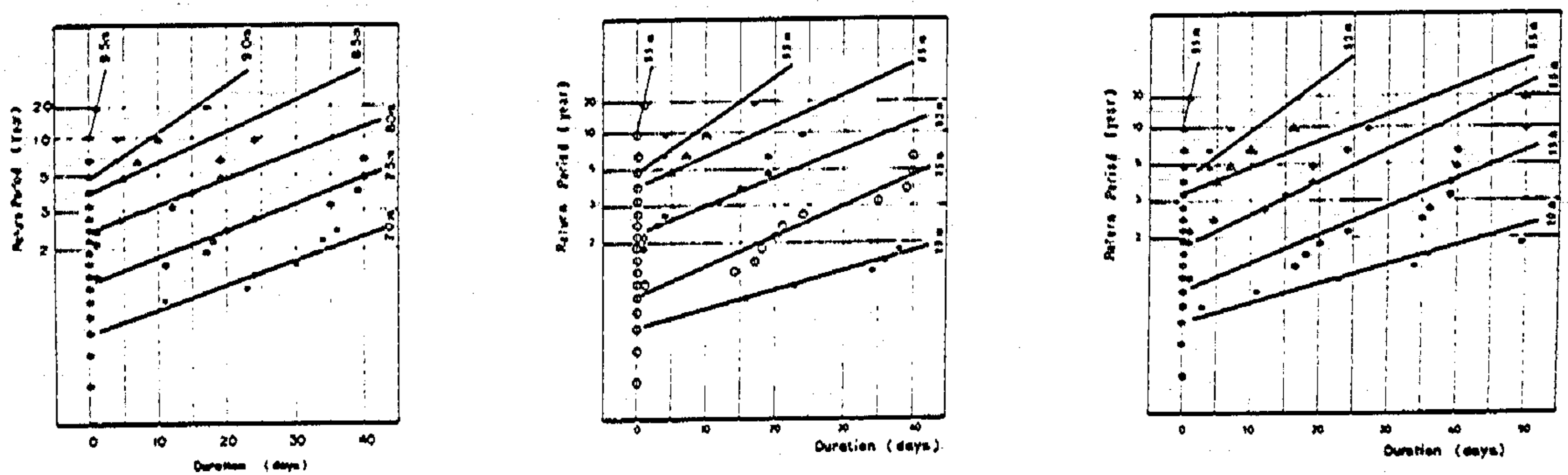


(May - Aug.)

(Mar. - Sept.)

(Annual)

Fig. 5.6 RETURN PERIOD OF WATER LEVEL DURATION AT LAKE TEMPE

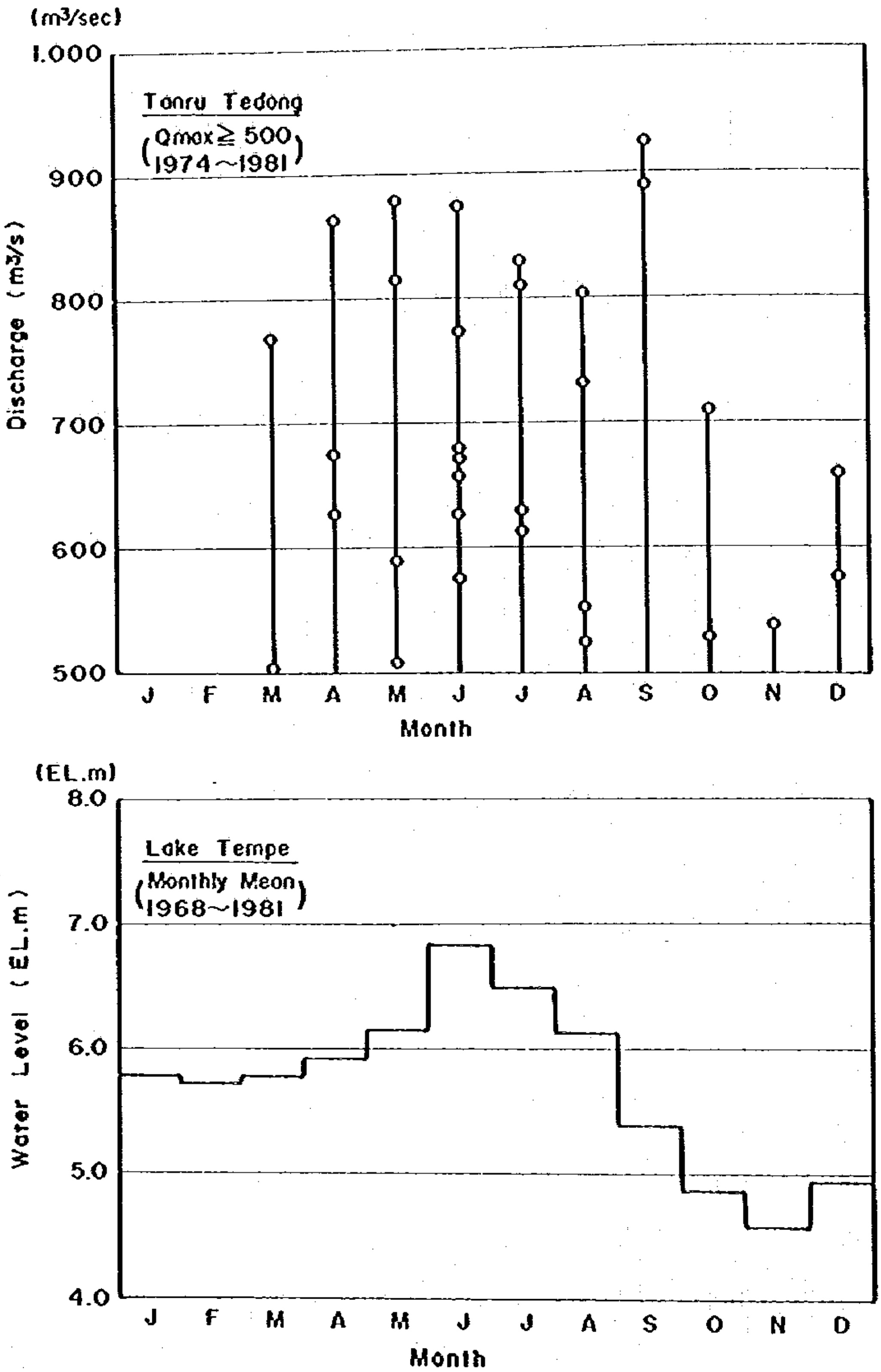


Fig. 5.7 ANNUAL PATTERN OF PEAK DISCHARGE AND WATER LEVEL

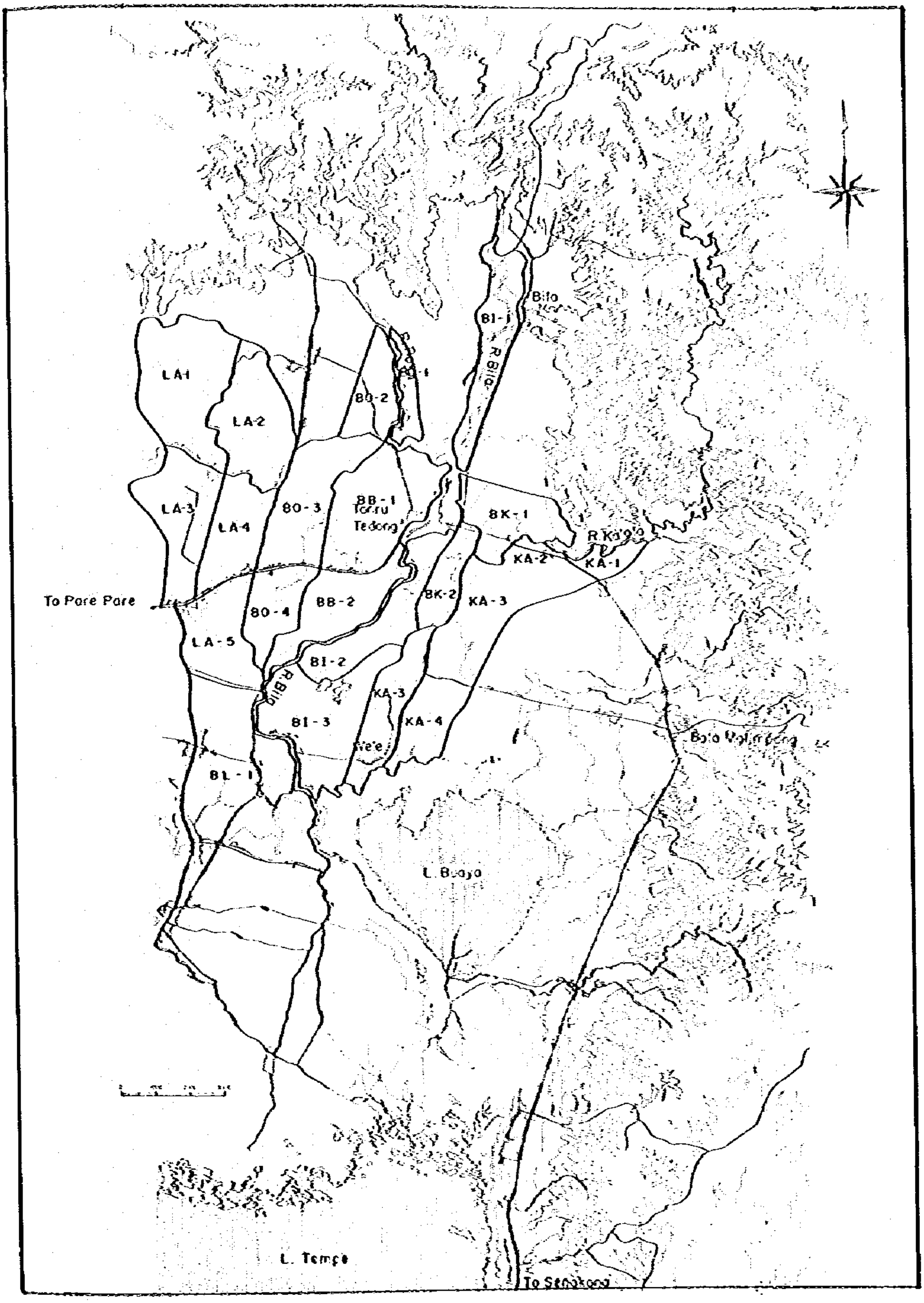


Fig. 5.8 INUNDATION AREA

ANNEX - II

SOIL AND LAND CLASSIFICATION

ANNEX-II SOIL AND LAND CLASSIFICATION

CONTENTS

ANNEX-II SOIL AND LAND CLASSIFICATION

1. SOILS

1.1 General

The findings of the reconnaisance land resources survey of the Bila Irrigation Project area are presented in two preceding study reports;

(1) Reconnaissance land resources survey in the South Sulawesi area, soil map (scale: 1/500,000), 1968, Soil Research Institute, Bogor.

(2) Master Plan for the Central South Sulawesi Water Resources Development Project, Soil Map (scale: 1/50,000), 1980, Japan International Cooperation Agency, Tokyo.

The present soil study aims at identifying major soil groups and their distribution and examining the suitability of each soil group for irrigation farming on the basis of field investigation and the findings of past studies mentioned above.

Based on the agreed "Scope of Works", the survey area of the Bila Irrigation Project is defined as the flat alluvial plain of about 10,000 ha extending mainly on the left bank of the Bila river and includes a bit of land on the right bank of the river. The area is bounded with the inundation area of the Lake Tempe on the south, the Bila and Boya rivers on the west and the hilly regions on the north and the east.

The soil survey area is, however, expanded toward the northeastern hilly lands up to 20,000 ha, for there exists a considerable extent of the paddy field along the foot of the northeastern hilly lands and it is needed for determination of the project scale to assess the land resources in these areas in terms of irrigability.

The present report deals with the procedure of the field investigation, major characteristics and land capability of the soil units identified in the project area. The result of the present soil studies are summarized in the SOIL MAP (see Fig. 1.1).

1.2 Procedure of Soil Survey

The field survey was carried out over the above-mentioned area of about 20,000 ha by using the topographic maps and aerial photos scaled 1/25,000. The pre-studies on the distribution of soils were made on the basis of the aerial photo interpretation for land-forms. The information obtained through photo interpretation is fully used in the field survey. The identification and delineation of the land units were checked and adjusted through the field reconnaissance. The soil profile survey was then made on the basis of the provisional land unit map thus prepared and 50 soil pits were dug to a depth of about one meter or up to bedrock or gravel layer. Each soil profile was observed in accordance with the standards of "Guideline for Soil Profile Description" published by the Food and Agriculture Organization of the United Nations (FAO). Furthermore, more than 100 test boring observation with one meter soil auger was additionally practiced for further adjustment of provisional boundaries of each soil group.

For physico-chemical analyses in laboratory, a total of 30 soil samples were taken from the distinguishable horizons of 11 representative soil profiles in the survey area. These soil samples were analyzed at the Chemical Research Institute (BALAI PENELITIAN KIMIA), Ujung Pandang. The items of physico-chemical analyses are (1) pH (H_2O, KCl), (2) total carbon, (3) total nitrogen, (4) available phosphate, (5) cation exchange capacity (CEC), (6) exchangeable base (Ca, Mg, Na, K), (7) free iron and (8) soil particle size distribution. The results are given in Table 1.1.

1.3 Soil Classification

In the light of the morphological characteristics and the results of laboratory analysis, the soils in the study area are classified into 5 soil units, according to the FAO/UNESCO soil classification system, i.e., Eutric Fluvisols (Je), Eutric Gleysols (Ge), Eutric Regosols (Re), Plinthic Acrisols (Ap) and Ferric Acrisols (Af). Major characteristics of each soil unit are outlined as follows:

Eutric Fluvisols (Je) or Brown Alluvial Soils in the Indonesian system mainly extend over the flat alluvial plain developed in between the Bila river and eastern hilly land. These soils are developed in recent alluvial deposits and generally immature with no predominant morphological characteristics. The effective soil depth is generally deep. In general, these soils have A-(B)-C horizons with dark brown to grayish brown color. The soil texture is clay to silty clay. The soil structure varies with location, ranging from structureless massive to weakly developed fine to medium angular blocky structure. As for chemical properties, pH value of these soils shows over 6.3 throughout the profile. The cation exchange capacity is generally over 20 meq/100 g with more than 60% of the base saturation degree. Most of these soils are presently put under cultivation of rain-fed paddy. These soils have generally good agricultural potential and are often intensively used. The soils are suitable not only for rice but also for a wide range of crops. These soils occupy about 11,200 ha or 56.0% of the survey area.

Eutric Gleysols (Ge) or Grey Alluvial and Greyish Brown Alluvial Soils are the poorly drained soils in the low-lying areas and/or in depressions. These soils are formed from unconsolidated sediment materials. These soils are influenced by high groundwater tables and/or periodic stagnant water by seasonal floods and heavy rainfalls, and therefore show hydromorphic properties. These soils have a reducing condition in lower part of soil profile because of continuously saturated condition with the water. The effective soil depth is generally deep. These soils have (A)-Ag-Cg horizons with grayish color in general and the texture is generally clay to silty clay. The structure is massive. The pH value ranges from 6.2 to 7.4. The cation exchange capacity is over 25 meq/100 g. The base saturation degree averages more than 50%. These soils are generally used for growing paddy. These soils occupy 2,500 ha in total or 12.5% of the survey area.

Eutric Regosols (Re) or Brown Regosols extend along the river terraces which are found along the Bila and Kalola rivers and their tributaries. These soils are developed on the unconsolidate materials, having no diagnostic horizons other than ochric A horizon. The effective soil depth is shallow to moderately deep, depending on location. These soils have A-(B)-C horizons with brown to black colored sandy loam. The structure is generally massive. These soils are mainly used for cultivation of upland crops and perennial crops. The agricultural use of these soils varies with the availability of surface water. These soils occupy 2,500 ha in total or 12.5% of the survey area.

Plinthic Acrisols (Ap) or Brown and Redish Brown Latosols extend along the foot of the eastern hilly land. These soils have a distinct argillic B horizon with plinthite within 100 cm from the ground surface. The effective soil depth is generally shallow. These soils have A-Bg-Bt-C horizons with dark greyish brown to dark yellowish brown colored sandy loam. The soil structure ranges structureless massive to weakly developed fine angular blocky. The pH value shows less than 6.0. The cation exchange capacity is around 15 meq/100 g with less than 50% of base saturation degree. These soils are mainly used for perennial crops. These soils occupy 900 ha in total or 4.5% of the survey area.

Ferric Acrisols (Af) or Yellowish Red Podozolic Soils extend over the eastern hilly land. These soils have an ochric A horizon and argillic B horizon. The effective soil depth is generally shallow. These soils have A-Bt-C horizons with brown to reddish brown color. The soil texture is sandy loam to clay loam with varied soil structure from structureless massive to weakly developed fine angular blocky. The pH value shows less than 5.0. The cation exchange capacity of the surface soil is generally low, showing less than 7 meq/100 g. The land cover of these soils are mainly recognized as grass land. Although these soils are partly used for growing various crops, yields are generally low. These soils occupy 2,900 ha in total or 14.5% of the survey area.

The typical soil profile of these soil unit are shown in Table 1.2.

2. LAND CAPABILITY

2.1 General

Three major land classification systems have been applied for the water resources development projects in Indonesia. They are:

(1) USDA land capability classification system 1/

(2) USBR land classification system 2/

(3) FAO land suitability classification system 3/

The USDA system is most widely used, but it does not meet the particular requirement for irrigation project. It is mainly used for rainfed agriculture in general. The USBR system was devised originally for irrigated land use. However, the basic concept of the USBR system is generally to assess the lands under arid claimate and/or to assess land productivity for dry field crops like wheat, barley, cotton, etc. Some modification of this system is required under Indonesian condition due to the different requirements for irrigated paddy cultivation under humid climate. Although several approaches to the modification have been made by various study groups, none of them has been fully authorized at present. The FAO system is more flexible than US ones and can be applied to the full range of environments. It is the system that the Soil Research Institute, Bogor, recommends for use in Indonesia. This system is, however, still under development and does not serve the detailed criteria for suitability assessment on the irrigated paddy cultivation.

Considering all these, it is conceived that the Japanese land classification standard 4/ for paddy can be applied to the feasibility study on the Bila Irrigation Project. The Japanese system is devised originally for paddy cultivation and its classification criteria are detailed enough for land capability assessment on a feasibility study level. In the Japanese system, lands are classified into 4 capability classes, i.e., I, II, III and IV. Each class is defined as follows:

(1) Class I: Land has almost no limitation for crop production and/or no risk of soil conservation. It is naturally fertile and has a great potential for crop production without any improvement practices of soils.

(2) Class II: Land has some limitations for crop production and/or some risks of soil conservation, and requires some soil improvement practices for normal crop production.

1/: Land Capability Classification, Agricultural Handbook No. 210, 1961, Soil Conservation Services, USDA

2/: Bureau of Reclamation Manual Vol. 5 Irrigated Land Use, Part 2: Land Classification, 1953, USBR

3/: A Framework for Land Evaluation, 1976, FAO

4/: Outline of Land Classification based on Soil Survey in Japan, 1977, National Institute of Agricultural Science, Tokyo

(3) Class III: Land has many limitations for crop production and/or is likely subject to risks of soil conservation, and fairly intensive improvement practices are required.

(4) Class IV: Land has great natural limitations than these in Class III, but can be utilized for cultivation of some specific crops under very careful management.

In the USDA system, lands are classified into 8 classes and the lower 4 classes from V to VIII are ranked as "not suitable for agricultural production". The USBR system has 6 classes, I to III being arable, IV being suitable only for special uses and VI non arable. Class V is reserved for undecided suitability, but in practice this class is often omitted. The Japanese system, 4 class classification of arable land, is, therefore, correlative with these US systems.

The FAO system for land suitability classification is used for assessment of lands in terms of their relative suitability for a specific type of use. The Bila Irrigation Project aims at increasing rice production under irrigated condition and the land use type envisaged is double cropping of paddy as described in ANNEX-V. In the FAO system, the land suitability classes for each specific utilization type reflect degrees of suitability or of limitation, i.e., S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), N1 (currently not suitable, having limitations which are considered unsurmountable with existing knowledge at currently acceptable cost) and N2 (permanently unsuitable). It is considered that the suitability classes from S1 to N1 nearly correspond to 4 classes described in the Japanese system.

In view of above consideration, the Japanese system seems to be most suitable for land capability classification for paddy fields due to its detailed specification and 4 class rating which can be correlative with other systems.

2.2 Specification of Land Capability Classification

In the Japanese system, there are 13 factors for assessment of land capability as shown below:

(1) thickness of top soil
(2) effective soil depth
(3) gravel content in top soil
(4) easiness of plowing
(5) permeability under submerged condition
(6) state of redox potentiality
(7) wetness of land 1/
(8) inherent fertility
(9) content of available nutrient

1/: factors for upland crops only

(10) degree of hazard
(11) frequency of hazard
(12) slope 1/
(13) erosion

The specification of land capability class are explained as follows:

(1) Thickness of top soil (code: t)

Top soil is the first horizon where plant roots can easily penetrate, and generally corresponds to the plowed layer. The classes are grouped according to the thickness of top soils as follows (when effective depth of soil (d) is placed to class IV, this factor also is placed to class IV):

t	Class		
	Paddy	Upland	Orchard
(cm)			
25	I	I	I
25 - 15	I	II	I
15	II	III	III

(2) Effective depth of soil (code: d)

Effective depth of soil is the depth up to bedrock, hard pan and gravel layer which plant roots can not penetrate. The classes are grouped according to thickness of the effective soil depth as follows:

d	Class		
	Paddy	Upland	Orchard
(cm)			
100	I	I	I
100 - 50	I	II	II
50 - 25	II	III	III
25 - 15	III	III	IV
15	IV	IV	IV

(3) Gravel content in top soil (code: g)

Gravel contents in top soil are expressed by the percentage of the exposed surface area of gravel on the soil profile, and graded into the following classes:

1/: factors for upland crops only

g	Class		
	Paddy	Upland	Orchard
(%)			
5	I	I	I
5 - 10	I	II	I
10 - 20	I	II - III	I - II
20 - 50	I - II	III - IV	II - III
50	IV	IV	IV

(4) Easiness of plowing (code: p)

Easiness of plowing largely depends upon the quantity and quality of clay and organic matter and moisture condition. In order to estimate the class of this factor, the following 4 sub-factors are used:

(a) Soil texure of top soil;

	content of clay	content of sand
1. coarse :	less than 15%	more than 85%
2. medium :	less than 15%	less than 85%
3. fine :	15 - 25%	-
4. very fine:	more than 25%	-

(b) Stickness of top soil;

1. none and/or slightly sticky
2. sticky
3. very sticky

(c) Consistence when dry;

1. lose
2. hard
3. very hard

These sub-factors are combined together to determine capability classes as follows:

Sub-factors			Class	Criteria
a	b	c		
1	1	(2)	I	Easy to slightly difficult
2	2	2	I	
2	2	2	I	
2	2	3	II	Moderately difficult
3	3	3	II	
2	2	3	III	Very difficult
3	3	3	III	

(5) Permeability under submerged condition (code: l)

This factor affects irrigation water requirement, soil temperature, and leaching of the nutrients or development of reduced condition of the soil. This standard factor is evaluated mainly by the combination of soil texture and the presence of compact layer within 50 cm of the surface, as sub-factors:

(a) Soil texure;

	content of clay	content of sand
1. very fine:	more than 25%	-
2. fine :	25 - 15%	-
3. medium :	less than 15%	less than 85%
4. coarse :	less than 15%	more than 85%

(b) Compactness;

1. compact : more than 14.0 kg/cm² by hardness matter
2. medium : 14.0 - 1.4 kg/cm² by hardness matter
3. loose : less than 1.4 kg/cm² by hardness matter

Sub-factors		Class	Criteria
a	b	Paddy	
1	1	I	Poorly to imperfectly permeable
1	2	I	
2	2	II	Moderately to well permeable
3	2	II	
3	3	III	Well to excessively permeable

(6) State of redox potentiality (code: r)

This factor indicates the risk of root damage owing the strong reduction of soil, resulting in low rice production. The following sub-factors are used for the evaluation of this factor.

(a) Content of easily decomposable organic matter in top soil;

1. low : less than 10 mg NH_4-N/100 g
2. medium : 10 - 20 mg NH_4-N/100 g
3. high : more than 20 mg NH_4-N/100 g

(b) Content of free iron oxides in top soil;

1. high : more than 1.5% for dry soil
2. medium : 1.5 - 0.8%
3. low : less than 0.8%

(c) Degree of gleyzation;

1. weak : no gley horizon within 50 cm from the surface
2. medium : gley horizon exist within 50 cm
3. strong : gley horizon exist throughout profile or exist below plowing layer

Sub-factors			Class	Criteria (Risk of root damage)
a	b	c		
1	1	2	I	
1	3	2	I	None to weak
2	1	2	I	
1	1-2	3	II	
1	3	3	II	Moderate to strong
2	1-2	3	II	
3	1	2	II	
2	3	3	III	
3	2	2	III	Very strong
3	1	3	III	
3	3	2	III	

(7) Wetness of land (code: w; wet condition, (w); dry condition)

This factor is only applied to upland and orchard. This factor is used for the estimation of wet or drought injury of upland crops and trees, and is evaluated by the combination of the following 3 sub-factors:

(a) Permeability;

1. high
2. medium
3. low

(b) Water holding capacity (evaluated by maximum water-holding capacity);

1. high : more than 80
2. medium : 80 - 40
3. low : less than 40

(c) Moisture condition;

(2). dry
1. slightly moist
2. moist
3. wet

Sub-factors a	b	c	Class	Criteria (Risk of drought or wetness)
1	3	(2)	(IV)	High possibility of drought
1	3	1	(III)	Possibility of drought
1	2	1	(II)	Low possibility of drought
1	1	1	I	None
2	2	2	II	Low possibility of overwetness
1-3	1	3	III	Possibility of overwetness
3	2	3	IV	High possibility of overwetness

(8) Inherent fertility (code: f)

Inherent fertility is evaluated by the combination of the following 3 sub-factors:

(a) Nutrient holding capacity (evaluated by CEC);

1. high : more than 20 me/100 g
2. medium : 20 - 6 me/100 g
3. low : less than 6 me/100 g

(b) Nutrient fixation power (evaluated by coefficient of P_2O_5 absorption);

1. very low : less than 700
2. low : 700 - 1,500
3. medium : 1,500 - 2,000
4. high : more than 2,000

(c) Base status in soil (evaluated by base saturation degree);

1. good : more than 50%
2. medium : 50 - 30%
3. poor : less than 30%

(i) For paddy

Sub-factors a	b	c	Class	Criteria
1	1-2	2	I	Fertile
2	1-2	1	I	
1	1-2	3	II	
1	3-4	2	II	Medium
2	1-2	2	II	
3	1	2	II	
2	3-4	3	III	
3	2	2	III	Infertile
3	3-4	3	III	

(ii) For upland and orchard

Sub-factors			Class	Criteria
a	b	c		
1	2	1	I	Fertile
2	1	2	I	
1	2	3	II	
2	1	3	II	Medium
1	3	1	II	
1	3	2	II	
1	3	3	III	
3	1	1	III	Infertile
2	4	2	II - III	

(9) Content of available nutrients (code: n)

Content of available nutrients in soil are closely related to the inherent soil fertility, and are evidently influenced by cultivation practices. The value of the class is evaluated by the combination of the following sub-factors:

(a) Content of exchangeable calcium;

1. high : more than 200 CaO mg/100 g
2. medium : 200 - 100 CaO mg/100 g
3. low : less than 100 CaO mg/100 g

(b) Content of exchangeable magnesium;

1. high : more than 25 MgO mg/100 g
2. medium : 25 - 10 MgO mg/100 g
3. low : less than 10 MgO mg/100 g

(c) Content of available potassium;

1. high : more than 15 K_2O mg/100 g
2. medium : 15 - 8 K_2O mg/100 g
3. low : less than 8 K_2O mg/100 g

(d) Content of available phosphate;

1. high : ore than 10 P_2O_5 mg/100 g
2. medium : 10 - 2 P_2O_5 mg/100 g
3. low : less than 2 P_2O_5 mg/100 g

(e) Content of available nitrogen;

1. high : more than 20 N mg/100 g
2. medium : 20 - 10 N mg/100 g
3. low : less than 10 N mg/100 g

(f) Content of available silica;

1. high : more than 15 SiO_2 mg/100 g
2. medium : 15 - 5 SiO_2 mg/100 g
3. low : less than 5 SiO_2 mg/100 g

(g) Content of micro-elements (evaluated by the risk of deficiency);

1. none and/or weak
2. medium
3. serious

(h) Acidity (evaluated by pH);

Paddy	Upland & Orchard		
1.	1.	weak	: more than 6.0
2.	2.	midium	: 6.0 - 5.0
3.	3.	strong	: 5.0 - 4.5
3.	4.	very strong	: less than 4.5

Class	Criteria
I	High
II	Medium
III	Low

(10) Degree of hazard (code: i)

This factor means limitation caused by the presence in excess of substances such as sulphur compounds, soluble salts, heavy metals, etc. Dependent sub-factors for this factor are as follows:

(a) Presence of harmful substances;

(i) Harmful sulfphur compounds:

1. none
2. slightly
3. moderately
4. seriously

(ii) Salts content (evaluated by chlorine content as an indicator):

1. low : less than 0.1% for dry soil
2. medium: 0.1 - 0.3%
3. high : more than 0.3%

(iii) Heavy metals:

1. none
2. slightly
3. moderately
4. seriously

(iv) Irrigation water quality:

		Temp. (°C)	pH	Total N (ppm)	Salts content (ppm)
1.	good	20	6.0-7.5	1.0	500
2.	medium	20-15	4.0-6.0 or 7.5-8.5	1.0-5.0	500-2,000
3-4.	polluted	15	4.0 or 8.5	5.0	2,000

(b) Physical hazard;

Presence of bedrock, pan, compact layer or gravel layer that disturb root development within 50 cm of the surface, and difficulty of their removal:

1. none
2. slightly difficult
3. very difficult

The class of this factor is decided by the lowest grade among the dependent sub-factors.

Class	Criteria
I	None
II	Slightly
III	Moderately
IV	Seriously

(ii) Frequency of hazard (code: a)

This factor is mainly influenced by natural environmental condition. The class of this factor is determined by the combination of the following two dependent sub-factors:

(a) Risk of overhead flooding inundation;

1. none and/or rarely: no risk if rainfall with high intensity occurs

2. moderately: even if inundation occurs due to high rainfall intensity, excess water is drained out in a short period

3. frequently: inundation continuous for a long period if rainfall with high intensity occurs

(b) <u>Risk of land creep:</u>

1. none and/or rarely

2. moderately

3. frequently

The class of this factor is determined by the lowest grade of two dependent sub-factors.

Class	Criteria
I	None to rarely
II	Moderately
III	Frequently

(12) <u>Slope</u> (code: s)

This factor is applied to upland and orchard only. The class of this factor is decided by the combination of the following sub-factors:

(a) Natural slope as a main dependent sub-factors: 5 grades as shown in the following table.

(b) Direction of slope.

(c) Artificial slope.

Steepness of Slope (°)	Class	
	Upland	Orchard
3	I	I
3 - 8	II	I - II
8 - 15	III	I - III
15 - 25	IV	II - III
25	IV	IV

(13) Erosion (code: e)

The class of this factor is determined by the combination of the following sub-factors:

(a) Occurrence of rill or gully;

	Occurrence of rill	Occurrence of gully
1. none :	none	none
2. rarely :	rarely	none
3. moderately:	sometimes	none
4. frequently:	frequently	exsist

(b) Resisting power to water erosion;

1. strong
2. medium
3. weak

(c) Resisting power to wind erosion;

1. strong
2. medium
3. weak

Class	Criteria
I	None or very slightly
II	Slightlyy
III	Seriously
IV	Very seriously

The specification of land capability class are summarised in Table 2.1.

2.3 Land Capability

The land is evaluated by using the assessment factors mentioned above. The land capability class is determined at the lowest class of the factors, as shown in the following example.

	Factor	Code	Paddy	Upland
1.	thickness of top soil	t	I	III
2.	effective soil depth	d	I	I
3.	gravel content in top soil	g	I	I
4.	easiness of plowing	p	II (3,3,2)	II (2,2,2)
5.	permeability under submerged condition	l	II (1,3)	-
6.	State of redox potentiality	r	II (2,1,3)	-
7.	wetness of land	w	-	IV (3,1,3)
8.	inherent fertility	f	I (1,2,2)	III (1,2,3)
9.	content of available nutrient	n	II (2,1,1, 1,2,2,2,2)	III (3,3,3, 3,3,3)
10.	degree of hazard	i	I (1,1)	I (1,1)
11.	frequency of hazard	a	I (1,1)	I (1,1)
12.	Slope	s	-	I (1,S,1)
13.	erosion	e	-	I (1,1,1)

(1) Simplified:	Paddy ;	IIplrn
	Upland;	IVw IIItfn IIp
(2) Land capability class:	Paddy;	IIplrn
	Upland;	IVw

Based on the specifications of the Japanese land capability classification system, the soils and the lands in the survey area are classified into 4 classes for paddy as shown below:

Soil Unit	Land Capability	Survey Area (ha)	Proportional Extent (%)
Eutric Fluvisols (Fe)	I	5,900	29.5
	IIa	3,000	15.0
	IIIa	700	3.5
	IIIe	1,600	8.0
Eutric Gleysols (Ge)	IIg	1,500	7.5
	IIga	800	4.0
	IIIa	200	1.0
Eutric Regosols (Re)	IIIl	2,500	12.5
Plinthic Acrisols (Ap)	IIItdf	900	4.5
Ferric Acrisols (Af)	IVd	2,900	14.5
Total		20,000	100.0

Capability Class	Survey Area (ha)	Project Area (ha)	Proportional Extent (%)
I	5,900	5,900	52.7
IIa	3,000	3,000	26.8
IIg	1,500	1,500	13.4
IIga	800	800	7.1
Sub-total	11,200	11,200	100.0
IIIa	1,600	-	-
IIIle	900	-	-
IIIl	2,500	-	-
IIItdf	900	-	-
IVd	2,900	-	-
Total	20,000	11,200	100.0

The LAND CAPABILITY MAP is shown in Fig. 2.1.

Table 1.1 Results of Soil Analysis

Sample No.	pH H_2O	pH KCl	Total Carbon (%)	Total Nitrogen (%)	Available Phosphate (ppm)	Cation Exchange Capacity (me/100gr)	Exchangeable Base Ca (%)	Exchangeable Base Mg (%)	Exchangeable Base Na (ppm)	Exchangeable Base K (ppm)	Free Iron (%)	Soil Particle Size Distribution Clay (%)	Slit (%)	Sand (%)	Gravel (%)
1. Eutric Fluvisols															
21/1	6.9	4.9	0.99	0.09	3.55	19.64	0.15	0.13	32.93	38.41	2.49	45.96	40.04	10.99	3.01
21/2	6.3	4.6	0.63	0.06	2.96	27.90	0.26	0.22	36.14	45.17	2.00	48.26	47.83	2.09	1.82
21/3	6.9	4.9	0.71	0.05	10.05	30.85	0.33	0.24	34.62	47.60	2.29	63.74	34.74	1.85	-
21/4	6.2	5.2	0.46	0.07	11.56	31.14	0.28	0.20	39.59	45.41	1.72	48.81	44.85	6.34	-
23/1	6.3	5.4	0.71	0.06	7.03	35.84	0.69	0.14	94.06	68.53	1.56	46.41	51.86	1.73	-
23/2	6.4	5.6	0.64	0.06	9.47	45.19	0.69	0.16	74.66	58.24	1.53	54.88	43.07	2.05	-
25/1	6.3	5.7	0.73	0.08	9.33	46.88	0.70	0.17	87.59	76.15	1.74	61.51	36.85	1.64	-
25/2	6.6	5.8	0.60	0.05	10.59	41.35	0.67	0.17	78.51	78.51	1.69	74.57	18.67	6.76	-
25/3	6.6	5.5	0.36	0.09	5.12	37.92	0.61	0.14	77.82	41.69	1.79	36.74	54.67	8.59	-
2. Eutric Gleysols															
12/1	6.2	4.3	0.97	0.09	8.53	32.70	0.34	0.20	49.68	121.10	1.56	59.37	36.25	4.38	-
12/2	6.0	4.8	0.64	0.06	4.98	38.72	0.47	0.22	70.86	69.08	1.16	69.08	23.68	6.84	0.40
12/3	6.2	5.3	0.35	0.07	4.23	40.11	0.48	0.29	97.80	47.90	1.35	61.80	32.65	5.29	0.26
14/1	6.9	5.6	0.51	0.05	9.33	36.03	0.49	0.17	67.25	48.42	0.29	42.24	33.21	23.97	0.58
14/2	7.2	5.7	0.33	0.04	6.46	28.37	0.51	0.17	80.09	23.79	1.32	33.03	32.91	31.63	2.43
14/3	7.4	6.2	0.16	0.03	5.90	30.76	0.65	0.16	88.63	31.02	1.47	27.26	32.25	32.10	8.39
3. Eutric Regosols															
32/1	5.9	4.6	0.89	0.07	9.01	40.08	0.41	0.22	36.78	59.77	1.55	2.03	29.52	68.45	-
32/2	6.2	4.9	0.48	0.04	10.33	43.43	0.44	0.23	44.54	59.39	1.26	6.60	42.65	50.24	0.51
34/1	5.7	5.3	1.01	0.15	11.34	16.57	0.25	0.11	30.82	288.92	0.99	15.57	16.15	67.27	1.01
34/2	6.0	5.0	0.59	0.06	5.81	22.66	0.26	0.13	27.05	132.80	1.42	17.80	17.18	65.02	-
4. Plinthic Acrisols															
22/1	4.9	3.9	0.62	0.07	3.83	15.31	0.13	0.06	47.45	65.70	0.30	19.02	45.11	25.63	10.24
22/2	5.4	4.0	0.23	0.05	10.56	15.92	0.12	0.04	29.90	31.39	0.55	21.86	31.81	28.96	17.37
22/3	5.3	4.0	0.16	0.03	4.61	16.33	0.12	0.04	32.60	52.40	0.74	24.54	15.64	8.24	51.58
30/1	5.6	4.3	0.20	0.05	7.15	13.86	0.12	0.02	24.26	18.19	1.36	10.53	21.64	48.11	19.72
30/2	5.5	4.2	0.40	0.05	3.61	10.18	0.03	0.09	127.88	31.97	1.31	35.29	28.65	25.64	10.42
30/3	5.8	4.6	0.38	0.04	12.02	18.28	0.03	0.20	286.30	39.32	1.06	53.87	30.07	11.87	4.19
5. Ferric Acrisols															
6/1	4.7	3.4	0.73	0.06	3.59	3.16	0.04	0.07	37.38	39.25	0.75	23.50	25.10	45.83	5.57
6/2	4.8	3.7	0.34	0.04	3.05	7.61	0.09	0.10	21.60	56.71	0.64	20.79	36.96	40.82	1.43
28/1	4.5	3.8	1.08	0.08	4.05	6.88	0.03	0.02	12.42	32.60	0.85	19.63	28.59	22.92	28.86
28/2	4.5	3.9	0.63	0.05	7.41	8.25	0.01	0.03	3.59	10.78	1.28	27.31	33.30	22.32	17.07
28/3	4.8	4.0	0.23	0.05	2.31	6.29	0.03	0.01	11.07	19.92	0.52	29.14	26.71	13.32	30.88

Table 1.2 Soil Profile Description (1/5)

1. Profile Number	21
2. Soil Classification	Eutric Fluvisols
3. Date of Examination	September 9, 1981
4. Location	Callacu, Desa Kalola
5. Land Form	Alluvial plain
6. Slope	Flat
7. Vegetation or Land Use	Paddy field
8. Drainage Condition	Well drained

9. Profile Description

Ap	0 - 10	Gray (5Y5/1) moist; silty clay; weak fine angular blocky; few medium bright reddish brown (5YR5/8) mottles; sticky and plastic; fine roots; clear smooth boundary; pH 6.9 (H_2O)
Apg	10 - 25	Grayish yellow brown (10YR4/2) moist; silty clay; weak fine angular blocky; common medium bright reddish brown (5YR5/8) mottles; sticky and plastic; fine roots; clear smooth boundary; pH 6.3 (H_2O)
Cg_1	25 - 60	Grayish yellow brown (10YR5/2) moist; clay; weak medium angular blocky; sticky and plastic; clear smooth boundary; pH 6.9 (H_2O)
Cg_2	60 - 100(+)	Dark grayish yellow (2.5Y4/2) moist; silty clay; moderate medium angular blocky; common medium bright reddish brown (5YR5/8) mottles; sticky and plastic; pH 6.2 (H_2O)

Table 1.2 Soil Profile Description (2/5)

1.	Profile Number	12
2.	Soil Classification	Eutric Gleysols
3.	Date of Examination	August 26, 1981
4.	Location	Lompo Palia, Desa Anabanua
5.	Land Form	Alluvial plain
6.	Slope	Flat
7.	Vegetation or Land Use	Paddy field
8.	Drainage Condition	Poorly drained

9. Profile Description

Apg	0 - 10	Dark reddish gray (2.5YR3/1) moist; clay; structureless massive; few fine bright reddish brown (5YR5/8) mottles; sticky and plastic; fine roots; clear smooth boundary; pH 6.2 (H_2O)
Cg_1	10 - 45	Brownish black (10YR3/1) moist; clay; structureless massive; few fine reddish brown (5YR4/6) mottles; sticky and plastic; fine roots; clear smooth boundary; pH 6.0 (H_2O)
Cg_2	45 - 100(+)	Olive brown (2.5Y4/3) moist; clay; strucreless massive; few fine bright reddish brown (5YR5/8) mottles; sticky and plastic; pH 6.2 (H_2O)

Table 1.2 Soil Profile Description (3/5)

1.	Profile Number	34
2.	Soil Classification	Eutric Regosols
3.	Date of Examination	October 3, 1981
4.	Location	Jonkang, Desa Anabanua
5.	Land Form	Natural levee
6.	Slope	Flat
7.	Vegetation or Land Use	Perennial crops (coconuts)
8.	Drainage Condition	Well drained

9. Profile Description

A	0 - 25	Brownish black (10YR3/1) moist; sandy loam; structureless massive; slightly sticky and slightly plastic; few medium roots; clear smooth boundary; pH 5.7 (H_2O)
C	25 - 100(+)	Dark brown (10YR3/3) moist; sandy loam; structureless massive; slightly sticky and slightly plastic; pH 6.0 (H_2O)

Table 1.2 Soil Profile Description (4/5)

1.	Profile Number	30
2.	Soil Classification	Plinthic Acrisols
3.	Date of Examination	October 1, 1981
4.	Location	Lakadaan, Desa Anabanua
5.	Land Form	Undulating
6.	Slope	Gently sloping
7.	Vegetation or Land Use	Grass land
8.	Drainage Condition	Well drained

9. Profile Description

A	0 - 35	Dull yellow orange (10YR6/3) moist; sandy loam; weak fine angular blocky; slightly sticky and slightly plastic; few fine roots; clear smooth boundary; pH 5.6 (H_2O)
Bg_1	35 - 50	Grayish yellow brown (10YR5/2) moist; clay loam; weak fine angular blocky common medium faint red (7.5R4/8) mottles; sticky and plastic; clear smooth boundary; pH 5.5 (H_2O)
Bt_2	50 - 100(+)	Dull yellowish brown (10YR5/4) moist; clay; structureless massive; sticky and plastic; pH 5.8 (H_2O)

Table 1.2 Soil Profile Description (5/5)

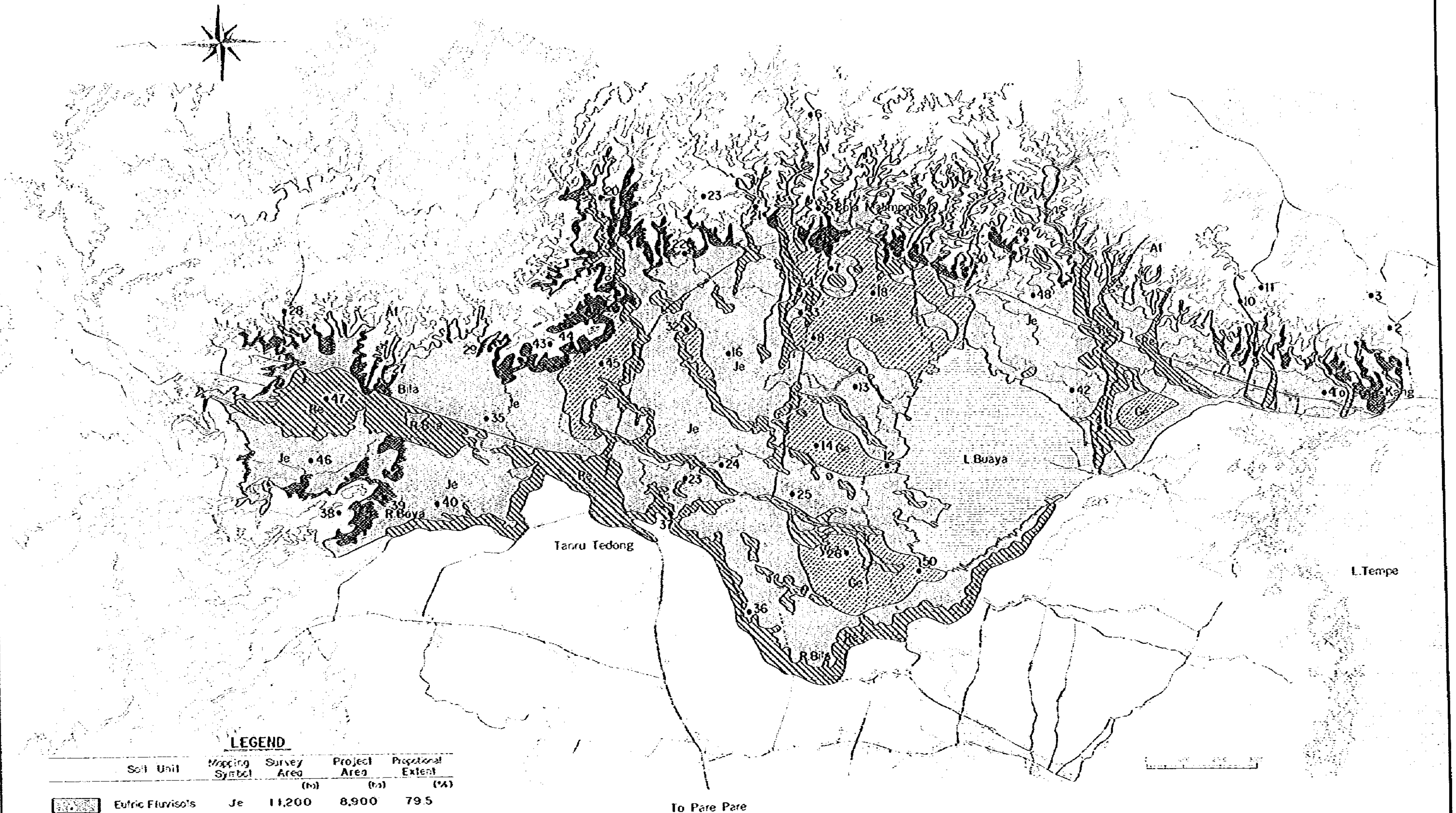
1.	Profile Number	28
2.	Soil Classification	Ferric Acrisols
3.	Date of Examination	October 1, 1981
4.	Location	Jampai, Desa Bila
5.	Land Form	Hilly land
6.	Slope	Sloping
7.	Vegetation or Land Use	Grass land
8.	Drainage Condition	Well drained

9. Profile Description

A	0 - 10	Dull reddish brown (5YR4/4) moist; sandy loam; weak fine angular blocky; slightly sticky and slightly plastic;few fine roots; clear smooth boundary; pH 4.5 (H_2O)
B_1	10 - 55	Bright brown (7.5YR5/8) moist; clay loam; structureless massive; sticky and plastic; clear smooth boundary; pH 4.5 (H_2O)
Bt_2	55 - 100(+)	Reddish brown (2.5YR4/8) moist; clay loam; structureless massive; sticky and plastic; pH 4.8 (H_2O)

Table 2.1 Summary of Land Classification

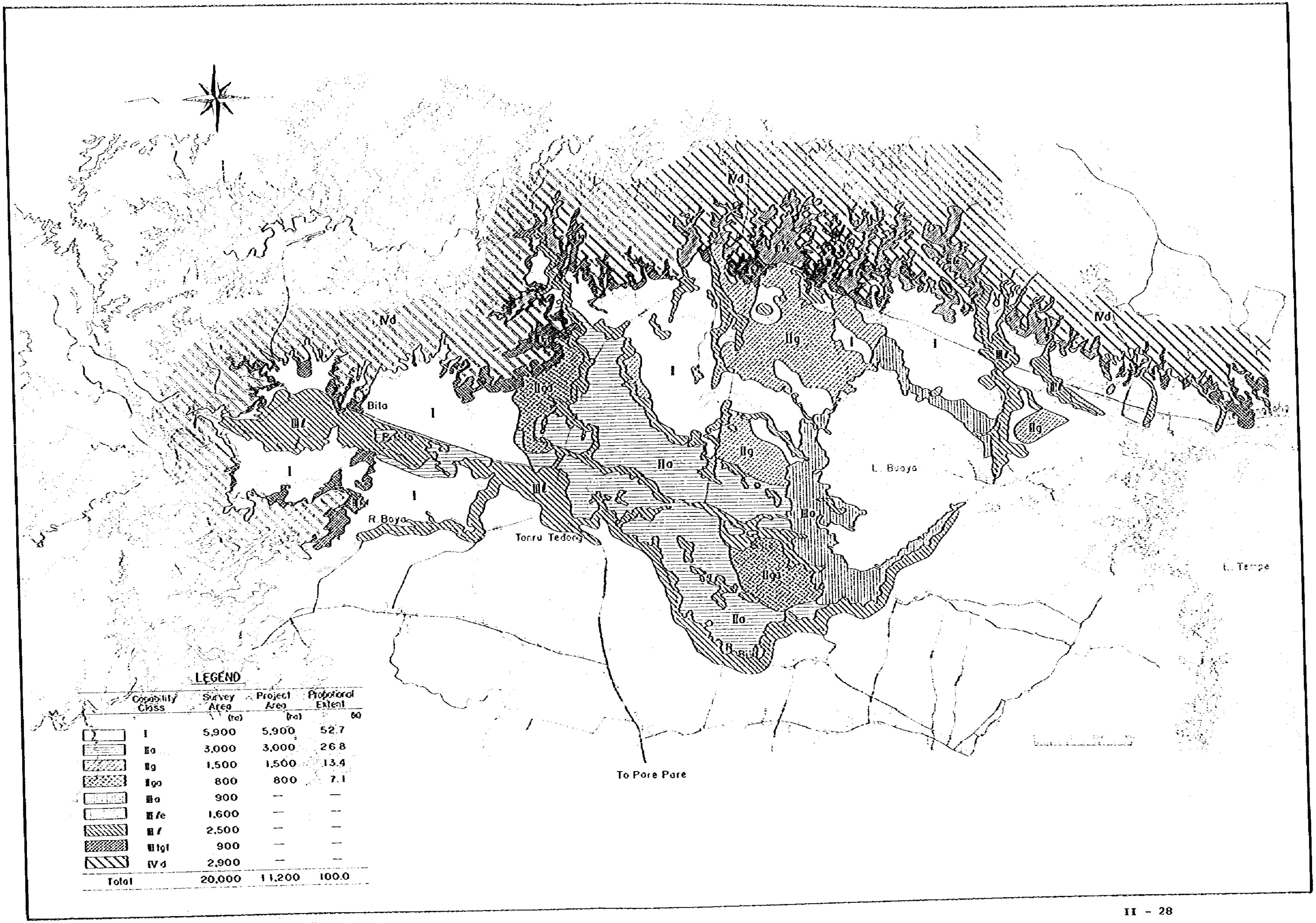
Item	Code	Class I Paddy	Class I Upland	Class I Orchard	Class II Paddy	Class II Upland	Class II Orchard	Class III Paddy	Class III Upland	Class III Orchard	Class IV Paddy	Class IV Upland	Class IV Orchard
1. Thickness of top soil	t	> 15 cm	> 25 cm	> 15 cm	< 15 cm	25 - 15 cm	-	-	< 15 cm		-	-	-
2. Effective depth of soil	d	> 50 cm	> 100 cm		50 - 25 cm	100 - 50 cm		25 - 15 cm	50 - 15 cm	50 - 25 cm	< 15 cm		< 25 cm
3. Gravel content in top soil	g	< 20 %	< 5 %	< 10 %	20 - 50 %	5 - 20 %	10 - 50 %	-	10 - 50 %	20 - 50 %	> 50 %	> 20 %	> 50 %
4. Easiness of plowing	p		Easy to slightly difficult			Moderately difficult			Very difficult		-	-	-
5. Permeability under submerged condition	l	Poorly to imperfectly permeable	-	-	Moderately to well permeable	-	-	Well to excessively permeable	-	-	-	-	-
6. State of redox potentiality (Risk of root damage)	r	None to weak	-	-	Moderate to strong	-	-	Very strong	-	-	-	-	-
7. Wetness of land (Risk of drought or wetness)	Wet: W Dry: (W)	- -	None None		- -	Low possibility of over wetness Low possibility of drought		- -	Possibility of over wetness Possibility of of drought		- -	High possibility of over wetness High possibility of drought	
8. Inherent fertility	f		Fertile			Medium			Infertile		-	-	-
9. Content of available nutrients	n		High			Medium			Low		-	-	-
10. Degree of hazard	i		None			Slightly			Moderately			Seriously	
11. Frequency of hazard	a		None to rarely			Moderately			Frequently		-	-	-
12. Slope	s	-	< 3°	< 15°	-	3 - 8°	8 - 25°	-	8 - 15°	15 - 25°	-	> 15°	> 25°
13. Erosion	e		None or very slightly			Slightly			Seriously			Very seriously	



LEGEND

	Soil Unit	Mapping Symbol	Survey Area (ha)	Project Area (ha)	Proportional Extent (%)
	Eutric Fluvisols	Je	11,200	8,900	79.5
	Eutric Gleysols	Ge	2,500	2,300	20.5
	Eutric Regosols	Re	2,500	—	—
	Plinthic Acrisols	Ap	900	—	—
	Ferric Acrisols	Af	2,900	—	—
Total			20,000	11,200	100.0

Fig. 1.1 SOIL MAP



LEGEND

	Capability Class	Survey Area (ha)	Project Area (ha)	Proportional Extent (%)
	I	5,900	5,900	52.7
	IIa	3,000	3,000	26.8
	IIg	1,500	1,500	13.4
	IIga	800	800	7.1
	IIIa	900	—	—
	IIIℓe	1,600	—	—
	IIIℓ	2,500	—	—
	IIItgl	900	—	—
	IVd	2,900	—	—
Total		20,000	11,200	100.0

Fig. 2.1 LAND CAPABILITY MAP

ANNEX - III

GEOLOGY

ANNEX-III GEOLOGY

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ANNEX-III GEOLOGY

1. INTRODUCTION

1.1 Purpose

Geological explorations at the Bila intake weir site and the Kalola damsite were carried out to make investigation into the adequacy of the sites and to provide coefficient information for preparation of reliable designs and cost estimate.

There are two alternative sites for constructing an intake weir in the Bila river. One is the site proposed by DOI, at which the investigation and the detailed design of a weir have been completed. The other is the site proposed in the Master Plan, which is located about 1 km upstream from the former. The geological information for the DOI site was obtained from the results of the past investigation, supplemented by the surface exploration. The core drilling for the Bila intake site was carried out at the Master Plan. The geological information at the DOI site is referred to the following reports:

(1) PENYELIDIKAN GEOLOGI TEKNIK DAM MEKANIKA TANAH RENCANA BENDUNG BILA DI PROP. SULAWESI SELATAN (P.T. TRICON, 1976)

(2) PENYELIDIKAN GEOLOGI TEKNIK DAM MEKANIKA TANAH RENCANA TANGGUL PENUTUP BENDUNG BILA, SALURAN INDUK DAN BANGUNAN-BANGUNANNYA DARI BBO S/D. BBKR. 17 D.I. BILA PROP. SULAWESI SELATAN (P.T.TRICON, 1978)

This report contains the results of the geological investigation of the Master Plan site of the Bila intake weir and the Kalola damsite, and the summary of the geological investigation of the DOI site of the Bila intake weir.

1.2 Method of Investigation

(1) Equipment

The equipment used for the drilling and the tests are the following:

(a) Drilling rig ; Rotary drilling machine with a capacity of 50 m in depth, with 76 mm and 66 mm diameter of metal crown

(b) Drilling pump ; Reciprocating piston type with discharge capacity of 60 lit/min and capable pressure of 15 kg/cm^2

(c) Packer ; Pneumatically expanding type rubber packer

(d) Penetration test; Raymond sampler and 63.5 kg drive hammer equipment

(2) Core drilling

Diameter of the drilling hole is 66 mm to 76 mm. All core samples taken at every depth of drill hole are kept in order in wooden cases which are marked with the depth of core recovery at every one meter interval and hole numbers. Samll wooden plate partition is placed at the position of depth where core barrel is recovered.

During drilling the following matters are recorded.

(a) Hole number, date of operation and diameter of hole,

(b) Groundwater table in the hole,

(c) Depth of drilling, progress of drilling and length of recovered core samples for each recovery of core barrel, and time for each progress of drilling,

(d) Change in quantity of return water from the hole, and

(e) Description of judgement on subsurface conditions, especially about boundary of each stratum.

According to the recovery of core barrel, rock quality designation, RQD, is calculated by the following:

$$RQD = \frac{\text{Total length of more than 10 cm core}}{\text{100 cm}} \times 100\%$$

(3) Standard penetration tests

The tests were made in drill holes by counting the number of blows of a drop humner with 63.5 kg of weight falling from 75 cm of height that was necessary to make a standard Raymond sampler penetrate 30 cm into the layer.

(4) Field permeability tests

The tests were performed in drill holes by every 3 to 5 m stage as a rule, by means of Lugeon test (pumping water injection method) and constant water head method (gravity pressure injection method). The pumping pressure for Lugeon test was changed by step, such as 0, 1, 2, 3, 2, 1 and 0 kg/cm^2 and the rate of leakage (injection rate) was observed for 10 minutes for every step of pressure.

The calculations of the coefficient of permeability and Lugeon unit were made by the following equations.

$$k = \frac{2.3\,Q}{2 \times 60\ L\,H} \log \frac{L}{r} \qquad Lu = \frac{10^2\,Q}{LH}$$

where: k ; Coefficient of permeability (cm/sec)
Lu; Lugeon unit
r ; Radius of bore holes (cm)
L ; Length of test section (cm)
Q ; Water injection rate (cm^3/min)
H ; Total water head (cm)

(5) Test pits

The test pits were excavated for the purpose of observation of geological condition of terrace, talus and highly weathered bedrock.

1.3 Items of Investigation

The following items and quantities of geological investigation were conducted by the Team:

(1) Alternative Bila intake site (Master Plan Site)

(a) Geological reconnaissance in the site with the map of 1/1,000.

(b) Drilling, standard penetration test and permeability test.

Hole No.	Depth (m)	Standard penetration test (nos.)	Permeability test (nos.)
BB 1	30	3	7
BB 2	25	-	6
BB 3	25	7	7
BB 4	30	3	7
Total	110	13	27

(c) Test pit

Pit No.	Depth (m)
BTp 1	3
BTp 2	3
BTp 3	2
BTp 4	4.2

(2) Kalola dam site

(a) Geological reconnaissance in the site with the map of 1/1,000.

(b) Drilling, standard penetration test and permeability test.

Hole No.	Depth (m)	Standard penetration test (nos.)	Permeability test (nos.)
KB 1	30	-	7
KB 2	30	11	7
KB 3	30	-	6
Total	90	11	20

(c) Test pit

Pit No.	Depth (m)
KTp 1	2
KTp 2	0.6

In addition, the following geological investigation for the DOI site has been conducted by DOI in 1976 and 1978:

(3) Bila intake site (DOI Site)

(a) Drilling, standard penetration test and permeability test. (1976)

Hole No.	Depth (m)	Standard penetration test (nos.)	Permeability test (nos.)
BH 1	20.3	4	5
BH 2	25.3	7	7
BH 3	20.3	5	5
BH 4	25.1	5	7
BH 5	15.3	4	4
Total	106.3	25	28

(b) Test pit
TP 1 to 7, total 7 points (1976)
TP 1 to 3, total 3 points (1978)

(c) Hand auger boring
BT 1 to 10, total 10 points (1976)
BT 1 to 8, 31 and 32, total 10 points (1978)

(d) Trench (1976)
TR 1 and 2

(e) Dutch cone sounding
S 1 to 7, total 7 points (1976)
S 1 to 11, 36 and 37, total 13 points (1978)

(f) Geoelectric sounding (1976)
R 1 to 15, total 15 points

(g) Laboratory soil tests (1976 and 1978)

2. GENERAL GEOLOGY

The project area is located in the north of Lake Tempe and Lake Buaya, and geologically in the northern part of the Tempe depression running NW-SE direction in the south arm of Sulawesi.

There are three main rivers, i.e., the Boya, Bila and Kalola rivers which originate from the northern mountain region and flow down with meanders into Lakes Buaya and Tempe. Those lakes are drained by the Cenranae river to the Bone bay. The northern mountain region is one of the most mountainous areas of Sulawesi, formed geologically by Upper Cretaceous to Lower Tertiary sedimentary and volcanic rocks.

The project area consists of wide and flat terrace and alluvial flood plain with surrounding gentle hills. The flat plain is underlain mainly by very soft clayey or silty Quarternary deposits, mostly covered by paddy fields. The surrounding gentle hills are underlain by Tertiary Pliocene molasse deposits composed of alternation of weak to moderate cemented sedimentary rocks, such as siltstone, sandstone and conglomerate, which are covered by a surface soil and partly thin silty talus deposits, and terrace deposits along the river.

The geological structures, bedding and faults, show mostly the strike of N 50^{o} - 90^{o}W, coincided with the topographical lineaments such as the flow direction of tributaries and the ridge direction of the hills.

The proposed irrigation area is located mostly in the wide and flat terrace and aluvial flood plain, and the main canal is proposed to run along the foot slope of the surrounding hills.

The Bila intake weir site and the Kalola damsite are proposed in the surrounding hilly area. The bedrocks of those sites are the above mentioned alternation of soft sedimentary rocks which are generally weathered in the surface portion, overlain by the Quarternary deposits.

The general geological condition in and around the project area is shown in Fig. 2.1 GENERAL GEOLOGICAL MAP.

3. GEOLOGY OF ALTERNATIVE BILA INTAKE WEIR SITE

3.1 General Geological Conditions of the Bila Intake Site

The alternative Bila intake weir site proposed in the Master Plan is geologically composed of Tertiary Pliocene sedimentary rocks and Quaternary deposits, such as terrace, talus and river bed deposits.

The Tertiary Pliocene sedimentary rocks are bedrocks in this area, which consist of alternating beds of conglomerate, and sandstone with partial intercalations of siltstone. Those are mostly greyish coloured massive and soft rocks. The bedrocks are generally covered by the surface soil, thin talus deposit, terrace deposit and/or river bed deposit. The outcrop of the bedrocks are observed only on the foot of the cliff along the left bank of the Bila river. The bedding of the bedrocks is about EW/30^{o}-50^{o}S. No evidence of fault structures was observed.

The Quaternary deposits are distributed mostly along the Bila river. A paddy field area on the right bank, which extends for about 200 m in length on the weir axis, is underlain by the terrace deposit with about 7 m of thickness, and below the terrace deposit lie the bedrocks.

The river bed deposit is found only in the Bila river bed with the width of 50 to 100 m. The talus deposit is generally very narrow and thin in this area.

The geological map and profile are shown on Fig. 3.1 and 3.2, and the drill logs are described in Fig. 3.3. The results of the field permeability tests and penetration tests at alternative Bila intake weir site are summarized in Table 3.1 and 3.2 respectively.

3.2 Geological Conditions of Each Layer

According to the field reconnaissance and drilling investigation, the geological condition of the bedrocks and the Quaternary deposits are assumed as follows:

(1) Bedrock

The bedrocks are composed of alternating beds of conglomerate and sandstone with pertial intercalations of siltstone which are greyish coloured soft and massive rocks in fresh zone. They are divided into three zones by the condition of weathering which are highly weathered rock zone, moderately weathered rock zone and slightly weathered to fresh rock zone, as shown on the geological profile, Fig. 3.2. The geological condition of each zones are as follows:

(a) Highly weathered rock zone

Judging from the observation of the test pit BTp 4 that was excavated in the conglomerate, the rock textures such as cracks, joints and bedding texture were not clear. The conglomerate looks like compact and poorly consolidated brown residual sediments composed of clayey to silty sand, gravels and boulders (about 30 cm in the maximum diameter). Those gravels and boulders are mostly weathered and weakened. The thickness of this zone is 4 to 5 m in the both abutments.

The N-value is 18 to 34 in the upper part of this zone and more than 50 in the middle to lower part. The coefficient of permeability is in the order of 10^{-5} cm/sec (2.8 to 4.1 Lugeon) in the right abutment and 10^{-4} cm/sec (21 to 44 Lugeon) in the left abutment.

(b) Moderately weathered rock zone

The thickness of this zone is about 5 m in the left abutment and about 8 m in the right abutment. The geological condition is brown and partly grey coloured massive and soft rock. The gravels and boulders in the conglomerate are mostly fresh and hard.

The N-value is more than 50 and the coefficient of permeability is the order of 10^{-4} cm/sec (10 to 62 Lugeon) in the both abutments.

(c) Slightly weathered to fresh rock zone

This zone is found 12 to 13 m below the ground surface in the right abutment and 9 to 10 m below in the left abutment, composed of grey coloured massive and soft rock.

The N-value of this zone is more than 50 and the coefficient of permeability is in the order of 10^{-4} cm/sec (12 to 64 Lugeon) in the left abutment and in the order of 10^{-5} cm/sec (less than 10 Lugeon) or less in the other portion.

(2) Terrace deposit

The terrace deposit is composed of silty to clayey sand layer and sand and gravels layer. Those are brownish coloured soft and loose unconsolidated deposit.

The N-value of this deposit shows 9 to 18, and the coefficient of permeability shows mostly in the order of 10^{-4} cm/sec (20 to 46 Lugeon), and partly in the order of 10^{-5} cm/sec in the clayey layer and 10^{-3} cm/sec (206 Lugeon) in the sand and gravels layer.

(3) Other Quarternary deposit

The river bed deposit is unconsolidated very loose deposit, composed of sand, gravels and boulders (diameter of less than 30 cm). The thickness may be 1 to 2 m at the proposed weir axis portion.

The talus deposit is composed of sandy silt, gravels and boulders. As the distribution of this deposit is very nallow and thin in this area, it is neglected on the geological map and profile, Fig. 3.1 and 3.2.

3.3 Consideration for Weir Design

(1) Excavation line

The intake weir at this site is of fixed type concrete gravity type weir combined with earth fill dyke. The concrete gravity weir can be placed on the slightly weathered to fresh rock zone. The dyke is mostly placed on the terrace portion of the right bank. However, the terrace deposit contains high pervious sand and gravels layer, and shows low strength (N-value is less than 20). Therefore, core trench cut will be required in the terrace deposit up to the bedrocks for the design of the dyke.

(2) Foundation treatment

The coefficient of permeability of the bedrocks shows mostly in the order of 10^{-4} cm/sec. Therefore, the foundation treatment, such as curtain grouting and/or soil blanket, will be required to prevent water leakage through the foundation. For the foundation of the concrete gravity weir, consolidation grouting will be required since the foundation rock, even the fresh rock, is not so hard and cemented.

4. GEOLOGY OF KALOLA DAM SITE

4.1 General Geological Conditions of the Kalola Dam Site

The Kalola damsite is geologically composed of Tertiary Pliocene sedimentary rocks and Quaternary deposits, such as terrace, talus and river bed deposit, nearly similar to the Bila intake weir site.

The Tertiary Pliocene sedimentary rocks are bedrocks of this area, consisting of alternating beds of sandstone and conglomerate with pertial intercalations of siltstone. Those rocks are generally grey coloured massive and soft rocks in fresh rocks. The bedding of the bedrocks is around EW/30° - 50°S, and fault structure was not observed in this area.

The terrace deposit is distributed along the Kalola river and upstream reservoir area widely, most of which is covered by paddy fields. At the dam axis portion, its width is about 100 meters and the thickness is about 15 meters.

The talus deposit is found on the slope of ridge, especially on the downstream side of the left abutment ridge. The river bed deposit is very limitted in this area.

The geological map and profile are shown on Fig. 4.1 and 4.2, and the drill logs are described in Fig. 4.3. The results of the field permeability tests and penetration tests at alternative Kalola dam site are summarized in Table 4.1 and 3.2 respectively.

4.2 Geological Conditions of Each Layer

According to the results of the geological investigation, the geological condition of the bedrocks and the Quaternary deposits are as follows:

(1) Bedrock

The bedrocks are Tertiary Pliocene sedimentary rocks which are composed of alternating beds of sandstone and conglomerate with pertial intercalations of siltstone, grey coloured soft and massive rocks in fresh rocks.

Those rocks are also divided into three zones which are highly weathered rock zone, moderately weathered rock zone and slightly weathered to fresh rock zone by the extent of weathering like in the alternative Bila intake weir site.

The geological condition of each zone is as follows:

(a) Highly weathered rock zone

This zone consists of highly decomposed and weakened rocks by weathering. The boring core, consisting mostly of brownish coloured silty sand in the sandstone part or clayey to slity sand and weathered gravels in the conglomerate part, seems to be compact and semi-consolidated residual sediments.

The thickness is about 4 to 5 m in both abutments at the dam axis portion.

The N-value may be less than 50 in the upper part of this zone and more than 50 in the middle to lower part.

The coefficient of permeability is in the order of 10^{-5} to 10^{-4} cm/sec (6.5 to 18 Lugeon).

(b) Moderately weathered rock zone

This zone is composed of brown or grey coloured soft and massive rocks. The thickness is 9 to 10 m in both abutments at the dam axis portion.

The N-value is more than 50 and the coefficient of permeability is in the order of 10^{-4} cm/sec (17 to 36 Lugeon).

(c) Slightly weathered to fresh rock zone

This zone is composed of grey coloured massive and soft rocks which is distributed below the depth of 13 to 15 m from the ground surface in both abutments at the dam axis portion.

The highly to moderately weathered rock zone does not occur below the terrace deposit which overlies immediately the slightly weathered to fresh rock zone.

The coefficient of permeability is in the order of 10^{-4} cm/sec (11 to 39 Lugeon) in the upper to middle part of both abutments and 10^{-5} cm/sec or less in the other portion.

(2) Terrace deposit

The terrace deposit is brown coloured soft and loose, unconsolidated deposit, composed of silty sand layer and sand and gravels layer.

The N-value shows 7 to 29, mostly 11 to 18, and the coefficient of permeability shows generally very high, the order of 10^{-4} to 10^{-3} cm/sec (19 to 208 Lugeon).

(3) Other deposits

The talus deposit which is widely distributed on the downstream side slope of the left bank ridge, is formed by sandy to clayey silt, gravels and a few boulders.

The thickness may be 3 to 5 m. The geological condition is very soft and loose brown coloured unconsolidated deposit.

The river bed deposit is very limitted in this area, mostly composed of loose sand and gravels.

4.3 Consideration for Dam Design

(1) Dam type

The foundation of the dam site permits the introduction of either of rockfill and homogeneous fill type dams.

(2) Excavation line of core zone

The terrace deposit and the upper part of highly weathered rock zone are not suitable for the foundation of core zone of fill type dam because of its low strength and high permeability. The moderately to slightly weathered and fresh rock zone will be used for the foundation of core zone with careful foundation treatment.

(3) Foundation treatment

The coefficient of permeability of the bedrocks in both abutments shows relatively high, in the order of 10^{-4} cm/sec. Therefore, foundation treatment, such as curtain grouting, blanket grouting and/or soil blanket, will be required to prevent the leakage through the foundation.

(4) Others

Sub-dam and/or rim grouting will be required on the left abutment ridge, which is very thin and not higher than EL. 60 m.

5. GEOLOGY OF BILA INTAKE SITE

5.1 General Features

The DOI site is located about 1 km downstream from the alternative weir site proposed in the Master Plan. The geological condition is nearly similar to the Master Plan site as mentioned in CHAPTER 3. The bedrocks are Tertiary Pliocene sedimentary rocks which are alternating beds of conglomerate, sandstone and siltstone, overlain by Quaternary deposits.

The main structures in this site are concrete gravity intake weir on the right bank of the river and earth fill dyke for daming the present river flow. The geological conditions of those main structure portions are described in the succeeding Sections. The locations of the geological investigation conducted are as shown in Fig. 5.1 and Fig. 5.2. The geological profiles are shown on Fig. 5.3, 5.4, 5.5 and 5.6, referred to the reports prepared by P.T.TRICON on 1976 and 1978.

5.2 Geological Conditions of Intake Site

5.2.1 Intake weir site

The intake weir is designed on the right bank of the Bila river by the coupure construction method.

The intake weir portion is geologically composed of the above mentioned sedimentary rocks which are poorly consolidated soft rocks, weakened by weathering. The N-value and the coefficient of permeability of foundation are as follows:

Depth (m)	Geology	N-value	Coefficient of permeability (cm/s)
0 to 1.5	Surface soil	-	-
1.5 to 9.0	Highly weathered bedrock	21 to 48	1×10^{-4} to 1×10^{-5}
Below 9.0	Moderately to slightly weathered bedrock	More than 60	Less than 1×10^{-5}

5.2.2 Closure dam site

The bedrocks of the closure dam site are the same as the weir portion, covered by the Quaternary deposits such as terrace, talus and river bed deposit.

The terrace deposit is distributed widely on the left bank of the river. The geological condition of the terrace deposit may be nearly the same as of the right bank of the Master Plan site. It may be composed of silty to clayey sand layer and high pervious sand and gravels layer.

The talus deposit is distributed on the slope of the right bank, and the river bed deposit is distributed on the present river bed. Those deposits are unconsolidated loose and soft deposits.

5.3 Consideration for Intake Design

(1) Intake weir

The concrete gravity weir can be placed on the moderately weathered bedrocks which are found about 9 m below the ground surface (EL. 25m).

(2) Closure dam

The earthfill dam can be placed on the bedrocks, even the highly weathered bedrocks. It will be better that the Quaternary deposits such as terrace, talus and river bed deposits are excavated by cutoff trench to prevent the leakage through the foundation.

6. FURTHER INVESTIGATION TO BE REQUIRED

6.1 Kalola Dam Site

Prior to implementation of the Project, further investigation is required to confirm the more detailed geological conditions of foundation and embankment materials by means of boring, permeability test, grouting test, seismic exploration, test adit and test pit.

6.2 Bila Intake Site

For the Bila intake site investigated by the DOI, the following investigation is further required at the closure dam site:

(1) Depth of bedrock surface (thickness of terrace, talus and river bed deposit), and

(2) Permeability of the terrace deposit on the left bank.

Table 3.1 Result of Field Permeability Tests at Alternative Bila Intake Site

Drill hole no.	Depth (m)	Section length (cm)	Hole radius (mm)	Permeability coefficient (cm/sec)	Lugeon unit
BB-1	0 - 3	300	76	3.3×10^{-5}	2.8
	3 - 6	300	"	4.8×10^{-4}	4.1
	6 - 10	400	"	1.2×10^{-4}	10
	10 - 15	500	"	8.3×10^{-4}	64
	17 - 22	500	"	2.5×10^{-4}	16
	22 - 27	500	"	1.5×10^{-4}	12
	27 - 30	300	"	2.0×10^{-4}	21
BB-2	0 - 3	300	76	5.4×10^{-4}	46
	3 - 6	300	"	2.4×10^{-3}	206
	6 - 11	500	"	6.9×10^{-5}	5.4
	11 - 16	500	"	5.3×10^{-5}	5.2
	16 - 21	500	"	-	Less than 1.0
	21 - 25	400	"	-	"
BB-3	0 - 3	300	76	2.3×10^{-4}	20
	3 - 6	300	"	7.5×10^{-5}	6.4
	6 - 9	300	"	5.5×10^{-5}	4.7
	9 - 12	300	"	3.9×10^{-5}	3.4
	12 - 15	300	"	7.6×10^{-5}	6.6
	15 - 21	600	"	-	Less than 1.0
	21 - 25	400	"	-	"
BB-4	0 - 3	300	76	5.1×10^{-4}	44
	3 - 6	300	"	2.5×10^{-4}	21
	6 - 10	400	"	7.7×10^{-4}	62
	10 - 15	500	66	3.2×10^{-4}	24
	15 - 20	500	"	1.1×10^{-4}	8.3
	20 - 25	500	"	-	Less than 1.0
	25 - 30	500	"	-	"

Table 3.2 Result of Standard Penetration Tests

Site	Drill hole no.	Depth	N-value	Remarks
Bila intake site	BB-1	2.15 (m) - 2.45	18	Highly weathered conglomerate
		3.15 - 3.38	more than 50	"
		4.15 - 4.30	"	"
	BB-3	1.15 - 1.45	15	Terrace deposit
		2.15 - 2.45	9	"
		3.15 - 3.45	10	"
		4.15 - 4.45	12	"
		5.15 - 5.45	16	"
		6.15 - 6.45	18	"
	BB-4	1.15 - 1.44	18	Highly weathered conglomerate
		2.15 - 2.45	34	"
		4.15 - 4.26	more than 50	"
Kalola dam site	KB-2	1.15 - 1.45	18	Terrace deposit
		2.15 - 2.45	21	"
		3.15 - 3.45	18	"
		4.15 - 4.45	19	"
		5.15 - 5.45	15	"
		6.15 - 6.45	11	"
		7.15 - 7.45	11	"
		8.15 - 8.45	11	"
		9.15 - 9.45	29	"
		11.65 - 11.95	7	"
		12.15 - 12.45	18	"

Table 4.1 Result of Field Permeability Tests at Kalola Dam Site

Drill hole no.	Depth	Section length	Hole radius	Permeability coefficient	Lugeon unit
	(m)	(cm)	(mm)	(cm/sec)	
KB-1	0 - 3	300	76	1.1×10^{-4}	9.8
	3 - 6	300	"	8.0×10^{-5}	6.9
	6 - 11	500	"	8.4×10^{-5}	6.5
	11 - 16	500	"	4.8×10^{-4}	36
	16 - 21	500	"	5.2×10^{-4}	39
	21 - 26	500	"	1.1×10^{-4}	8.8
	26 - 30	400	"	1.8×10^{-5}	1.2
KB-2	3 - 6	300	76	4.0×10^{-4}	35
	6 - 9	300	"	2.2×10^{-4}	19
	9 - 11	200	"	2.2×10^{-3}	208
	11 - 13.7	270	"	6.0×10^{-4}	53
	15.5 - 20	450	66	-	Less than 1.0
	20 - 25	500	"	-	"
	25 - 30	500	"	-	"
KB-3	0 - 5	500	76	1.2×10^{-4}	9.3
	5 - 10	500	66	2.5×10^{-4}	18
	10 - 15	500	"	2.0×10^{-4}	17
	15 - 20	500	"	1.5×10^{-4}	11
	20 - 25	500	"	-	Less than 1.0
	25 - 30	500	"	1.2×10^{-5}	"

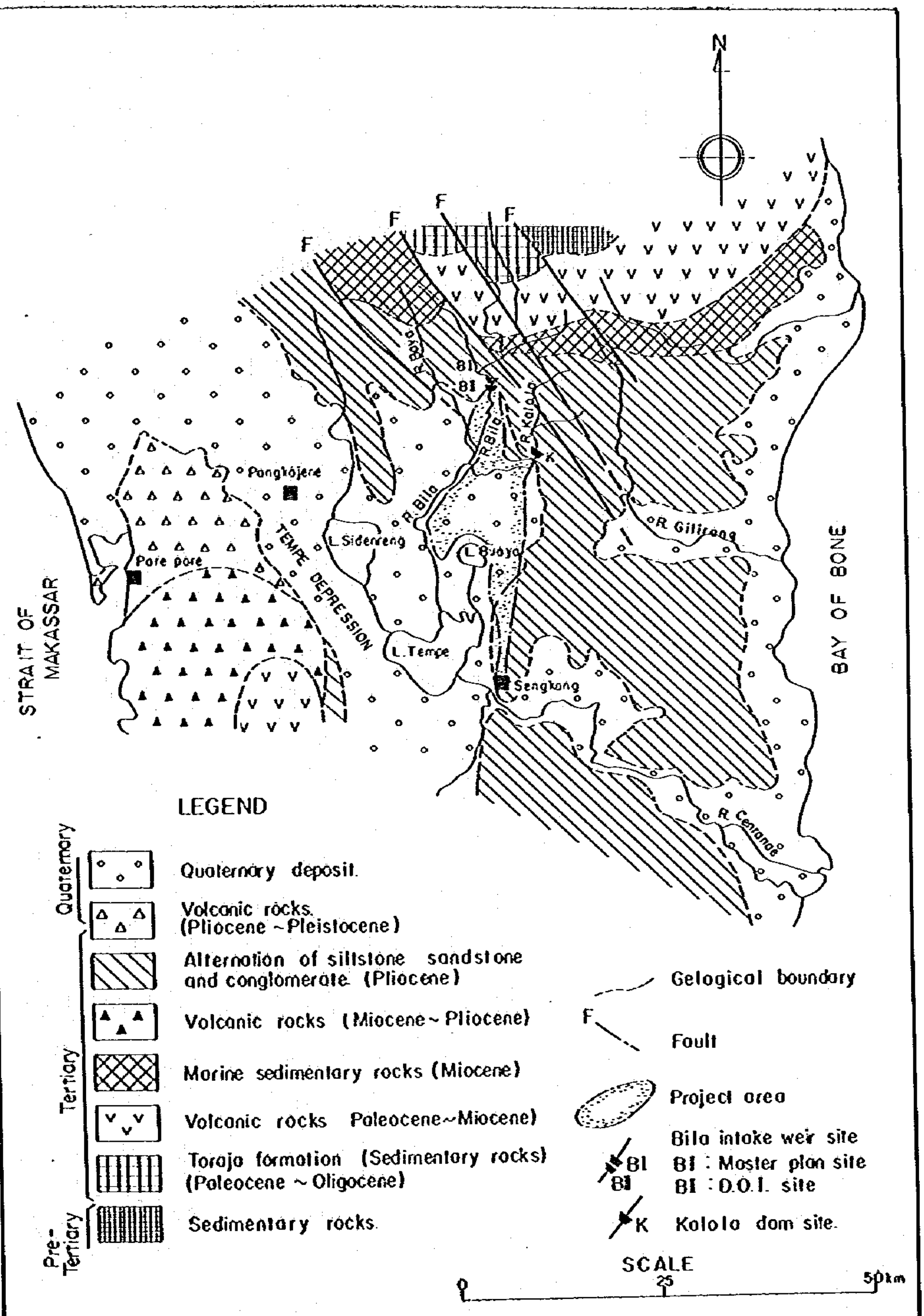


Fig. 2.1 GENERAL GEOLOGICAL MAP

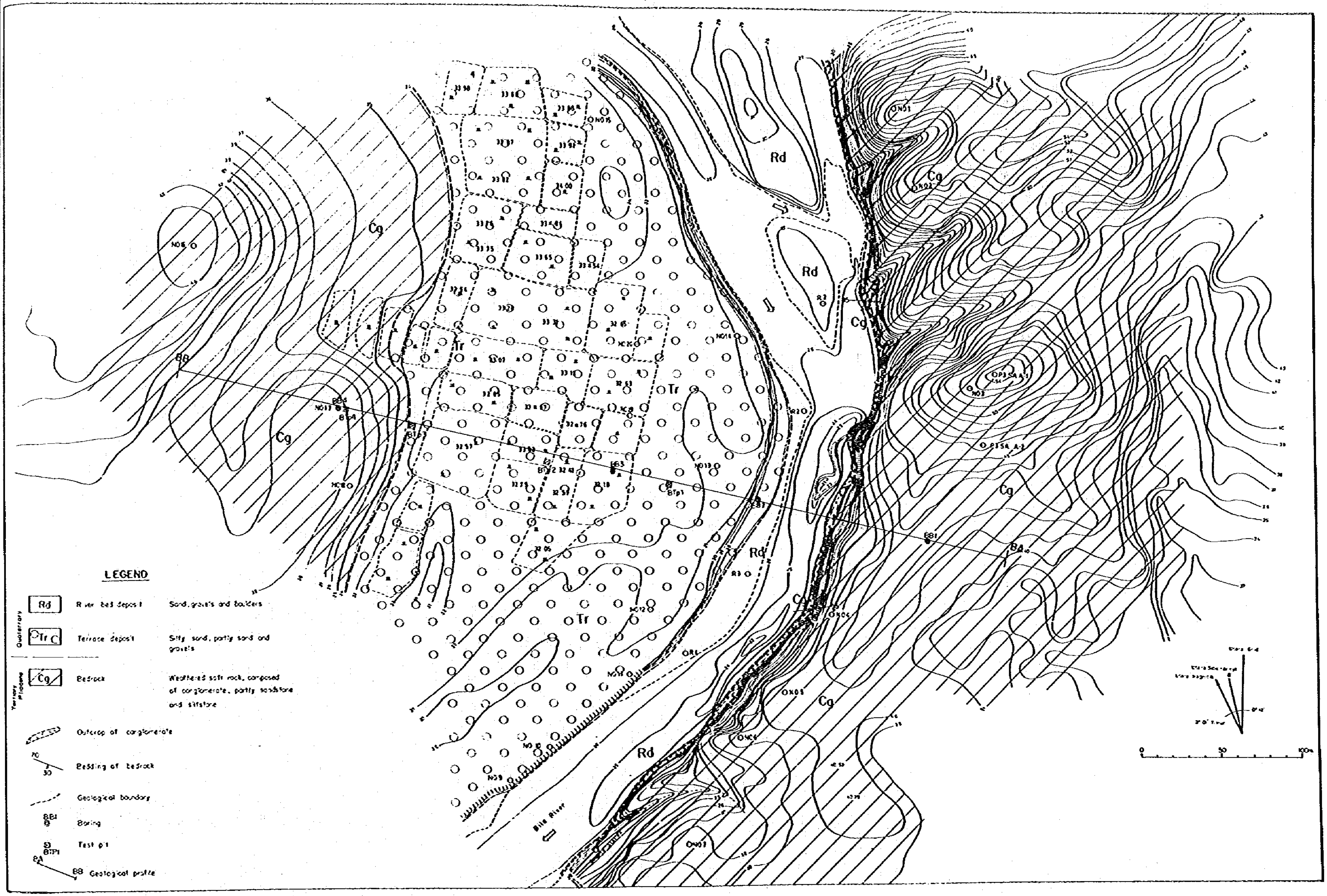


Fig. 3.1 GEOLOGICAL MAP OF ALTERNATIVE BILA INTAKE WEIR SITE

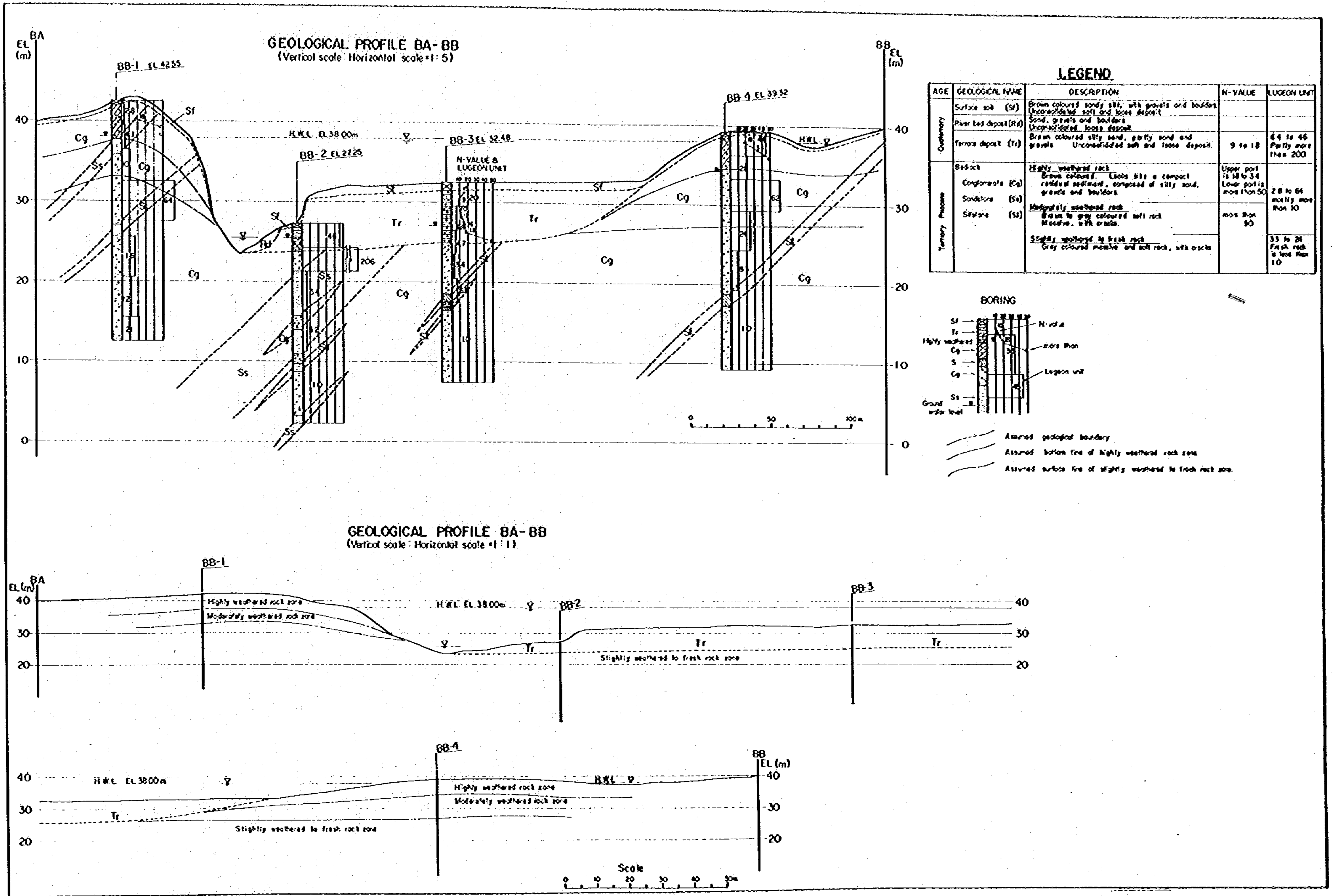


Fig. 3.2 GEOLOGICAL PROFILE OF ALTERNATIVE BILA INTAKE WEIR SITE

DEPTH	ELEVATION	THICKNESS	COLUMN SECTION	ROCK TYPE OR FORMATION	DESCRIPTION	G. W. L	CORE RECOVERY	R. Q. D	WATER PRESSURE TEST (LUGEON VALUE) AND N-VALUE.
	42.55								
0.50	42.05	0.50		Surface soil					
4.80	37.75	4.30		Conglomerate	Highly weathered. Brown to reddish brown. Clayey. 4.45	▽			2.8, 18, 4.1
6.50	36.05	1.70		Coarse sandstone.	Moderately weathered. Brown.				
9.50	33.05	3.00		Conglomerate					
15.50	27.05	6.00		Conglomerate	Slightly weathered. Grey.				
17.00	25.55	1.50		Coarse sandstone	Fresh soft rock.				
30.0	12.55	13.00		Conglomerate	Fresh soft rock. Grey. Sometimes containing coral fossils. Conglomerate portion shows relatively low core recovery. Recovering coves are mostly only gravels and boulders of conglomerate. Fine matrix flowed out by drilling water civculation.				21

HOLE NO. BB - 1

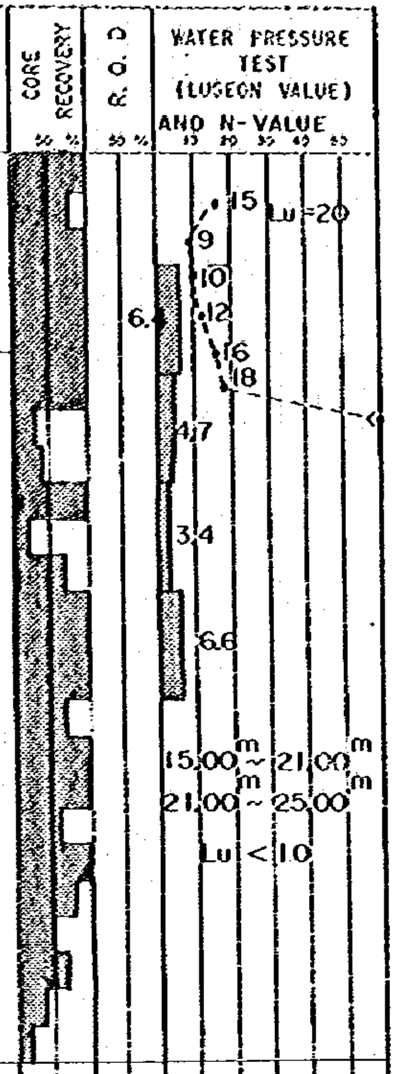
Fig. 3.3 DRILL LOG OF BILA WEIR SITE (1/4)

DEPTH	ELEVATION	THICKNESS	ROCK TYPE OR FORMATION	DESCRIPTION	G. W. L	WATER PRESSURE TEST (LUGEON VALUE)
	27.25			EL. 27.25		
0.50	26.75	0.50	Surface soil	Terrace deposit.		46
2.25	25.00	1.75	Silty sand	Brown & loose. 1.80	▽	
3.50	23.75	1.25	Sand&gravls.	Terrace deposit.		
6.00	21.25	2.50	Conglomerate.	Slightly weathered. Brown.		206
9.00	18.25	3.00	Finesandstone and siltstone.	Slightly weathered. Grey.		6.4
11.5	15.75	2.50	Coarse sandstone	Fresh and grey soft vock.		
13.3	13.95	1.80	Conglomerate			6.2
16.3	10.95	3.00	Coarse sandstone			
17.5	9.75	1.20	Conglomerate	Fresh. Grey.		
18.5	8.75	1.00	Coarse sandstone	Fresh. Grey.		16m to 21m, 21m to 26m Lu<1
24.0	3.25	5.50	Conglomerate	Fresh. Grey. Sometimes containing coral fossils.		
25.0	2.25	1.00	Finesandstone	Contain fossil.		

HOLE NO. BB-2

Fig. 3.3 DRILL LOG OF BILA WEIR SITE (2/4)

DEPTH	ELEVATION	THICKNESS	COLUMN SECTION	ROCK TYPE OR FORMATION	DESCRIPTION	G. W. L.
	32.48					
1.00	31.48	1.00		Sandy silt	Surface soil. Dark brown.	
7.50	24.98	6.60		Silty sand with gravels	Terrace deposit. Loose. Brown.	5.40
14.0	18.48	6.50		Conglomerate	Slightly weatheved. Grey to Brown. From 11m, fresh and soft rock.	
15.0	17.48	1.00		Sandy siltstone	Fresh. Grey.	
15.6	16.88	0.60		Conglomerate	Fresh and grey soft rock.	
16.0		0.40		Siltstone		
25.0	7.48	9.00		Conglomerate	17.0 ~ 21.5 Containing many coral fossils.	



HOLE NO. BB-3

Fig. 3.3 DRILL LOG OF BILA WEIR SITE (3/4)

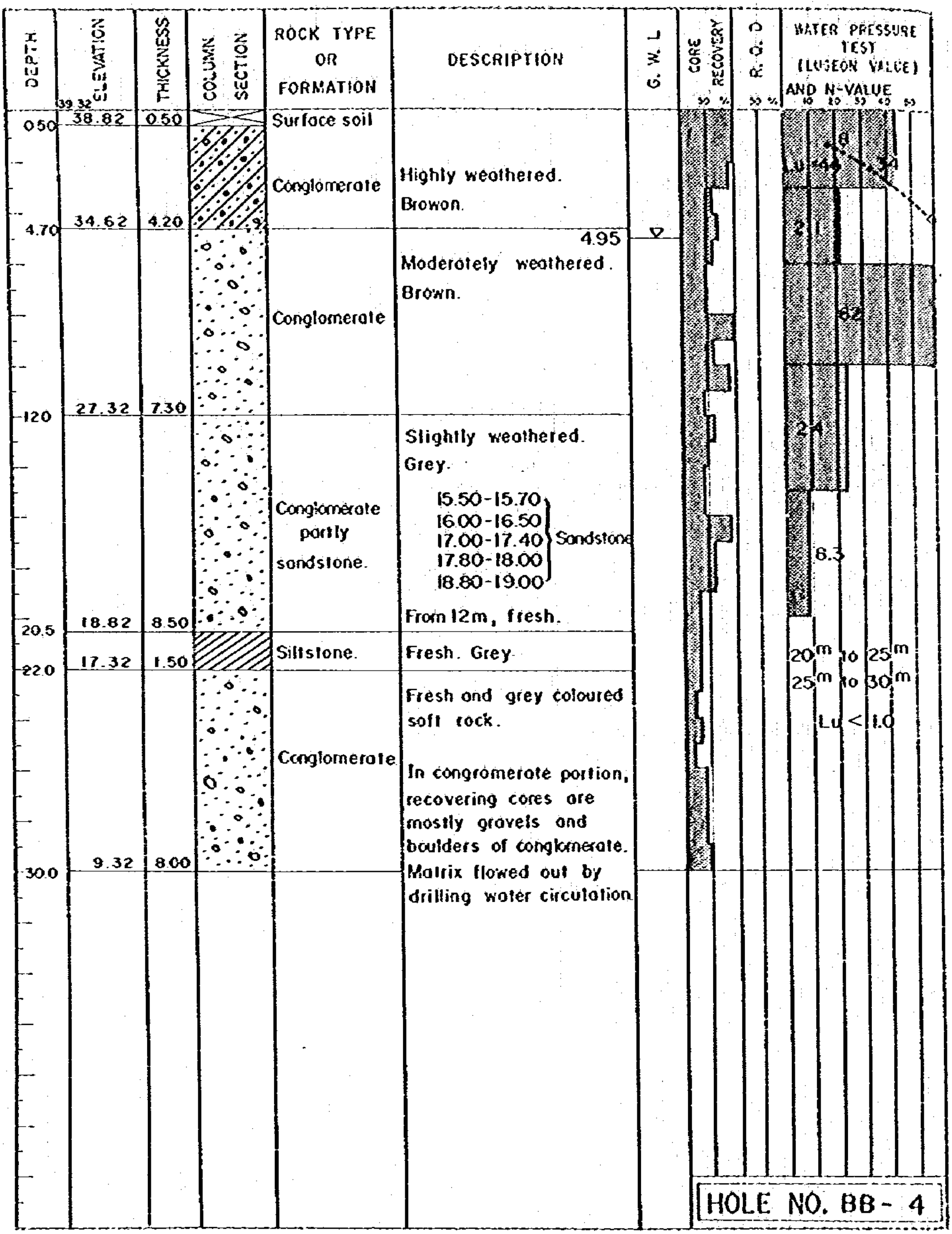


Fig. 3.3 DRILL LOG OF BILA WEIR SITE (4/4)

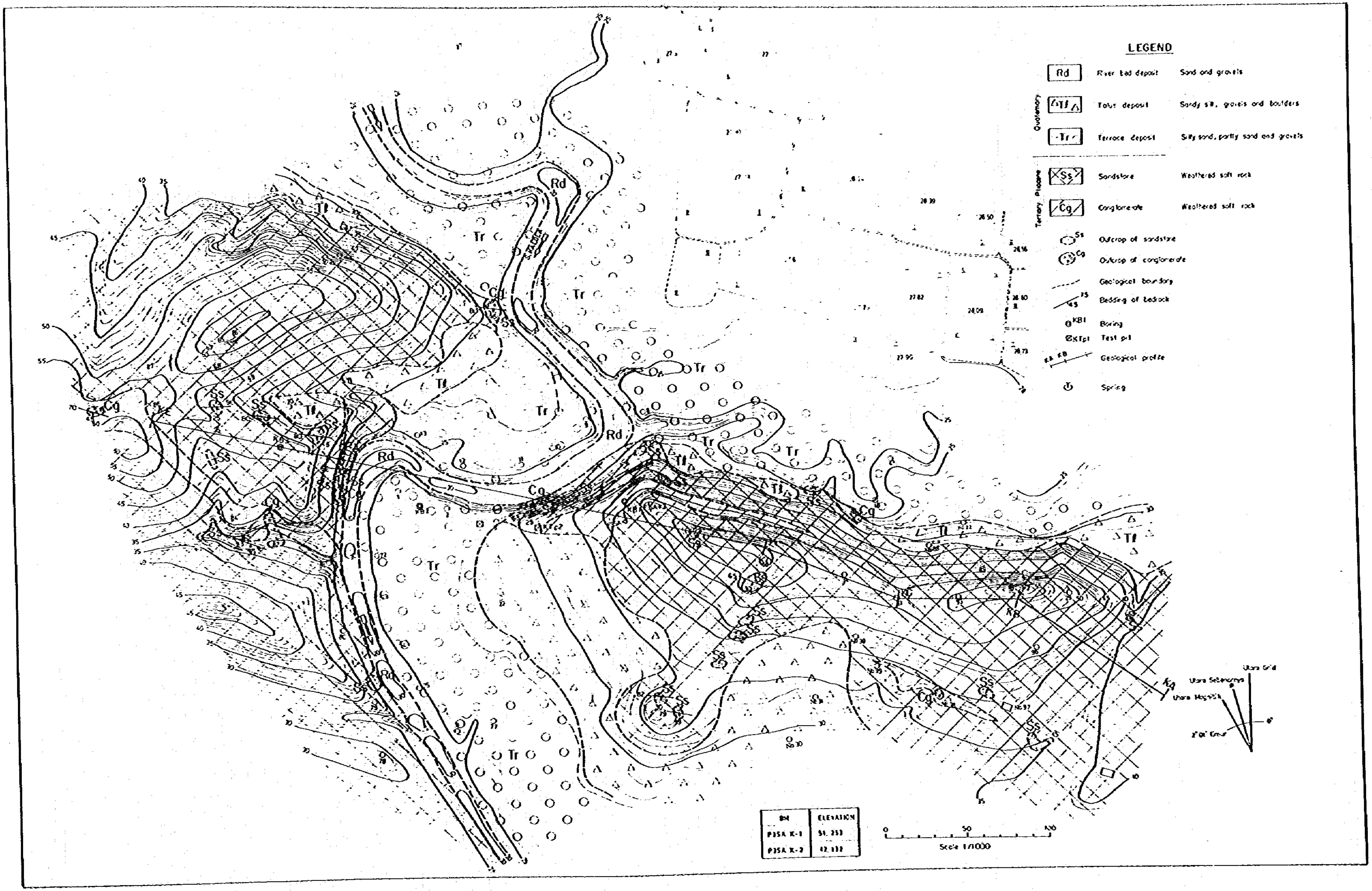
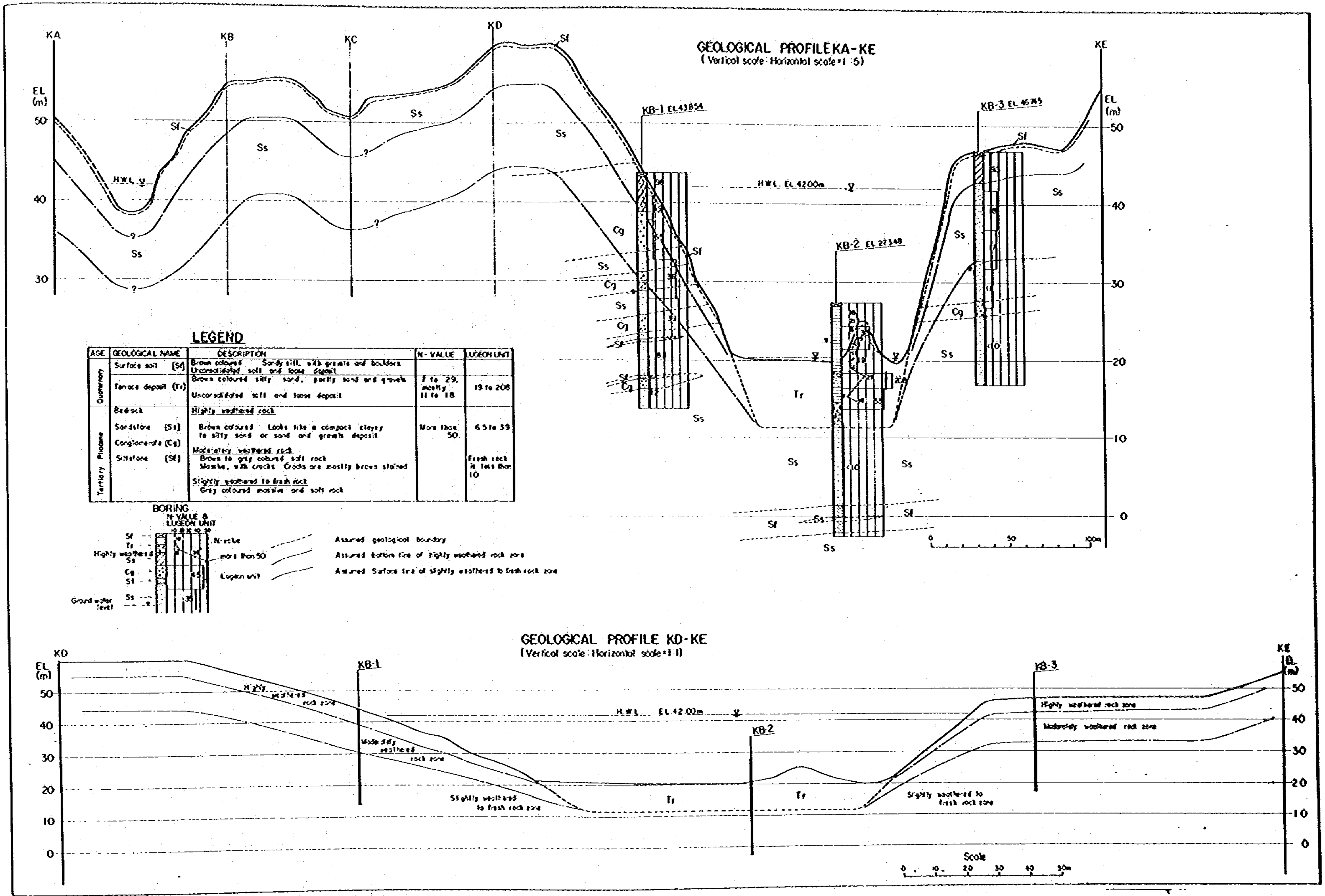


Fig. 4.1 GEOLOGICAL MAP OF KALOLA DAM SITE



LEGEND

AGE	GEOLOGICAL NAME	DESCRIPTION	N-VALUE	LUGEON UNIT
Quaternary	Surface soil [Sf]	Brown coloured Sandy silt, with gravels and boulders Unconsolidated soft and loose deposit		
	Terrace deposit (Tr)	Brown coloured silty sand, partly sand and gravels Unconsolidated soft and loose deposit	7 to 29, mostly 11 to 18	19 to 208
Tertiary Pliocene	Bedrock	Highly weathered rock		
	Sandstone [Ss] Conglomerate (Cg) Siltstone [St]	Brown coloured Looks like a compact clayey to silty sand or sand and gravels deposit Moderately weathered rock Brown to gray coloured soft rock Massive, with cracks Cracks are mostly brown stained Slightly weathered to fresh rock Gray coloured massive and soft rock	More than 50.	6.5 to 39 Fresh rock is less than 10

Fig. 4.2 GEOLOGICAL PROFILE OF KALOLA DAM SITE

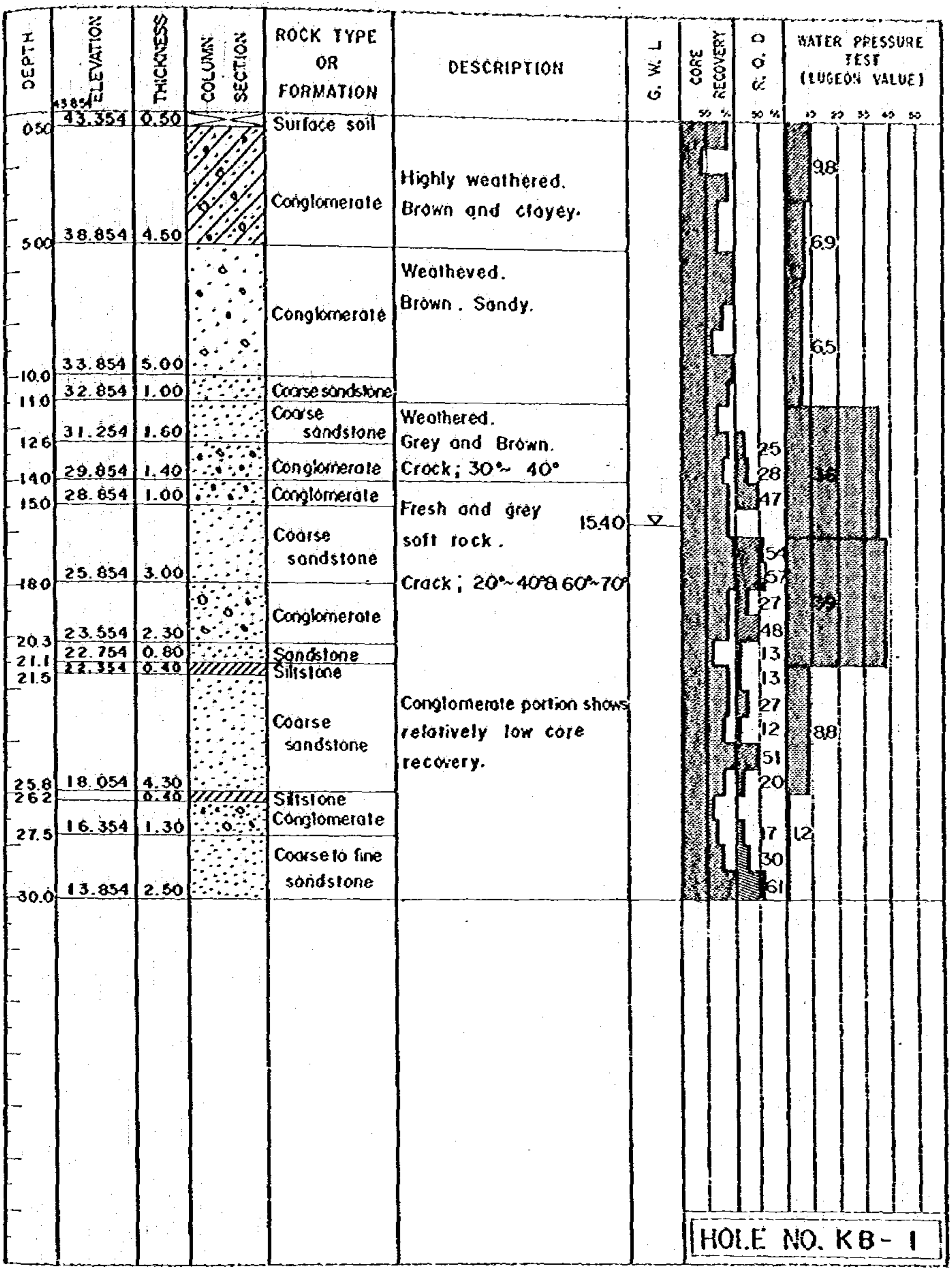


Fig. 4.3 DRILL LOG OF KALOLA DAM SITE (1/3)

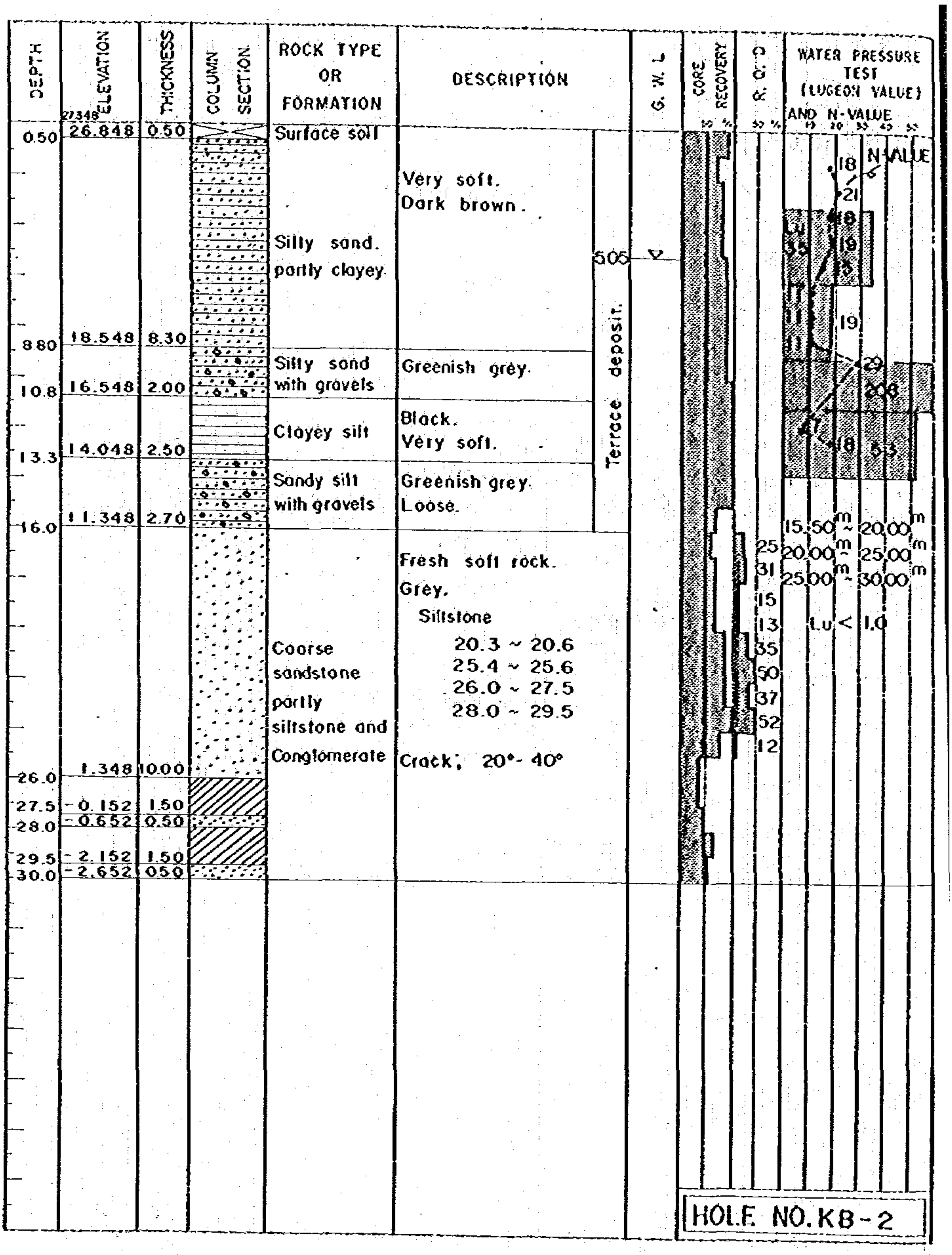


Fig. 4.3 DRILL LOG OF KALOLA DAM SITE (2/3)

DEPTH	ELEVATION	THICKNESS	COLUMN SECTION	ROCK TYPE OR FORMATION	DESCRIPTION	G. W. L	CORE RECOVERY	R. Q. D	WATER PRESSURE TEST (LUGEON VALUE)
	46.745								
0.50	46.245	0.50		Surface soil					
4.00	42.745	3.50		Sand stone	Highly weathered. Brown.				9.3
14.0	32.745	10.00		Coarse to medium sandstone	Moderately weathered soft rock. Brown. Crack; 10°~30° Observed slickenside at 5.70m(nearly 90°)			44, 46, 37, 26, 35, 12, 28	18, 17
18.1	28.645	4.10		Coarse sandstone	Partly weathered. Brown to gray soft rock. 16.4~16.5, 16.6~16.8 } Siltstone	15.25		10, 21, 23, 40	11
20.0	26.745	1.90		Conglomerate					
30.0	16.745	10.00		Coarse sandstone partly siltstone and conglomerate	Fresh and grey soft rock. Crack; 20°~30° Siltstone 20.2~20.3, 20.8~20.9, 28.8~29.4, 29.7~29.9 Conglomerate 20.9~21.5			15, [illegible], 15, 45, 41, 10, 28, 49, 33	20m to 25m, 25m to 30m Lu < 1.0

HOLE NO. KB - 3

Fig. 4.3 DRILL LOG OF KALOLA DAM SITE (3/3)

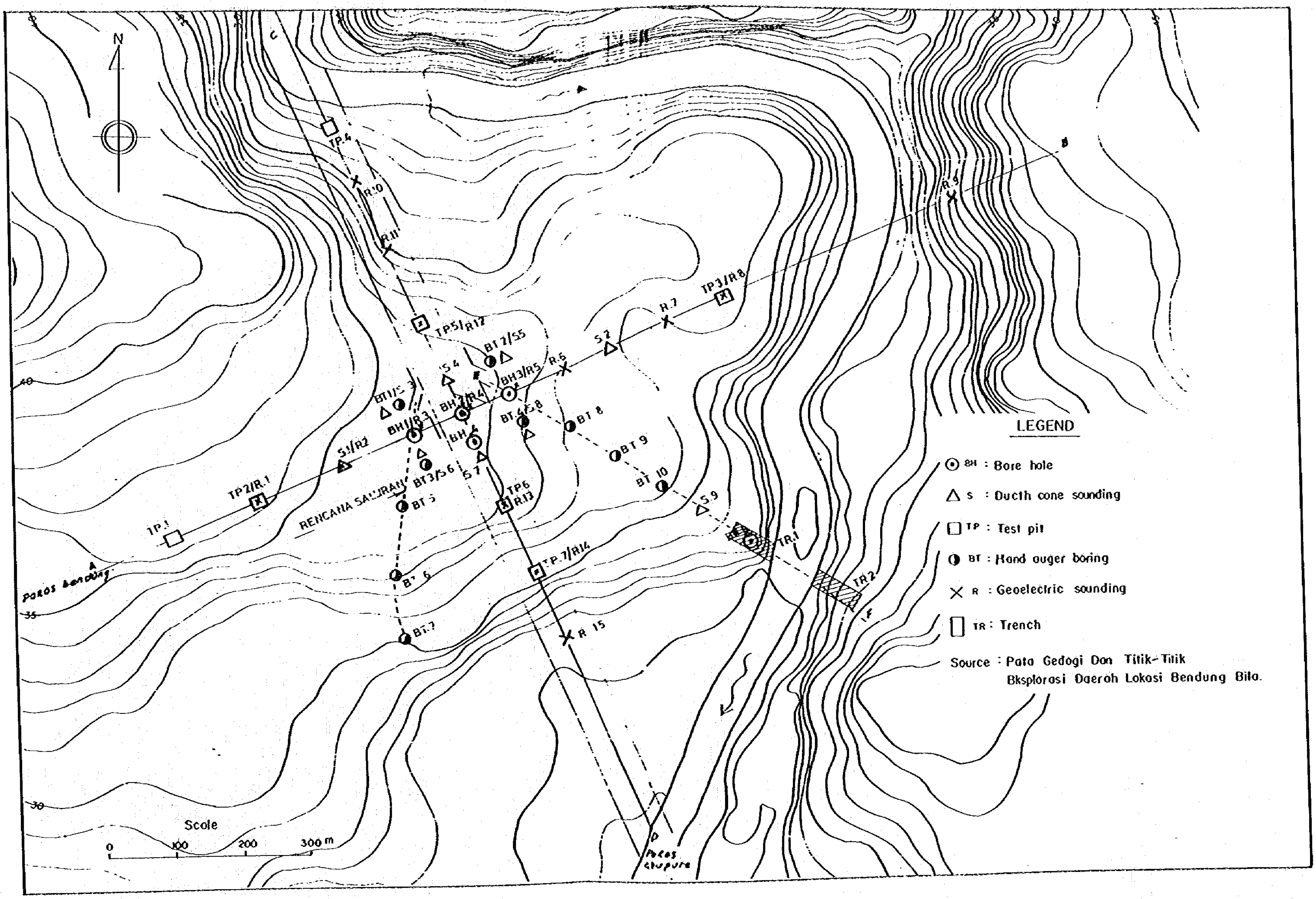


Fig. 5.1 LOCATION OF GEOLOGICAL INVESTIGATION OF BILA INTAKE WEIR SITE
(Investigated in 1976)

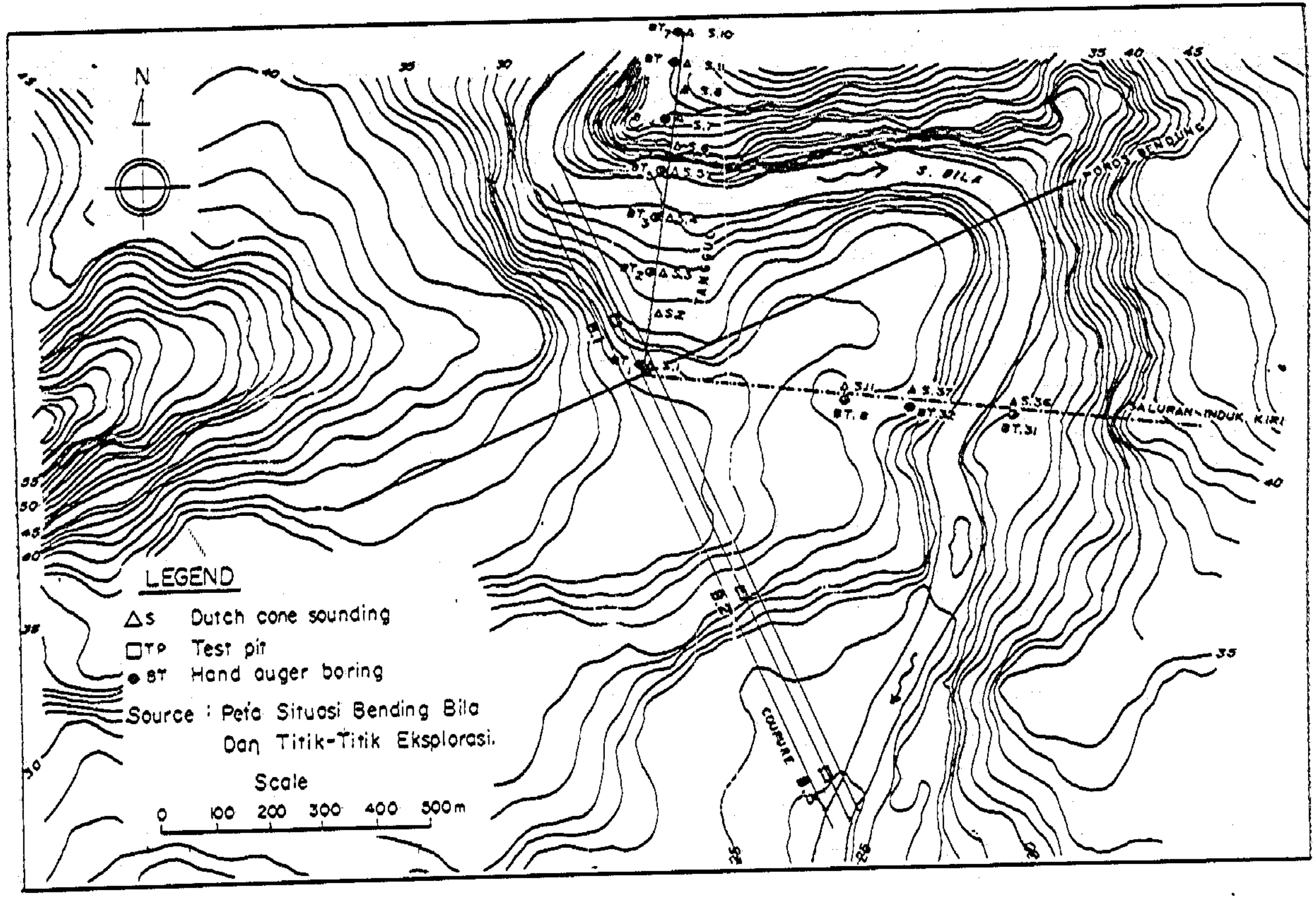


Fig. 5.2 LOCATION OF GEOLOGICAL INVESTIGATION OF BILA INTAKE WEIR SITE
(Investigated in 1978)

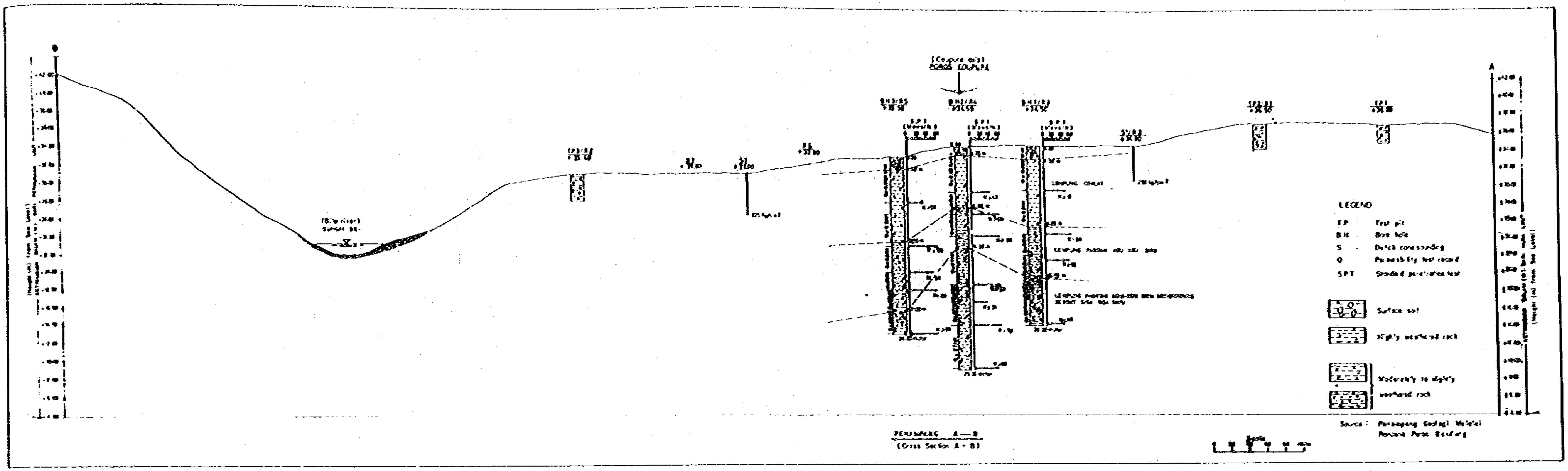


Fig. 5.3 GEOLOGICAL PROFILE OF BILA INTAKE SITE, SECTION A-B

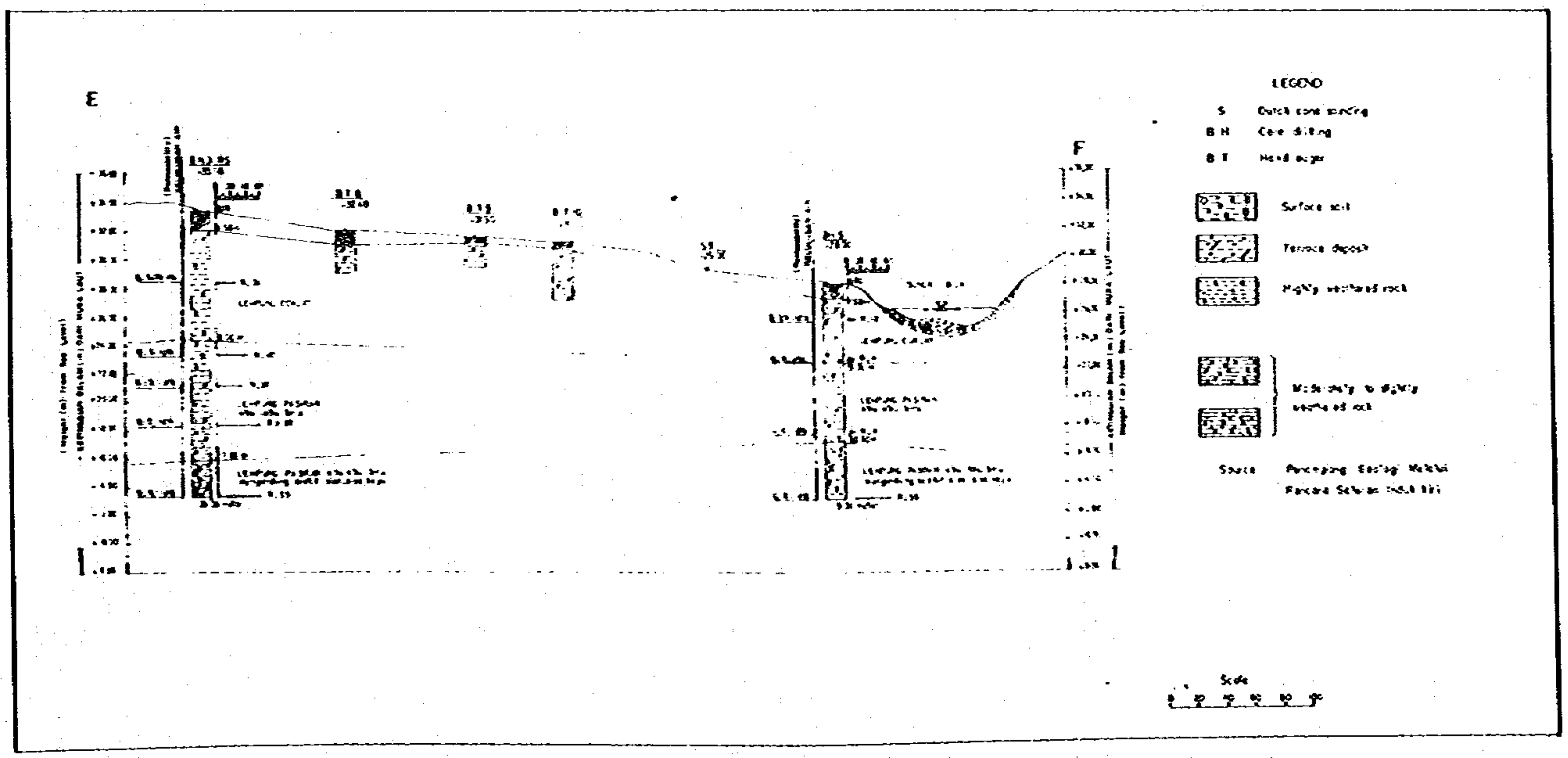


Fig. 5.4 GEOLOGICAL PROFILE OF BILA INTAKE SITE, SECTION OF SIPHON CROSSING

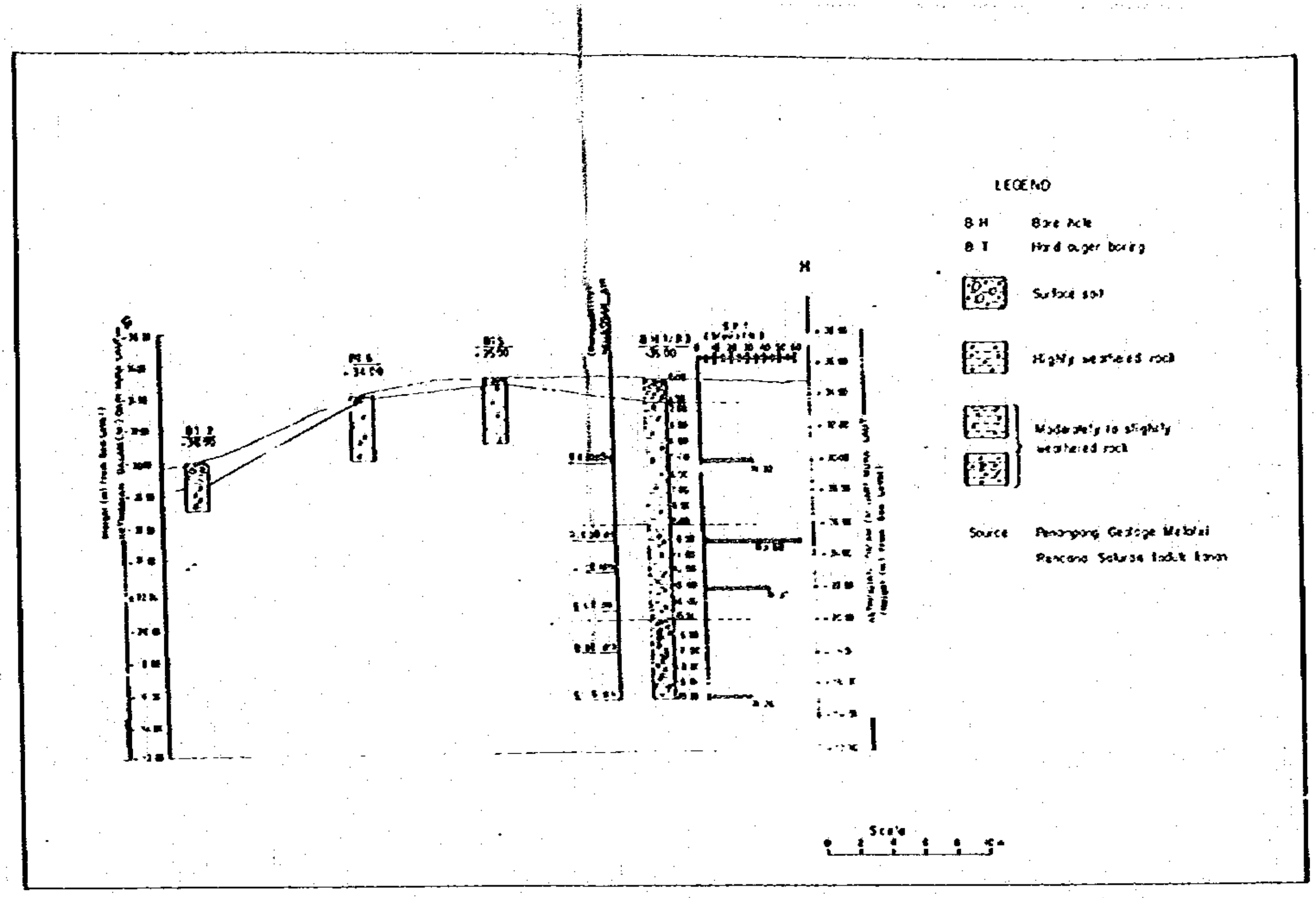


Fig. 5.5 GEOLOGICAL PROFILE OF BILA INTAKE SITE, RIGHT MAIN CANAL LINE

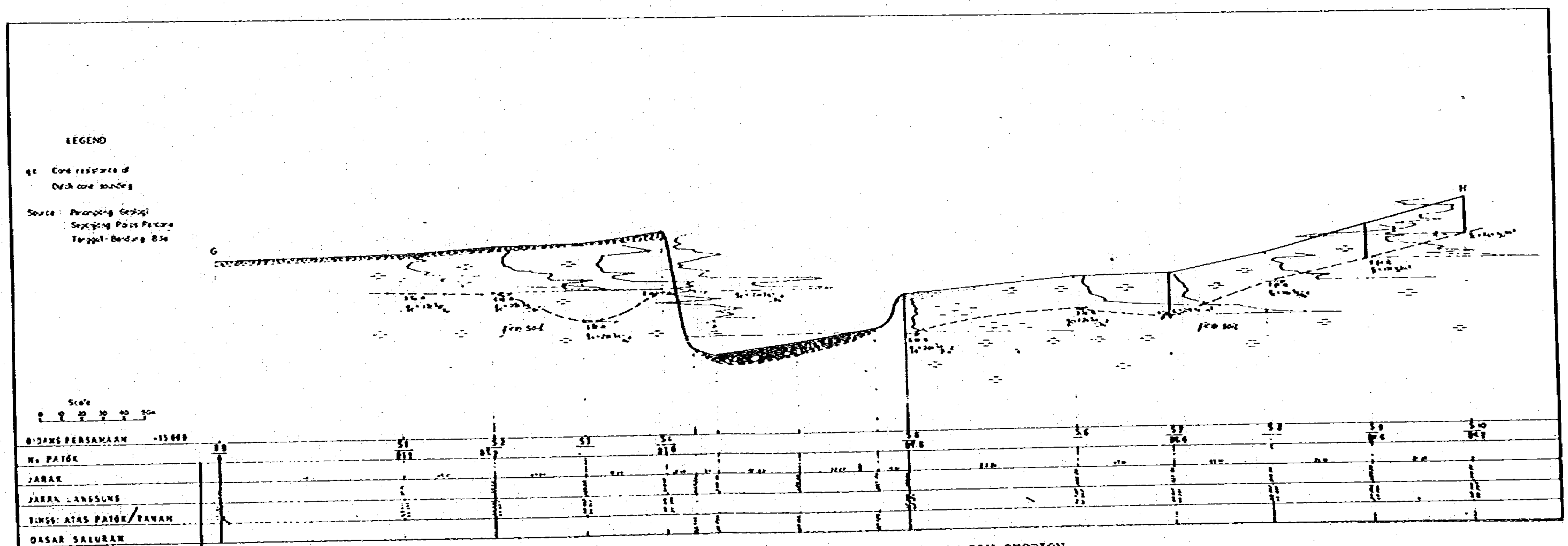
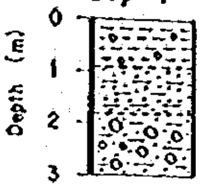


Fig. 5.6 GEOLOGICAL PROFILE OF BILA INTAKE SITE, CLOSURE DAM SECTION

BILA INTAKE WEIR SITE

BTp 1

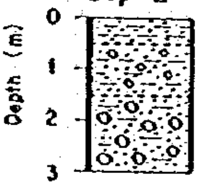


0 to 0.90m
Clayey silt. Brown coloured. Containing a few gravels (ø max. 2cm). Soft.

0.90 to 1.50m
Silty sand, partly clayey. Brown coloured. Soft. Very easy digged by pick.

1.50 to 3.00m
Silty sand and gravels (ø 0.5 ~ 2cm). Loose and soft. Easy digged by pick.

BTp 2

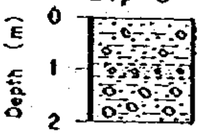


0 to 0.50m
Silty sand. very soft. Brown coloured.

0.50 to 1.50m
Silty sand, with a few gravels (ø 0.5 ~ 2cm). Soft. brown coloured.

1.50 to 3.00m
Silty sand and gravels (ø 0.5 ~ 4cm). Soft. Light brown.

BTp 3

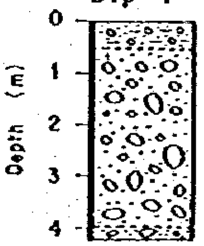


0 to 0.90m
Clayey sand. Brown coloured. Soft. Containing a few gravels (ø 0.5 ~ 2cm).

0.50 to 1.10m
Sand and gravels. Brown and loose.

1.10 to 2.00m
Silty sand and gravels (ø 0.5 ~ 4cm). Brown coloured. Soft.

BTp 4

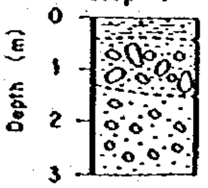


0 to 0.50m
Silty sand and gravels. Brown. Soft.

0.50 to 4.20m
Highly weathered conglomerate. Silty to clayey sand, gravels and boulders (ø max. 30cm) Brown coloured. 4.00 to 4.20m Partly grey coloured. Looks like a compact deposit.

KALOLA DAM SITE

KTp 1

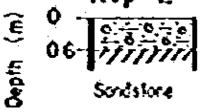


0 to 0.40m
Clayey sand, with a few gravels (ø max. 2cm).

0.40 to 1.50m
Sand, gravels and boulders (ø max. 30cm). Brown and compact.

1.50 to 3.00m
Sand and gravels (ø 0.5 ~ 2cm). Brown. Soft. Easy digged by pick.

KTp 2



0 to 0.60m
Silty sand and gravels (ø 0.5 ~ 2cm). Brown and soft. From 0.60m, highly weatherd sandstone.

Fig. 5.7 RECORD OF TEST PITS

ANNEX - IV

SOIL MECHANICS

ANNEX-IV SOIL MECHANICS

CONTENTS

ANNEX-IV SOIL MECHANICS

1. OBJECTIVES

In order to make the project study, the soil mechanical investigations were carried out with the following objectives:

(1) to clarify the foundation conditions of;

(a) alternative route of the main irrigation canal proposed in the Master Plan with the head water level of 35 m,

(b) flood control embankment along the Bila, Boya and Kalola rivers and flood way proposed in the Master Plan.

(2) to clarify the soil mechanical characteristics of materials to be used for construction;

(a) canal embankment,

(b) earth embankment to be required for alternative Bila intake proposed in the Master Plan,

(c) Kalola dam embankment,

(d) flood control embankment and flood way,

(e) concrete aggregates.

(3) to clarify the mechanical properties of riverbed materials of the Bila, Boya, Kalola and Lancirang rivers.

2. INVESTIGATION

2.1 General

The investigation consists of field investigations and laboratory testing made in BINA MARGA LABORATORY in Ujung Pandang arranged by the Government. The investigations include the following:

(1) Field investigations

(Unit: Nos)

Investigation item	Bila intake	Main canal	River bank		
			Bila river	Boya river	Kalola river
Test pit	2	9	-	-	-
Swedish sounding	2	8	-	-	-
Cone penetration	-	2	4	1	3

(2) Laboratory tests

(a) Soil mechanical test

(Unit: Nos)

Test item	Main canal	Flood control embankment	Flood way
Specific gravity	14	2	3
Grain size analysis	14	2	3
Water content	14	2	7
Atterberg limit	14	2	3
Compaction test	9	1	1
Shrinkage limit	3	-	-

(b) Riverbed material test

(Unit: Nos)

Test item	Bila river	Boya river	Kalola river	Lancirang river
Water absorption	5	1	1	1
Specific gravity	5	1	1	1
Grain size analysis	5	1	1	1

2.2 Field Investigation

2.2.1 Foundation conditions

(1) Foundation along alternative route of main irrigation canal

According to the proposed route of the main irrigation canal as made in the Master Plan, the alternative route is aligned along skirts of eastern gentle hill and hillside. Nine (9) test pits are dug along the canal routes for observation of soil profile and sounding test as shown in Fig. 2.1. Top layer of skirts of gentle hill and hillside are residual sediment (upper part of highly weathered baserock) and/or moderately weathered baserock. Also moderately cemented molasse deposits such as siltstone, sandstone and conglomerate crop out in places along these alignments. The results of sounding tests are summarized in Table 2.1 and shown in Fig. 2.2 and the details of profiles of pits are as shown in Data Book.

According to the results of sounding tests, weathered deposits such as talus deposits, molasse deposits, would not have sufficient bearing capacity for the foundation of heavy and/or rigid canal structures since the N-value is generally less than nearly 10. Under those weathered deposits, however, moderately cemented siltstone, sandstone and talus deposits are developed and they are relatively firm and well compacted. The N-value of these layers is estimated to be greater than 20. They are favourable for the foundation of the related structures such as siphon, culvert, chute, aqueduct, etc. The depth of excavation to obtain sufficient foundation for structures is different from the degree of weathering. In highly weathered molasse deposits 2 meters of excavation, and in moderately weathered molasse deposits 1.5 meters of excavation.

Some alignments of the main canal pass across paddy fields and terrace deposits. The soil profile of paddy fields is composed of blackish alluvial deposits, and terrace deposits of dark brown clayey sand and/or clay. According to the results of sounding test, the bearing capacity of those deposits is too small to construct canal structures; the N-value is about five (5).

(2) Flood control embankment and floodway

In order to investigate the foundation conditions of the flood control embankment for making flood control planning, cone penetration test is conducted at 7 places along the Bila, Boya and Kalola rivers. The results of penetration tests are as summarized in Fig. 2.2.

According to surface observation of river courses, their opposite banks of rivers are vertically shaped and height of slopes ranges from 3 m to 5 m. It seems to be formed by erosion owing to velocity of flood flow. Those deposits are composed of sandy silt, clayey silt and/or silty clay. At the watersides, riverbed deposits consisting of silty sand, sand and gravels dominantly develop.

According to thes results of sounding tests, the deposits shaped in nearly vertical or gentle slopes will not have enough bearing capacity for the foundation of embankment. The N-value is assumed to be less than 3. Stable and bearable foundation is, however, underlain by the surface deposits of 3 meters in depth. Further, stable foundation for embankment will be obtained 15 to 20 m away from river courses.

The floodway to connect the Bila river with Lake Buaya has been proposed in the Master Plan, crossing the existing paddy field in the Project area. Along the alignment of the floodway proposed in the Master Plan, 2 test-pits are dug for observation of soil profile and sounding test. The results are as summarized in Fig. 2.2. The soil profile of floodway route is composed of blackish alluvial deposits. According to the results of sounding test, mean N-value is estimated at about three and half (3.5), and the layer with N-value of three and half (3.5) is continued for more than ten (10) meters. Generally, where the layer having