Profile description;

Apg: 0 - 15 cm, Grayish brown (7.5YR5/2) loam (L) with some humus, common distinct fine tubular orange (7.5YR6/6) mottles, moderate medium granular structure, common fine pores, slightly compact slightly plastic, slightly sticky, common roots. Clear smooth boundary

B1g: 15 - 35 cm, Dull orange (7.5YR7/3) sandy clay loam (SCL), common distinct fine tubular brown (7.5YR4/4) mottles, weak fine subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky, few roots. Gradual smooth boundary

B2g: 35 - 65 cm, Light yellowish orange (7.5YR8/3) sandy loam (SL), common distinct cloudy orange (7.5YR6/8) mottles, single grain, common fine pores, slightly compact, non plastic, non sticky. Clear smooth boundary

Cg: 65 - 100 cm, Light gray (7.5YR8/1) loamy sand (LS) few distinct cloudy orange (7.5YR6/8) mottles, single grain, common fine pores, slightly compact, non plastic, non sticky

* Ground water level: 65 cm

Profile No.9

Date of survey	:	15 June 1981
Location	:	Ban Mae Ka, Changwat Chiang Mai
Physiographic position	:	Low terrace, lower part
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent material	:	Old alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil series	:	Lp/Sai association (Hang Dong Series)

Profile description;

Apg: 0 - 15 cm, Grayish yellow brown (10YR6/2) light clay (LiC), with some humus, common distinct fine tubular brown (7.5YR4/4) mottles, weak medium subangular blocky structure, common fine pores, slightly compact, plastic sticky, common roots. Clear smooth boundary

B1g: 15 - 40 cm, Grayish yellow brown (10YR5/2) clay loam (CL) with some humus, common distinct fine tubular brown (7.5YR4/4) mottles, weak medium subangular blocky structures, common fine pores, compact, plastic, sticky, common roots. Clear smooth boundary

B2g: 40 - 65 cm, Dull yellowish brown (10YR4/3) clay loam (CL), common distinct cloudy brown (7.5YR4/6) mottles, moderate coarse subangular blocky structure, common fine pores, slightly compact, plastic, sticky, Clear smooth boundary

Cg: 65 - 100 cm, Brownish gray (10YR4/1) loam (L), moderate coarse subangular blocky structure, common fine pores, compact, slightly plastic, slightly sticky

Profile No.10

Date of survey	:	15 June 1981
Location	:	Ban Ko Saliam, Changwat Chiang Mai
Physiographic position	:	Low terrace, lower part
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent material	:	Old alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil series	:	Lampang Series (Lp)

Profile description:

Apg: 0 - 14 cm, Grayish yellow brown (10YR6/2) loam (L), common distinct diffuse tubular brown (7.5YR4/6) mottles, weak medium subangular blocky structure, common fine pores, slightly compact (16 mm), slightly plastic, slightly sticky, EC 200 μ mho/cm.25°C, common roots. Gradual smooth boundary

B2g: 14 - 30 cm, Brownish gray (5Y6/1) silty clay loam (SiCL), common round fine gravels (10%), common distinct cloudy brown (7.5YR4/4) mottles, few manganese concretions, weak medium subangular blocky structure, common fine pores, compact (21 mm), plastic, sticky, EC 218 μ mho/cm.25°C, few roots. Gradual smooth boundary

Clg: 30 - 50 cm, Brownish gray (5Y6/1) silty clay loam (SiCL) many round fine gravels (20%), common distinct cloudy brown (7.5 YR4/6) mottles, massive, few fine pores, very compact (26 mm), plastic, sticky, EC 118 μ mho/cm.25°C. Clear smooth boundary

IIC2g: 50 - 100 cm, Light gray (5Y7/1) silty clay loam (SiCL), many round and angular fine gravels (25%), many distinct filmy brown (7.5YR4/6) mottles, massive, few fine pores, very compact (28 mm), plastic, sticky, EC 110 μ mho/cm.25°C.

Profile No.11

Date of survey	:	18 June 1981
Location	:	Ban Muang Kwak, Changwat Lamphun
Physiographic position	:	Semi-recent terrace
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent material	:	Semi-recent alluvial deposits
Great soil group	:	Hydromorphic Nor-Calcic Brown Soils
Soil series	:	Mae Sai Series (Ms)

Profile description;

Apg: 0 - 15 cm, light brownish gray (7.5YR7/2) silty clay loam (SiCL) with some humus, common distinct fine tubular brown (7.5YR4/6) mottles, weak medium subangular blocky structure, common fine pores, compact (20 mm), slightly plastic, slightly sticky, EC 162 μ mho/cm.25°C, many roots. Gradual smooth boundary

A2g: 15 - 25 cm, Grayish brown (7.5YR6/2) clay loam (CL) with some humus, common distinct cloudy bright brown (7.5YR5/6) and dark brown (7.5YR3/4) mottles, weak medium subangular blocky structure, common fine pores, very compact (25 mm), slightly plastic, slightly sticky, EC 243 μ mho/cm.25°C, common roots. Clear smooth boundary

B2g: 25 - 55 cm, Grayish yellow brown (10YR6/2) sandy clay loam (SCL), common distinct cloudy orange (7.5YR6/6) mottles, weak coarse subangular blocky structure, common fine pores, very compact (24 mm), slightly plastic, slightly sticky, EC 252 μ mho/cm.25°C, few roots. Gradual smooth boundary

Cg: 55 - 100 cm, Dull yellow orange (10YR6/3) sandy clay loam (SCL), common distinct cloudy dark brown (7.5YR3/4) mottles, Weak coarse subangular blocky structure, common fine pores, very compact (26 mm), slightly plastic, slightly sticky, EC 243 μ mho/cm.25°C

Profile No.12

Date of survey	:	15 June 1981
Location	:	Ban Phap, Changwat Lamphun
Physiographic position	:	Semi-recent terrace
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent material	:	Semi-recent alluvial deposits
Great Soil Group	:	Non-Clacic Brown Soils

Soil series : Kamphaeng Saen Series (Ks)

Profile description;

Apg: 0 - 15 cm, Grayish olive (5Y5/2) light clay (LiC) with some humus, common distinct fine tubular brown (7.5YR4/6) mottles, moderate medium subangular blocky structure, common fine pores, slightly compact (17 mm), plastic, sticky, common roots. Clear smooth boundary

A2g: 15 - 35 cm, Olive black (5Y3/2) light clay (LiC) with some humus, common distinct cloudy brown (7.5YR4/4) mottles, moderate medium subangular blocky structure, common fine pores, compact (21 mm), very plastic, very sticky, few roots. Clear smooth boundary

B2g: 35 - 70 cm, Grayish brown (7.5YR4/2) heavy clay (HC), common distinct cloudy brown (7.5YR4/6) mottles, weak coarse subangular blocky structure, common fine pores, compact (22 mm), very plastic, very sticky. Gradual smooth boundary

Cg: 70 - 100 mm Grayish brown (7.5YR5/2) heavy clay (HC), common distinct cloudy bright brown (7.5YR5/6) mottles, weak coarse subangular blocky structure, common fine pores, compact (22 mm), very plastic, very sticky

Profile No.13

Date of survey	:	17 June 1981
Location	:	Ban Mai San Khong, Changwat Chiang Mai
Physiographic position	:	Low terrace, lower part
Surrounding land form	:	Gently undulating
Land use	:	Paddy field
Parent material	:	Old alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil series	:	San Sai Series (Sai)

Profile description;

Apg: 0 - 17 cm, Grayish brown (7.5YR5/2) sandy loam (SL) with some humus, common distinct fine tubular brown (7.5YR4/4) mottles, weak medium subangular blocky structure, common fine pores, compact (21 mm), slightly plastic, slightly sticky, EC 176 μ mho/cm.25°C, common roots. Abrupt smooth boundary

B1g: 17 - 35 cm, Dull orange (7.5YR7/3) loamy sand (LS), common distinct fine tubular brown (7.5YR4/6) mottles, weak medium subangular blocky structure, common fine pores, compact (19 mm), non plastic, non sticky, EC 198 μ mho/cm.25°C, common roots. Clear smooth boundary

B2g: 35 - 55 cm, Dull orange (7.5YR7/3) loamy sand (LS), many distinct cloudy brown (7.5YR4/6) mottles, single grain, common fine pores, slightly compact (12 mm), non plastic, non sticky, EC 185 μ mho/cm.25°C, few roots. Clear smooth boundary

Cg: 55 - 100 cm, Light brownish gray (7.5YR7/1) sandy clay loam (SCL), many round and angular fine to medium gravels, common distinct cloudy bright brown (7.5YR5/6) mottles, single grain, common fine pores, slightly compact (18 mm), non plastic, non sticky

Profile No.14

Date of survey	:	17 June 1981
Location	:	Ban Pa Sak Luang (on the east), Changwat Chiang Mai
Physiographic position	:	Semi-recent terrace
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent material	:	Semi-recent alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil series	:	Hnag Dong Series (Hd)

Profile description;

Apg: 0 - 12 cm, Dull yellowish brown (10YR5/4) light clay (LiC) with some humus, few faint fine tubular dark brown (7.5YR3/4) mottles, weak medium subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky, common roots. Clear smooth boundary

A2g: 12 - 20 cm, Dark brown (10YR3/3) light clay (LiC) with some humus, few faint fine tubular dark brown (7.5YR3/4) mottles, moderate medium subangular blocky structure, common fine pores, compact, slightly plastic, slightly sticky, common roots. Clear smooth boundary

B1g: 20 - 35 cm, Dull yellowish brown (10YR4/3) clay loam (CL) few faint cloudy brown (7.5YR4/4) mottles, moderate medium subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky, few roots. Gradual smooth boundary

B2g: 35 - 70 cm, Grayish yellow brown (10YR4/2) clay loam (CL), few distinct cloudy dark brown (7.5YR3/4) mottles, moderate medium subangular blocky structure, common fine pores, compact, slightly plastic, slightly sticky. Clear smooth boundary

Cg: 70 - 100 cm, Brownish gray (10YR5/1) clay loam (CL), many distinct cloudy bright brown (7.5YR5/6) mottles, weak coarse subangular blocky structure, common fine pores, compact, slightly plastic, slightly sticky

Profile No.15

Date of survey	:	17 June 1981
Location	:	Ban Pa Sak Luang (on the west), Changwat Chiang Mai
Physiographic position	:	Semi-recent terrace

Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent material	:	Semi-recent alluvial deposits
Great Soil Group	:	Low Humic Gley Soils
Soil series	:	Hang Dong Series (Hd)

Profile description;

Apg: 0 - 12 cm, Yellowish brown (10YR5/6) light clay (LiC), with some humus, few distinct fine tubular dark brown (7.5YR3/4) mottles, weak medium subangular blocky structure, common fine pores, slightly compact, plastic, sticky, common roots. Clear smooth boundary

A2g: 12 - 20 cm, Dark brown (10YR3/4) light clay (LiC) with some humus, few faint fine tubular dark brown (7.5YR3/4) mottles, weak medium subangular blocky structure, common fine pores, compact, plastic, sticky, common roots. Clear smooth boundary

B1g: 20 - 35 cm, Dull yellowish brown (10YR4/3) clay loam (CL), few faint cloudy brown (7.5YR4/4) mottles, moderate medium subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky, few roots. Gradual smooth boundary

B2g: 35 - 65 cm, Grayish yellow brown (10YR4/2) clay loam (CL), common distinct cloudy brown (7.5YR4/6), mottles, moderate coarse subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky. Clear smooth boundary

Cg: 65 - 100 cm, Brownish gray (10YR5/1) and bright brown (7.5 YR5/6) loam (L), moderate coarse subangular blocky structure, common fine pores, compact, non plastic, slightly sticky

Profile No.16

Date of survey	:	17 June 1981
Location	:	Ban Dai Yao, Cahngwat Chiang Mai
Physiographic position	:	Low terrace, lower part
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent material	:	Old alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil series	:	San Sai Series (Sai)

Profile description;

Apg: 0 - 14 cm, Grayish yellow brown (2.5Y6/2) sandy loam (SL), common distinct fine tubular bright brown (7.5YR5/6) mottles, weak medium subangular blocky structure, common fine pores, very compact (25 mm), non plastic, non sticky, EC 190 μ mho/cm.25°C common roots. Clear smooth boundary

B1g: 14 - 25 cm, Dull yellow orange (2.5Y7/2) loamy sand (LS), common distinct fine tubular orange (7.5YR6/6) mottles, weak medium subangular blocky structure, common fine pores, compact (22 mm), non plastic, non sticky, EC 209 μ mho/cm.25°C, common roots. Gradual smooth boundary

B2g: 25 - 50 cm, Dull yellow orange (2.5Y7/2) loamy sand (LS), common distinct cloudy brown (7.5YR4/6) mottles, and few distinct spotty dark brown (7.5YR3/4) manganese concretion, single grain, common fine pores, compact (22 mm), non plastic, non sticky, EC 244 μ mho/cm.25°C, few roots. Gradual smooth boundary

Cg: 50 - 100 cm, Light gray (2.5Y8/2) sand (S), few fine angular gravel (Laterite), common distinct cloudy brown (7.5YR4/6) mottles and common distinct spotty dark brown (7.5YR3/4) manganese concretions, single grain, common fine pores, compact (20 mm), non plastic, non sticky, EC 210 μ mho/cm.25°C

Profile No.17

Date of survey	:	17 June 1981
Location	:	Ban Rong Khun, Changwat Chiang Mai
Physiographic position	:	Low terrace, lower part
surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent material	:	Old alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil series	:	Lp/Sai association, unidentified

Profile description;

Apg: 0 - 15 cm, Grayish brown (7.5YR5/2) light clay (LiC) with some humus, common distinct fine tubular dark brown (7.5 YR3/4) mottles, weak medium subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky, common roots. Clear smooth boundary

B2g: 15 - 40 cm, Grayish yellow brown (10YR4/2) clay loam (CL) with some humus, common distinct spotty brown (7.5YR4/6) mottles, weak medium subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky, few roots. Clear smooth boundary

Cg: 40 - 100 cm, Dull yellow orange (10YR6/3) sandy loam (SL), common distinct cloudy bright brown (7.5YR5/8) mottles, moderate medium subangular blocky structure, common fine pores, compact, non plastic, non stickly.

Profile No.18

Date of survey	:	18 June 1981
Location	:	Ban Pa Yang, Cangwat Chiang Mai
Physiographic position	:	Hill
Surrounding land form	:	Rolling
Land use	:	Wild use

Parent material : Residum (weathering products derived from sand stone and shale)

Great soil group : Lithosols

Soil series : Slope Complex (SC)

Profile description;

R: 0 - 5 cm, Gravels, many medium angular and round gravels. Abrupt smooth boundary

IC: 5 - 40 cm, Orange (7.5YR6/6) Sandy clay loam (SCL), many distinct diffuse tubular reddish brown (5YR4/8) mottles, moderate coarse angular blocky structure, few fine pores, extremely compact (30 mm), slightly plastic, slightly sticky, EC 131 μ mho/cm. 25°C, few roots. Abrupt smooth boundary

IIC: 40 - 80 cm, Gray (N6/0) clay loam (CL), common prominent filmy dark reddish brown (5YR3/3) mottles, moderate medium platelike structure, few fine pores, very compact (27 mm), slightly plastic, slightly sticky, EC 96 μ mho/cm.25°C

Profile No.19

Date of survey : 18 June 1981

Location : Ban Phayak Luang, Changwat Chiang Mai

Physiographic position : Semi-recent terrace

Surrounding land form : Flat to gently undulating

Land use : Paddy field

Parent material : Semi-recent alluvial deposits

Great soil group : Low Humic Gley Soils

Soil series : Hang Dong Series (Hd)

Profile description;

Apg: 0 - 15 cm, Brownish gray (10YR5/1) sandy clay loam (SCL) with some humus, common distinct fine tubular brown (7.5YR4/6) mottles, moderate medium subangular blocky structure, common fine pores, compact (21 mm), non plastic, slightly sticky, EC 123 μ mho/cm.25°C, many roots. Clear smooth boundary

A2g: 15 - 35 cm, Brownish black (10YR3/1) clay loam (CL) with some humus, common distinct cloudy dark brown (7.5YR3/4) mottles, moderate medium subangular blocky structure, common fine pores, slightly compact (17 mm), slightly plastic slightly sticky, EC 238 μ mho/cm.25°C, few roots. Clear smooth boundary

Blg: 35 - 55 cm, Brownish gray (10YR3/1) clay loam (CL) with some humus, common distinct cloudy dark brown (7.5YR3/4) mottles, moderate medium subangular blocky structure, common fine pores, slightly compact (17 mm), slightly plastic slightly sticky, EC 238 μ mho/cm.25°C, few roots. Clear smooth boundary

Bqg: 55 - 80 cm, Grayish yellow brown (10YR6/2) sandy clay loam (SCL), common distinct cloudy brown (7.5YR4/4) mottles, weak fine subangular blocky structure, common fine pores, slightly compact (18 mm), slightly plastic, slightly sticky, EC 280 μ mho/cm.25°C. Clear smooth boundary

Cg: 80 - 100 cm, Light gray (10YR7/1) light clay (LiC), few fine round gravels, common distinct cloudy brown (7.5YR4/4) mottles, massive, few fine pores, compact (22 mm), plastic, sticky

* Ground water level: 75 cm

Profile No.20

Date of survey	:	18 June 1981
Location	:	Ban Phayak Luang, Changwat Chiang Mai
Physiographic position	:	Semi-recent terrace
Surrounding land form	:	Falt to gently undulating
Land use	:	Paddy field
Parent material	:	Semi-recent alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil Series	:	Hang Dong Series (Hd)

Profile description;

Apg: 0 - 15 cm, Brownish gray (10YR5/1) loam (L) with some humus, common distinct fine tubular brown (7.5YR4/6) mottles, moderate medium subangular blocky structure, common fine pores, compact, slightly plastic, slightly sticky, many roots. Clear smooth boundary

A2g: 15 - 33 cm, Brownish gray (10YR4/1) clay loam (CL) with some humus, common distinct fine tubular brown (7.5YR4/6) mottles, moderate medium subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky, few roots. Gradual smooth boundary

B1g: 35 - 55 cm, Brownish gray (10YR4/1) clay loam (CL), common distinct cloudy dark brown (7.5YR3/4) mottles, weak to moderate coarse subangular blocky strucutre, common fine pores, compact, slightly plastic, slightly sticky. Clear smooth boundary

B2g: 55 - 80 cm, Grayish yellow brown (10YR6/2) sandy clay loam (SCL), common distinct cloudy brown (7.5YR4/4) mottles, weak coarse subangular blocky structure, common fine pores, compact, slightly plastic, slightly sticky. Clear smooth boundary

Cg: 80 - 100 cm, Dull yellow orange (10YR7/2) light clay (LiC), few fine round gravels, massive, few fine pores, slightly compact, plastic, sticky

* Ground water level: 80 cm

Profile No.21

Date of survey	:	18 June 1981
Location	:	Ban Lak Pan, Cahngwat Chiang Mai
Physiographic position	:	Semi-recent terrace
Surrounding land form	:	Falt to gently undulating
Land use	:	Paddy field
Parent material	:	Semi-recent alluvial deposits
Great soil group	:	Low Humic Gley Soils
Soil series	:	Hang Dong Series (Hd)

Profile Description;

Apg: 0 - 15 cm, Grayish yellow brown (10YR5/2) loam (L) with some humus, common distinct fine tubular brown (7.5YR4/6) mottles, weak medium subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky, many roots. Clear smooth boundary

Abg: 15 - 35 cm, Grayish yellow brown (10YR6/2) loam (L) with some humus, common distinct fine tubular dark brown (7.5YR3/4) mottles, weak medium subangular blocky structure, common fine pores, compact, slightly plastic, slightly sticky, common roots. Clear smooth boundary

B2g: 35 - 55 cm, Dull yellow orange (10YR7/3) clay loam (CL), common distinct cloudy brown (7.5YR4/4) mottles, weak coarse subangular, blocky structure, common fine pores, compact, slightly plastic, slightly sticky. Clear smooth boundary

IIAg: 55 - 65 cm, Brownish block (10YR3/1) sandy clay loam (SCL) with some humus, common distinct fine tubular dark brown (7.5YR3/4) mottles, weak coarse subangular blocky structure, common fine pores, slightly compact, slightly plastic, slightly sticky. Clear smooth boundary

IIBg: 65 - 100 cm, Brownish gray (10YR5/1) clay loam (CL), common distinct diffuse tubular dark brown (7.5YR3/4) mottles, weak coarse subangular blocky structure, common fine pores, compact, slightly plastic, slightly sticky

Profile No.22

Date of survey	:	24 June 1981
Location	:	Ban Pa Tan, Changwat Lamphun
Physiographic position	:	Low terrace, lower part
Surrounding land form	:	Flat to gently undulating
Land use	:	Paddy field
Parent material	:	Old alluvial deposits
Great Soil Group	:	Low Humic Gley Soils
Soil series	:	San Sai Series (Sai)

Profile description:

Apg: 0 - 12 cm, Grayish brown (7.5YR6/2) sandy clay loam (SCL), few distinct fine tubular brown (7.5YR4/6) mottles, weak fine subangular blocky structure, many fine pores, very compact (25 mm), non plastic, non sticky, EC 167 μ mho/cm.25°C, common roots. Abrupt smooth boundary

B2g: 12 - 30 cm, Light gray (7.5YR8/2) sandy loam (SL), many distinct diffuse tubular bright brown (7.5YR5/6) mottles and few distinct spotty brownish black (7.5YR2/2) manganese concretion, weak medium subangular blocky structure, common fine pores, extremely compact (33 mm), non plastic, non sticky, EC 167 μ mho/cm.25°C. Gradual smooth boundary

Cg: 30 - 65 cm, Light gray (7.5YR8/1) sandy loam (SL), common distinct cloudy bright brown (7.5YR5/6) mottles and few distinct spotty brownish black (7.5YR3/2) manganese concretion, weak medium subangular blocky structure, common fine pores, extremely compact (30 mm), non plastic, non sticky, EC 195 μ mho/cm.25°C.

Table B 2-1 Mechanical Composition of Soil Samples

Location	Soil Series	Horizon and Depth (cm)		Mechanical Composition (%)				Texture	Textural Class
				C. Sand	F. Sand	Silt	Clay		
Ban Doi Kamphra	Nam Pong (Ng)	A	5-20	0.80	88.95	7.54	2.71	LS	Coarse
		C1	20-80	0.59	86.94	9.25	3.22	LS	
Doi Saket	San Sai (Sai)	Apg	0-20	1.53	76.26	18.12	4.09	SL	Coarse
		B1g	20-35	12.14	70.60	15.66	1.60	SL	
		B2g	35-70	0.76	75.66	19.70	3.88	SL	
Ban Ko Salim	Lampang (Lp)	Apg	0-14	4.41	15.98	61.44	18.17	SiCL	Medium
		B2g	14-30	2.23	9.47	47.95	40.35	SiC	
		C2g	30-50	1.19	5.45	28.93	64.43	HC	
Ban Muang Kwak	Mae Sai (Ms)	Apg	0-15	6.21	18.80	73.48	1.51	SiL	Medium
		A2g	15-25	4.33	15.66	65.25	14.76	SiL	
		B2g	25-55	2.53	14.30	82.81	0.36	SiL	
San Kamphang	Hang Dong (Hd)	Apg	0-13	6.05	14.06	35.31	44.58	LiC	Fine
		ABg	13-27	3.66	17.77	56.28	22.29	SiCL	
		B2g	27-45	7.71	21.02	67.04	4.23	SiL	
Ban Mae Pong	Ratchaburi (Rb)	Apg	0-15	5.33	9.27	34.45	50.95	HC	Fine
		B1g	15-35	7.61	7.90	44.99	39.50	LiC	
		B2g	35-70	8.08	14.05	59.82	18.05	SiCL	

Above tests are analysed by staff member of Chiang Mai University.

Table B 2-2 Major Chemical Properties at Soil Samples

Location	Soil Series Text Class	Horizon Depth (cm)	pH H_2O	pH KCl	Total C (%)	Total N (%)	Total C/N	Available P_2O_5 (ppm)	CEC (me/100gs)	Exch. Cation (me/100gs) Ca^{+2}	Mg^{+2}	Na^{+}	K^{+1}	Base Sat (%)
Ban Doi Kamphra	Nam Pong (Ng) Coarse	A 5-20	6.8	5.8	0.174	0.014	12.4	2.5	1.58	0.48	0.23	0.19	0.13	65.2
		C1 20-80	6.9	5.8	0.114	0.012	9.5	0.0	1.19	0.33	0.15	0.14	0.16	65.5
Doi Saket	San Sai (Sai) Coarse	Apg 0-20	6.3	5.3	0.454	0.036	12.6	2.3	3.18	1.31	0.77	0.37	0.19	83.0
		B1g 20-35	7.3	6.1	0.163	0.016	10.2	1.0	2.17	1.10	0.57	0.19	0.19	94.5
		B2g 35-70	7.5	5.8	0.143	0.014	10.2	0.0	2.25	1.12	0.54	0.14	0.16	87.1
Ban Ko Salium	Lampang (Lp) Medium	Apg 0-14	6.1	4.8	0.599	0.054	11.1	2.0	6.66	3.62	1.42	0.31	0.11	82.0
		B2g 14-30	6.0	4.7	0.272	0.024	11.3	1.0	7.39	4.37	1.40	0.41	0.19	86.2
		C2g 30-50	5.5	3.9	0.112	0.011	10.2	0.0	5.71	2.87	1.52	0.49	0.34	91.4
Ban Muang Kwak	Mae Sai (Ms) Medium	Apg 0-15	6.5	5.4	0.864	0.085	10.2	13.8	15.8	10.9	2.22	0.31	0.37	87.3
		A2g 15-25	7.3	6.4	0.599	0.052	11.5	11.0	13.2	10.0	2.49	0.34	0.23	98.9
		B2g 25-55	7.3	6.4	0.327	0.036	9.1	6.8	14.5	10.7	1.23	0.32	0.24	86.1
San Kamphang	Hang Dong (Hd) Fine	Apg 0-13	7.0	5.6	0.729	0.072	10.1	4.8	12.3	6.36	1.77	0.46	0.22	71.6
		A2g 13-27	7.5	5.7	0.473	0.042	11.3	2.0	10.8	6.33	1.66	0.50	0.21	80.6
		B2g 27-45	7.1	5.6	0.268	0.026	10.3	1.0	11.7	6.43	2.20	0.56	0.28	80.9
Ban Mae Pong	Ratchaburi (Rh) Fine	Apg 0-15	5.8	4.6	0.764	0.070	10.7	9.7	15.2	8.34	3.28	0.58	0.21	81.6
		B1g 15-35	7.0	5.4	0.518	0.054	9.6	6.5	14.0	8.59	3.10	0.52	0.16	88.4
		B2g 35-70	7.3	5.6	0.373	0.036	10.4	1.5	12.2	6.15	3.10	0.50	0.18	81.4

APPENDIX C. GEOLOGY

APPENDIX C. GEOLOGY

APPENDIX C GEOLOGY

Appendix C-6 Engineering Geological Assessment

Appendix C-7 Recommendation

Appendix C-8 Data and Records

Appendix C-9 Attached Figure

1. Introduction

At the Mae Kuang damsite, a primary geological investigations which consists of a geological reconnaissance survey and drillings were carried out for study of a feasibility of dam construction by Soil & Geology Div. R.I.D. in 1974. At the time, the scale of proposed dams were rather small (Crest height of the Main dam was only 33 meters), therefore the scale of the investigation works were also small and poor. The conclusion of the investigation was that there were some unsuitable geological conditions but a construction of dam was feasible by conducting of some foundation treatments. (Referene C-1)

After that, the Mae Kuang Project was started actually as a direct management of R.I.D. in 1976. According to the progress of the project more detailed geological informations were required and the second geological investigation was conducted by themselves in 1979. (Reference C-2)

By the time, the plan and design of dams had been changed to the one almost same to the present plan by R.I.D., more large scaled than the original plan. The location of proposed right saddle dam was also shifted to the present proposed site, a little upstream from the original location simultaneously.

Recently, the government of Thailand requested to the Japanese Government to review the project and to formulate a plan of overall agricultural development at the area because some question to the optimum scale of dam and some technical problems for dam construction had appeared. The Japanese Government send a presurvey team in 1980 and feasibility study teams on dry season and wet season in 1981, responding to the request. (See Main Report)

This report describes the results of additional geological investigations and review of existing geological data, conducted by the feasibility study team.

2. Geology of the Mae Kuang Valley

2-1. Topography

The Mae Kuang damsite is located at the boundary of the Chiang Mai basin and the mountainous area which restricts on east and northeast of the basin.

The Mae Kuang originates at the border mountain range betweeen Chiang Mai Province and Chiang Rai Province and flows down passing through the mountainous area as meandering complicatedly but toward west as a whole, then, down southward just upstream of the damsite, passing the damsite and pouring into the Chiant Mai basin. After pouring into the basin, the Mae Kuang flows down to southwest and after passing through the Amphoe Sansai the river branches to several channels, turning to southward totally, and finally reaches to the confluence with the Mae Ping at about 8 kilometers southwest from the Muang Lamphun.

The catchment area of the Mae Kuang is almost all occupied by heavy mountainous area. The Mountains have summit elevations of 700 - 900 meters, steep slopes and also have an extreme tendency trending NW - SE direction. This topographical tendency is presumed to be derived from the basic geological structure as described in following clause. (See Figure C 2-1)

The transition zone from the mountainous area to the Chiang Mai basin along the Mae Kuang, in other words the contact of the Mae Kuang valley and the Chiang Mai basin extends about 3.5 km in wideness and within the spread two small mountains are existing. For the wide spread, nevertheless the mouth of the valley is restricted by these mountains, the Mae Kuang has not formed a fan toward the basin.

The Mae Kuang damsite is set just at the mouth of the Mae Kuang valley stitching two small mountains. Because of this situation, the damsite consists of three dams, the main dam which dams up the Mae Kuang main flow between these two small mountains and two sub-dams which guard an overflow from saddles behind these small mountains. On the other hand, this situation allowes to keep a big storage capacity at immediate upstream fo these dams.

2-2. Geology

Northwestern Thailand including the project area is situated in a part of so-called Burmese-Malayan folded mountain ranges, and the bedrock of the region is heavily folded palaeozoic rocks.

A geology of the Mae Kuang valley is also composed of a bedrock which is regarded of as Palaeozoic in age and overlying unconsolidated sediments of Quaternary in age.

The bedrock consists of Khaeng Krachan formation which belongs to Carboniferous and Ratburi Limestone which is of Permian in age, and the former consists of sandstone, shale, slate and their alternations and latter is composed of massive limestone. Khaeng Krachan formation is widely distributed in this region forming a mountain range, but the distribution of Ratburi Limestone is restricted in a part along to a syncline existing at eastern part of this region trending NW - SE direction.

Quaternary deposits are composed of diluvium and alluvium. Diluvium is distributed around the mountain range which consists of the bedrock forming a foothill or a fan. Alluvium is widely distributed as a flood plane deposits caused by the Mae Ping, the Mae Kuang and other rivers and also as a talus in foot of the mountains. At a surface of these quaternary deposits, a laterite which is peculiar in humid tropical region is forming extensively. (See Table C 2-1)

2-3. Geological Structure

The region is situated in a part of Burmese-Malayan folded mountain ranges as mentioned above (see Figure C 2-2). This huge folding axis is passing across the region in south-north direction but at the

Mae Kuang valley it turns to NNW or NW direction. That is to say, the tendency trending NW-SE direction which is a characteristic of the topo-praphy in the area is just the direciton of this folding axis.

The foundation of mountainous area surrounding the Mae Kuang valley was folded in various grade, cut into blocks by numerous faults mainly parallel to the folding axis. Therefore a drainage pattern of the valley belongs to a rectangular pattern.

The tectonic line which separates the Chiang Mai basin and the mountainous area runs at southwestern hedge of the mountainous area, and a sub-tectonic line derived from the primary one is presumed to pass through the Left Saddle damsite.

The geological structure around the damsite looks like a monoclinic structure as a whole with NW-SE strikes and 40°~60° NE of dips, inclin-ing toward the syncline existing about four kilometers east. However the bedrock of the area has been cut by several faults and disturbed by small scaled folding, then the dips and strikes of the bedrock vary locally. Especially the foundation of the Left Saddle damsite has been disturbed heavily.

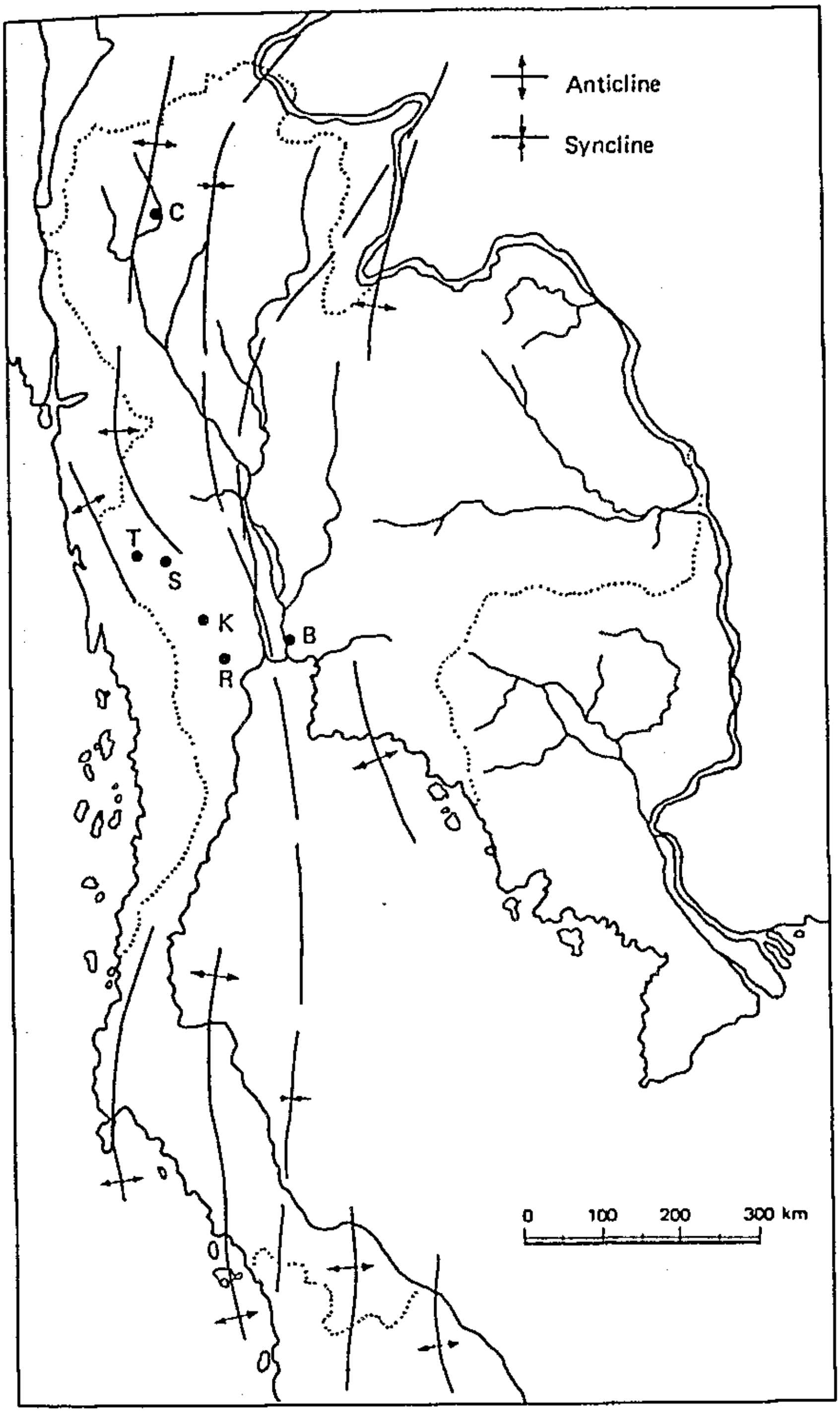
Table C 2-1 Geological Summary of West Thailand

Era	Age	Formation	Character
Cenozoic	Recent	Alluvium	Recent flood plain alluvials, sand, silts and swamps
Cenozoic	Pleistocene	Diluvium	Old fan deposits, colluvial and old flood plain deposits of high and low terraces consisting of gravels sand silts and laterite
Cenozoic	Tertiary	Si Sawat Gravel Bed	Moderately consolidated siltstone and gravel beds
Mesozoic	Jurassic	Khaeng Raboet Sandstones	Mainly red sandstones shales and basal conglomerates
Mesozoic	Triassic	Chong Khap Formation	Mainly shale with Doanella and Habbia; sandstone and interbeded limestone
Palaeozoic	Permian	Tha Madua Sandstones	Red sandstone, white quarts sandstone; thickly bedded
		Say Yok Limestones (Rat-Buri limestones)	Massive and bedded limestones containing fusulines brachiopods, and bryozoans
		Khao Muang Khrut Sandstones	Brown calcareous sandstone containing brachiopads, pelecypads bryozoans and corals.
	Carboniferous-Devonian	Khaen Krachan Formation	Pebbly mudstone, grey sandstone and dark grey shale, also red shale
	Devonian-Silurian	Bo Phloi Formation Kanchanabur Formation	Quartzite, phyllite, tuffaceous sandstone, limestone bands, brownish shale with Tentaculite, graptolite; and chert beds.
	Ordovisian	Thung Song Group	Banded, argillaceous limestone, argillite, quartzite and cephalopods
	Ordovisian-Cambrian	U Thong Marbles	Banded, white, sugary marbles; in part doromitized; also quartz mica shist
	Cambrian	Chao Nen Quartzite	Massive ortho-quartzite, bedded sandstone of brown to greenish colors, and calcareous shale
Proterozoic	Precambrian	Thabsila Gneisses	Metamorphic complexes; augen gneiss, granite gneiss, biotite microcline gneiss, quartz feldspathic gneiss, biotite schist, banded quartzite, calc silicate rocks and marbles

Age	Formation	Character
(Igneous Rocks)		
Mesozoic	Granites	Granite, granodiorite, diorite and quartz feldspathic dikes
Cenozoic	Bo Phloi Basalt.	Basalt

Source: 1978 DMR Geological Div. Geological Map of Changwat Suphan Buri (ND 47-7)

FIGURE C2-1 ILLUSTRATION MAP FOR TOPOGRAPHIC CONCEPT



T : Tong Pha Phum
S : Si Sawat
K : Kanchanaburi
R : Ratcha Buri
B : Bang Kok
C : Chiang Mai

Source: The Reservoir Photogeological Survey
Quae Yai No.1 Project

FIGURE C2-2 BRIEF GEOTECTONIC MAP OF THAILAND

3. Review of Existing Geological Investigation Data

3-1. Introduction

At the project site, the primary geological investigaiton for the dam foundation was carried out in 1974, and the second investigation was conducted in 1979. Farther the investigation for the overburden was also executed in 1978.

As a geological data in the Left Saddle damsite where some construction works are on going, There are grouting data and permeability data. These are records of the grouting works already executed according to the original design of R.I.D. and the results of permeability tests which were conducted before grouting at each stage of grout holes. Concerning to the data, there are some questions derived from a procedure and an arrangement of the test but they are available for the study of the foundation condition because of their enough quantity and conducting density.

As other geological references concerning to the area, there are a geological map of "CHANGWAT CHIANG RAI" (1/250,000 scaled) and a general geological map of Thailand (1/1,000,000 scaled), published from D.M.R. (Department of Mineral Resources).

This chapter describes a results of reviewing or analyzing for these existing reports and data, based on a study of wide scaled geological condition.

3-2. Review of Previous Investigation Reports

The first geological investigation (in 1974) consists of drillings (20 holes, total 705 m in depth) in the Left Saddle damsite, the Main damsite and the old Right Saddle damsite, in-situ permeability tests and standard penetration tests and a geological reconnaissance survey in 1/50,000 scale.

On the second investigation (in 1979), drilling works with in-situ tests (23 holes, total 457 m in depth) were carried out at the outlet line in the Left Saddle damsite, in the new Right Saddle damsite (but arched dam axis) and in the proposed spillway site. (See Table C 3-1)

As an investigation for the overburden (in 1978), 23 holes of drilling were also conducted in the Left Saddle, the Main and the old Right damsites. These drilling holes were generally short in depth (total 100 m in depth) and in-situ tests, standard penetration tests and permeability tests, at overburden were conducted.

The conclusion of the first investigation report are briefly summarised as foolws;

- Main Damsite -

a) There exists a thick and pervious river deposit in the site. The deposit should be cut off, and the depth of cut off trench is estimated as about ten meters.

b) Grouting operation should be needed because some small scaled faults are existing at places.

- Left Saddle Damsite -

a) Full cut off trench should be carried out in the site because the depth of overburden is not so thick.

b) The bedrock of the site must be improved by adequate foundation treatment. Especially on right side of the site an upmost care should be taken because a large scaled fault and sheared zone is existing.

- Right Saddle Damsite -

A right saddle damsite described by their report means an old proposed damsite where several hundreds meters downstream from the new damsite, so a description for this site has neglected.

The result of second investigation was reported as only geological logs of drilling holes and no description had been prepared. These data (logs and results of permeability tests) indicates the geological conditions as follows;

- Outlet (in the Left Saddle Damsite) -

a) Overburden materials are generally compacted and the depth of the overburden varies from 3 to 7 meters.

b) The bedrock consists of mainly slate, and the rock quality is rather sound but heavily cracked except a part of uppermost.

- Right Saddle Damsite -

a) The investigation was conducted in the new damsite but the supposed dam-axis was arched.

b) The depth of overburden is only one or two meters in both abutments, about eight meters at left side of the river bed and nearly 15 meters at right side of the river bed.

c) The overburden materials consist of sands and are compacted generally.

d) The bedrock consists of mainly sandstone and few slate beds intercalated. These rocks are usually hard but cracked. Two drilling holes at right side of the site catched sheared zones.

- Spillway -

a) The overburden on mountain slope has not developed intensively (only few meters in depth) but on the flood plain of downsteam side its depth becomes very large (about 15 meters in depth).

b) The characteristic of the overburden is sandy soil containing gravels.

c) The bedrock consists of mainly hard and cracked sandstone. Somewhere it has been weathered up to deep portions.

From these results, they concluded finally that the dam construction in the site was feasible providing an adequated foundation treatments should be executed in all damsites nevertheless the bedrocks at the site have many weak zones generally. In addition to that, they said that the geology of the reservoir area has no problem for dams and storage.

From reviewing and examining to the report and data, the following facts are clarified or pointed out.

At first, for the drilling works, a core recovery percentage was very poor for extreme example the total core length recovered was only 70 centimeters to 30 meters in drilling depth (it means only 3.5% of core recovery). These poor recovery percentages suggest that the geological conditions of the foundation must be bad considerably, but exact classification and estimation for the geological condition are almost impossible.

Then, at most holes a standard penetration test was performed in overburden but drilling cores were not recovered from every holes. It means the clues for judgement or classification of the materials are only samples taken by S.P.T. and they are only small parts and discontinuous. By these few clues judgement for the depth or classification of the overburden is very difficult. So, in some cases there are considerable differences between an estimated depth of overburden from the previous investigation and the one from the investigation executed in this time.

Farther, concerning to the permeability test, the procedure of a pressure permeability test in a rock formation (apart from a gravity test in an overburden) should be pointed out that it was not adequate as a permeability test for a dam foundation. That is, the tests in previous investigation were performed as a fixed pressure injection method but the pressure was low and the injection time was very short. If more high pressure ($10kg/cm^2$ or nearby it) and enough testing time were adapted, it was just same to "Lugeon Test" which is one of standard permeability test.

Anyhow, as a permeability test for a dam foundation "double stepped pressure injection method" should be adapted. And it is just essential to estimate a permeability coefficient and a critical pressure from a "pressure-intake curve" got by the test. (See Figure C 3-1)

From these consideration, the permeability of the bedrock calculated from the previous tests should not be estimated as the value itself.

In any events, the previous geological investigation should be considered totally that they were insufficient either in quality and in quantity, but it should be tolerated because the scale of dam plan at the site was very smaller than the present plan.

3-3. Review of Grouting Data

At the Left Saddle damsite, one row of curtain grouting and two rows of blanket grouting on the right abutment and on a part of the river bed have been conducted (Aug. 1981). In these grout holes a permeability test was carried out before grouting operaiton at every stages. The tests were conducted using a stepped pressure injection method and total quantity of the tests was enormous. Nevertheless the results of these tests contain considerable amounts of abnormal characters presumed to be derived from a defect of instruments or a leakage of injected water, they still have enough availability to appraise the permeability of the bedrocks because of their large quantity.

The permeability of the bedrock in the Left Saddle damsite varies extensively ranging from less than one lugeon to more than 100 lugeons. The lugeon map of the foundation was drawed up based on those data (Figure C 3-2). The map indicates the following situation.

From a glance of the map it is noticed that the parts having a very high permeability more than 100 lugeons extend mainly at uppermost of the foundation. This situation suggests that most of those extremely high permeability zones were derived from a weathering of the bedrock. However, some highly pervious zones distribute also in the depths and rather high permeability zones (more than several tens lugeons) usually extend to a deep portions of the foundation. And the distribution of these rather high permeability zones tends to extend vertically, certainly along some weak zones like as fault.

These permeability conditions are one of important hints for design of foundation treatment, especially for a curtain grout.

Then, "pressure-intake curves" grouped into enforcing blocks are shown in Figure C 3-1. The inclined scale of the graph means a lugeon value. The graph shows the foundation has wide ranged permeability coefficients, the lowest one is less than 0.1 lugeon and the highest one is more than 200 lugeons.

And the pressure-intake curves which indicate low permeability also indicate low critical pressure as pointed by black dot simultaneously. Among them there are some extreme cases that even the beginning pressure of the test has already exceeded its critical pressure. Farther the most of critical pressures shown in the graph are less than 5 kg/cm^2. This situation means very dangerous condition as a dam foundation, that is to say, the critical pressure at considerable part of the foundation should be less than the water head of proposed reservoir when the reservoir has filled up.

These pressure-intake curves are drawed separating the data of P-holes (Primary Holes) and the data of S-holes (Secondary Holes), but a difference between these two graphs has not recognized. It means the distance of P-holes (6 meters) is too far to improve the foundation effectively.

The relationship between a permeability and a grout intake is shown in Figure C 3-3. From the figure C 3-3 the correlation between permeability and grout intake is slightly recognized as a total view, but the variance is very large. This large variance is presumed to be derived from an error of permeability coefficient mentioned before and a problem of grouting method itself.

There are several problems concerning to the grouting method but two of the most essential problems are a leakage of grouting mixture to groundsurface and an unsuitable treatment for interrupted grout. A leakage up of grout mixture was mainly derived from a shortage of overloading or an incomplete blanket grouting. Unsuitable treatment for interrupted grout means that a flush out of the hole immeidate after the interruptation of grouting and regrouting operation had not completed. A large intake volume as compared with its low permeability mainly results from a leakage and to the contrary a small grout intake as compared with its high permeability was mainly owing to an unsuitable after treatment of an interrupted grout.

The figure has arranged seperating the P-holes and S-holes, and the figure also indicates no difference between these two groups.

Table C 3-1 Summary of Conducted Investigation

1) Primary Geological Investigation (1974)

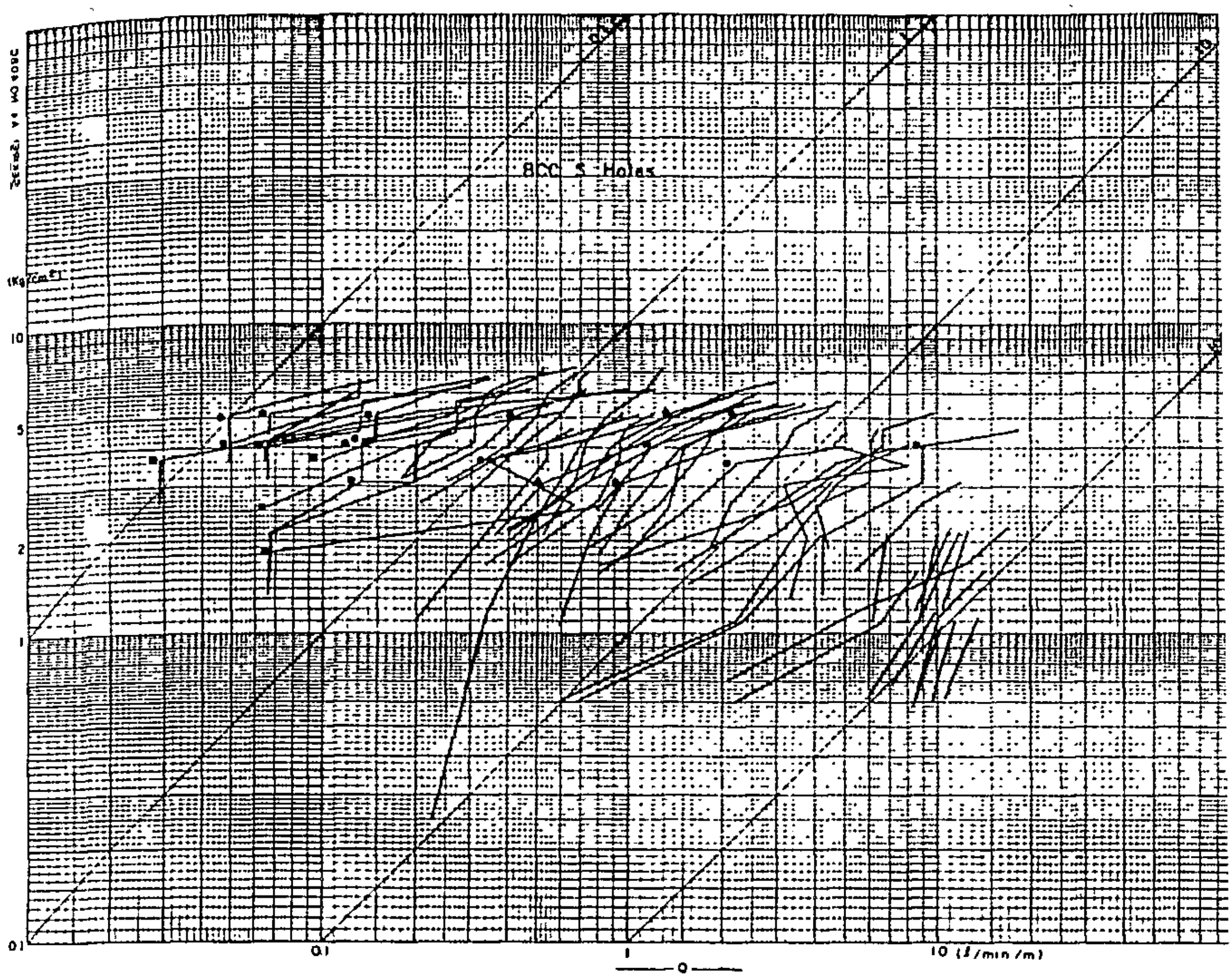
Site	Hole No.	Depth m	S.P.T.[1/] time	P.T.[2/] time	Location
Main Damsite	DH- 1	50	-	16	On center line of dam, right abutment
	DH- 2	50	-	16	On center line of dam, right abutment
	DH- 3	46	13	11	On center line of dam, river bed, right side
	DH- 4	50	-	14	On center line of dam, river bed, right side
	DH- 5	50	12	14	On center line of dam, river bed, center
	DH- 6	50	8	10	On center line of dam, river bed, left side
	DH- 7	66	-	15	On center line of dam, left abutment
	DH- 8	50	-	13	On center line of dam, left abutment
	DH- 9	50	0	13	River bed, upstream
	DH-10	43	-	9	River bed, downstream
	10	505	33	131	
Old Right Saddle Damsite	DH-11	20	-	4	On center line of dam, right abutment
	DH-12	20	8	4	On center line of dam, river bed, right side
	DH-13	20	7	5	On center line of dam, river bed, center
	DH-14	20	4	6	On center line of dam, river bed, left side
	DH-15	20	-	6	On center line of dam, left abutment
	5	100	19	25	
Left Saddle Damsite	DH-16	20	-	6	On center line of dam, right abutment
	DH-17	20	4	6	On center line of dam, river bed, right side
	DH-18	20	-	5	On center line of dam, river bed, center
	DH-19	20	3	5	On center line of dam, river bed, left side
	DH-20	20	-	5	On center line of dam, left abutment
	5	100	7	27	
Total	20 holes	705 m	59 times	183 times	

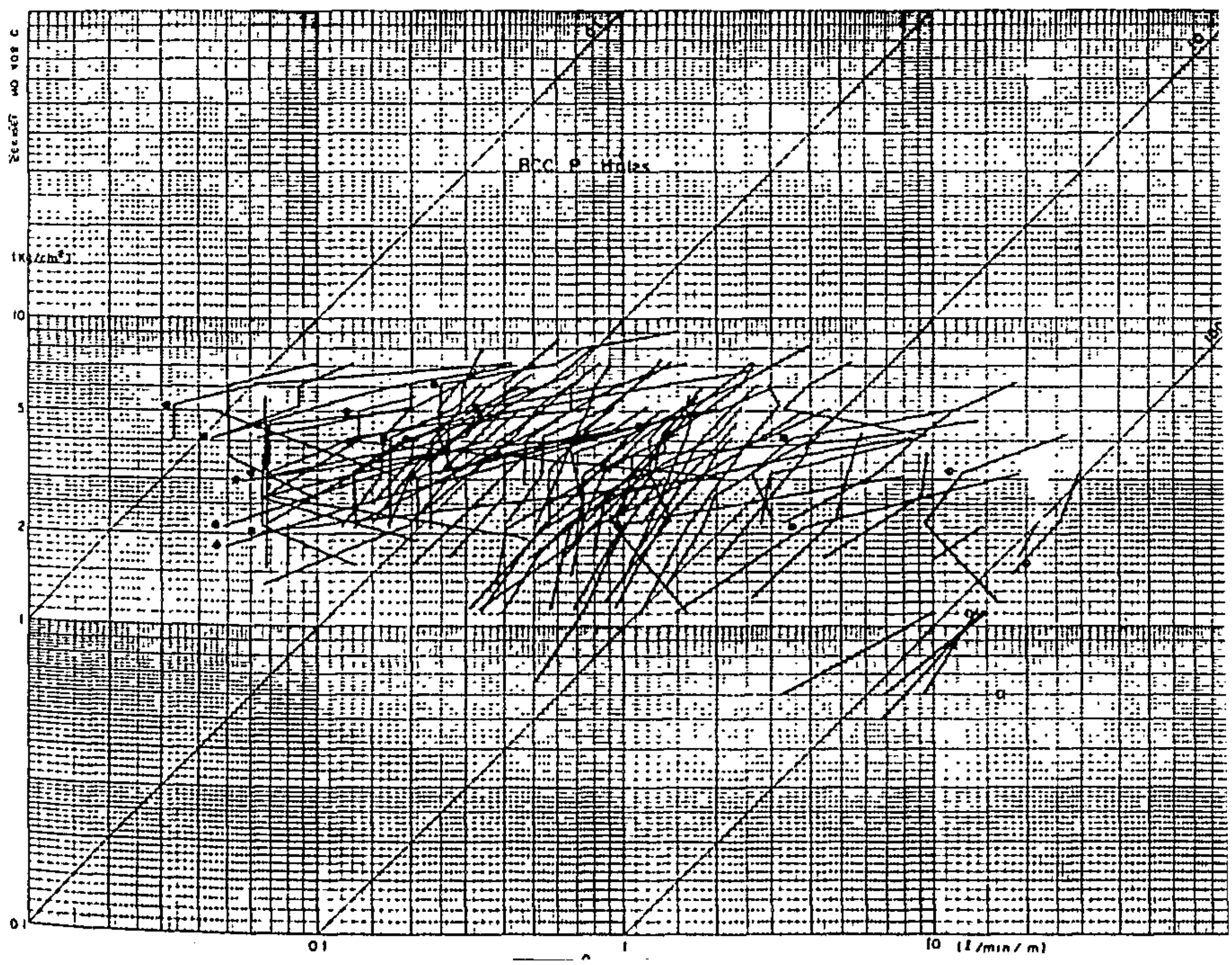
2) Second Geological Investigation (1979)

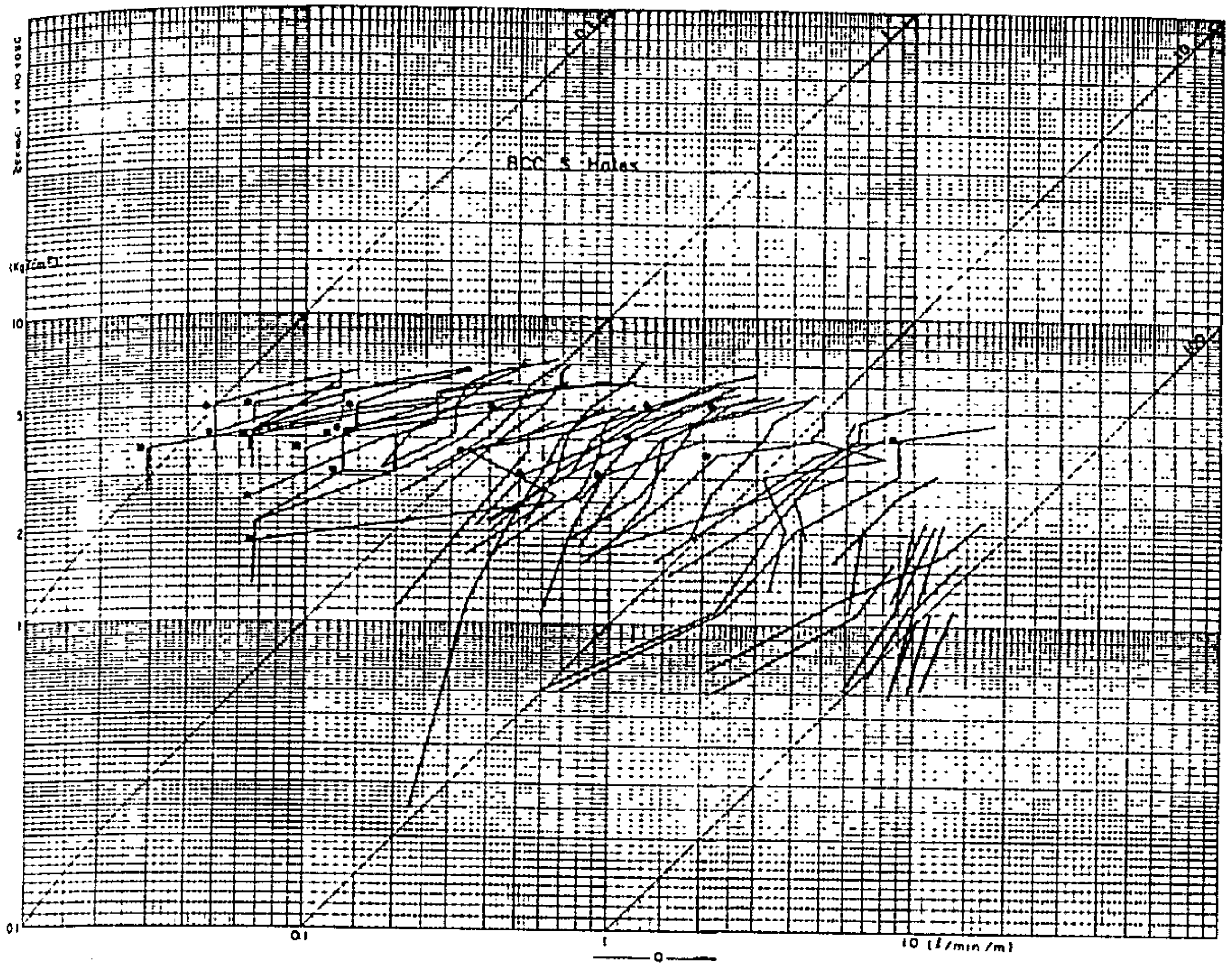
Site	Hole No.	Depth m	S.P.T.[1/] time	P.T.[2/] time	Location
Left Saddle Outlet	DH-01	20	4	15	On center line of outlet, upstream
	DH-02	20	6	15	On center line of outlet, upstream
	DH-03	20	3	15	On center line of outlet, on center line of dam
	DH-04	20	8	17	On center line of outlet, downstream
	DH-05	18	4	12	On center line of outlet, downstream
	5	98	25	74	
Spillway	DH-S1	9.5	5	6	Upstream, mountainside
	DH-S2	10.5	5	9	Upstream, mountainside
	DH-S3	12	5	10	Upstream, mountainside
	DH-S4	20	4	15	Top of the mountain
	DH-S5	17.5	5	9	Downstream, mountainside
	DH-S6	20	8	17	Downstream, mountainside
	DH-S7	13	11	12	Downstream, flood plane
	DH-S8	15.4	15	14	Downstream, flood plane
	DH-S9	14	13	12	Downstream, flood plane
	DH-S10	20	10	14	Downstream, flood plane
	DH-S11	20	13	15	Downstream, flood plane
	11	171.9	94	133	
Right Saddle Damsite (Arch axis)	DH-SD1	11	1	4	Left abutment
	DH-SD2	30	11	23	River bed, left side
	DH-SD3	30	9	21	River bed, center
	DH-SD4	30	15	21	River bed, right side
	DH-SD5	30	15	22	River bed, right side
	DH-SD6	30	6	22	River bed, right side
	DH-SD7	26.4	5	19	Right abutment
	7	187.4	62	132	
Total	23 holes	457.3 m	181 times	339 times	

1/ Standard penetration test

2/ Permeability test (including a gravity test)


BCC S Holes
(Kg/cm²)
10
5
2
1
0.1
0.1
1
10 (l/min/m)
Q


BCC P Holes
(Kg/cm²)
10
5
2
1
0.1
0.1
1
10 (l/min/m)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(Kg/cm²)
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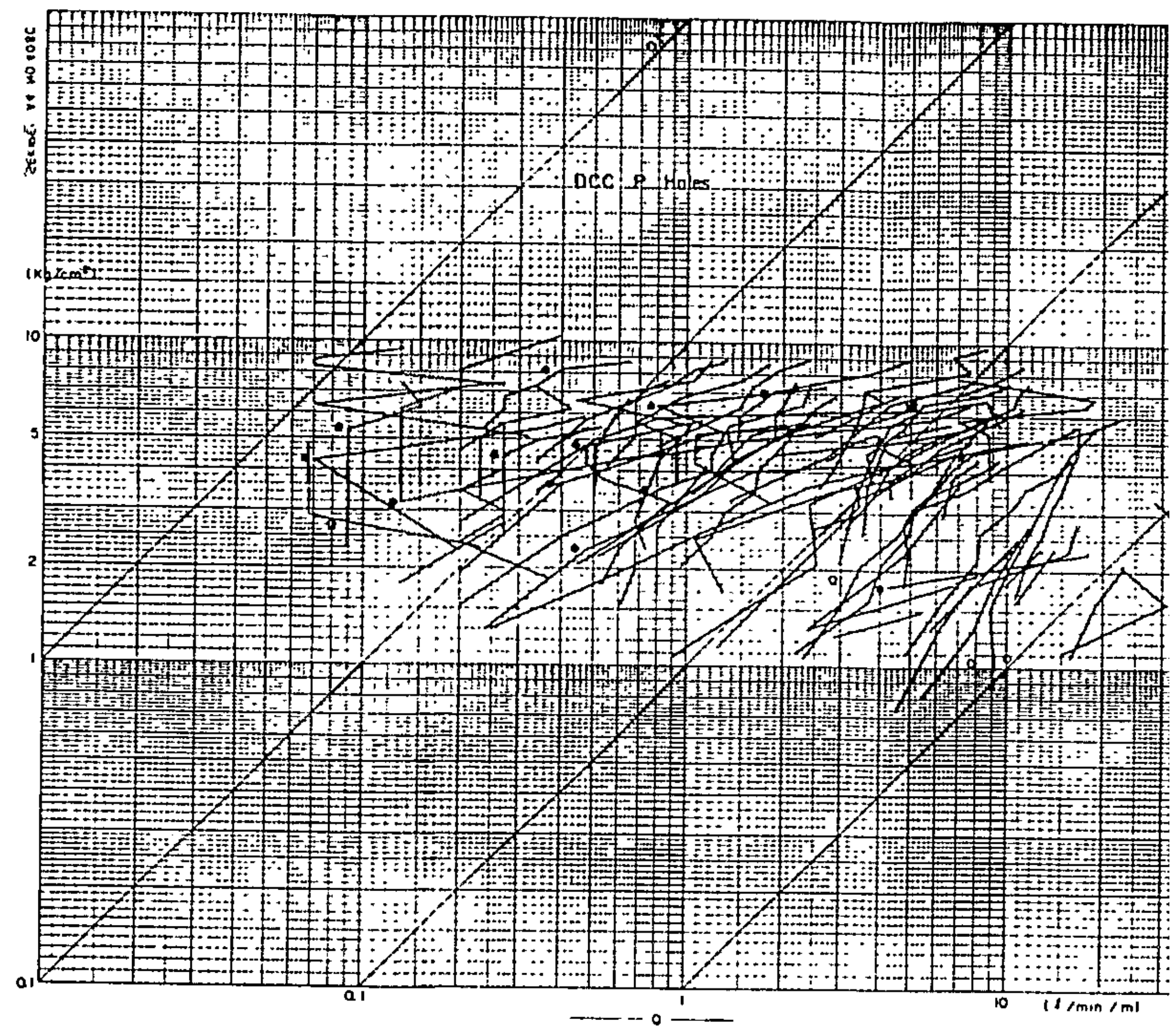
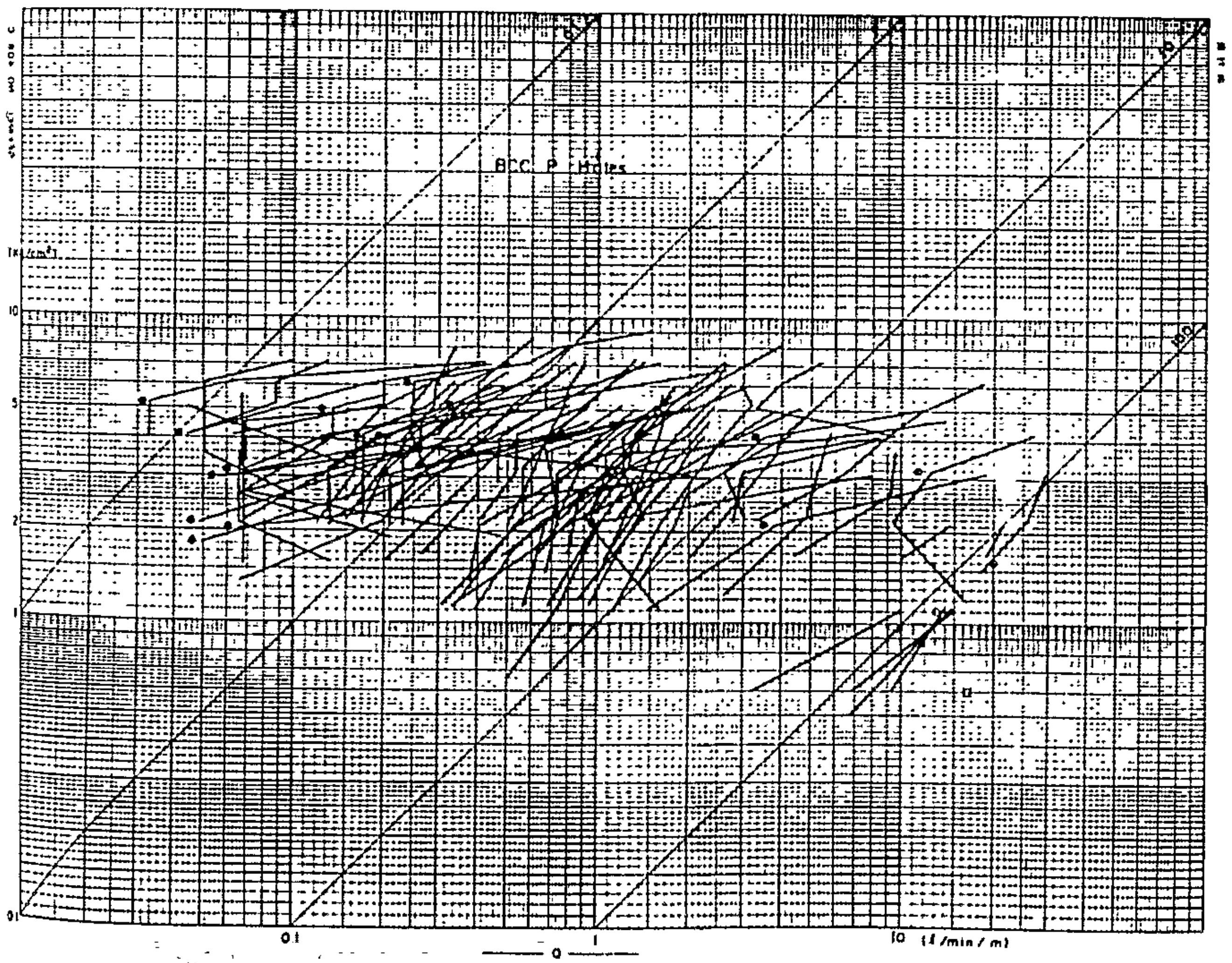

DCC P Holes
(Kg/cm²)
P
Q
(l/min/m)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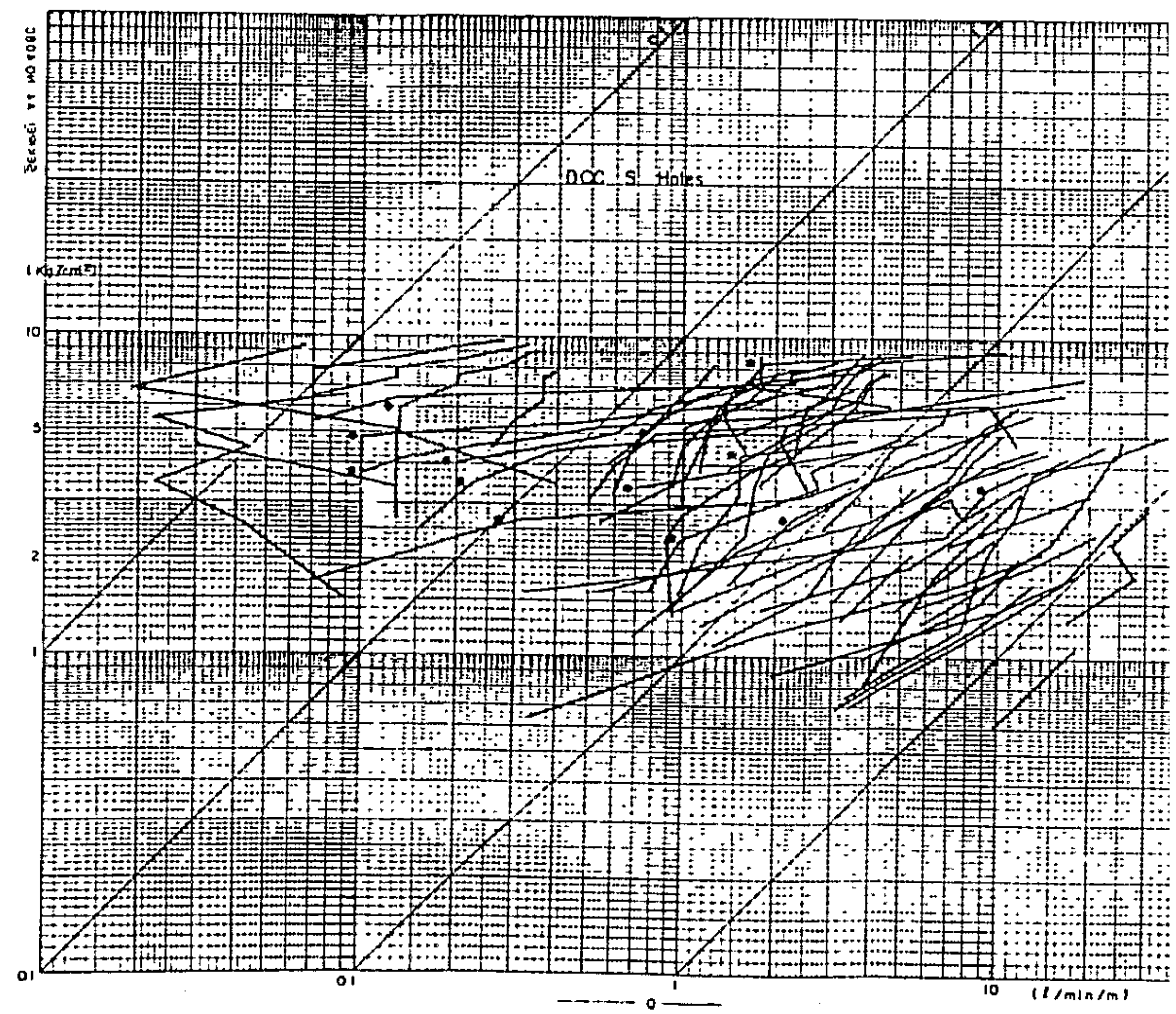

DCC S Holes
(Kg/cm²)
P
Q
(l/min/m)

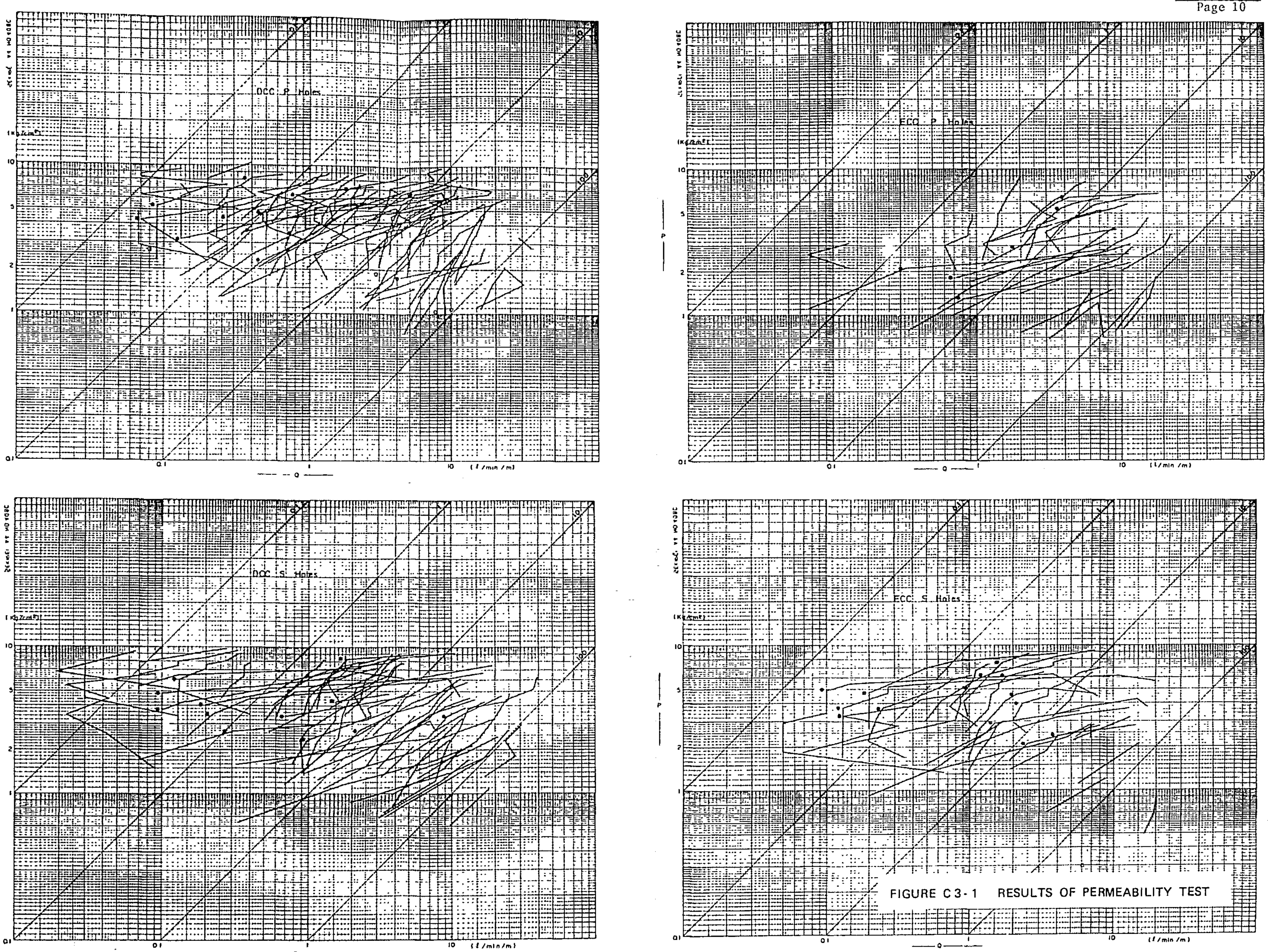
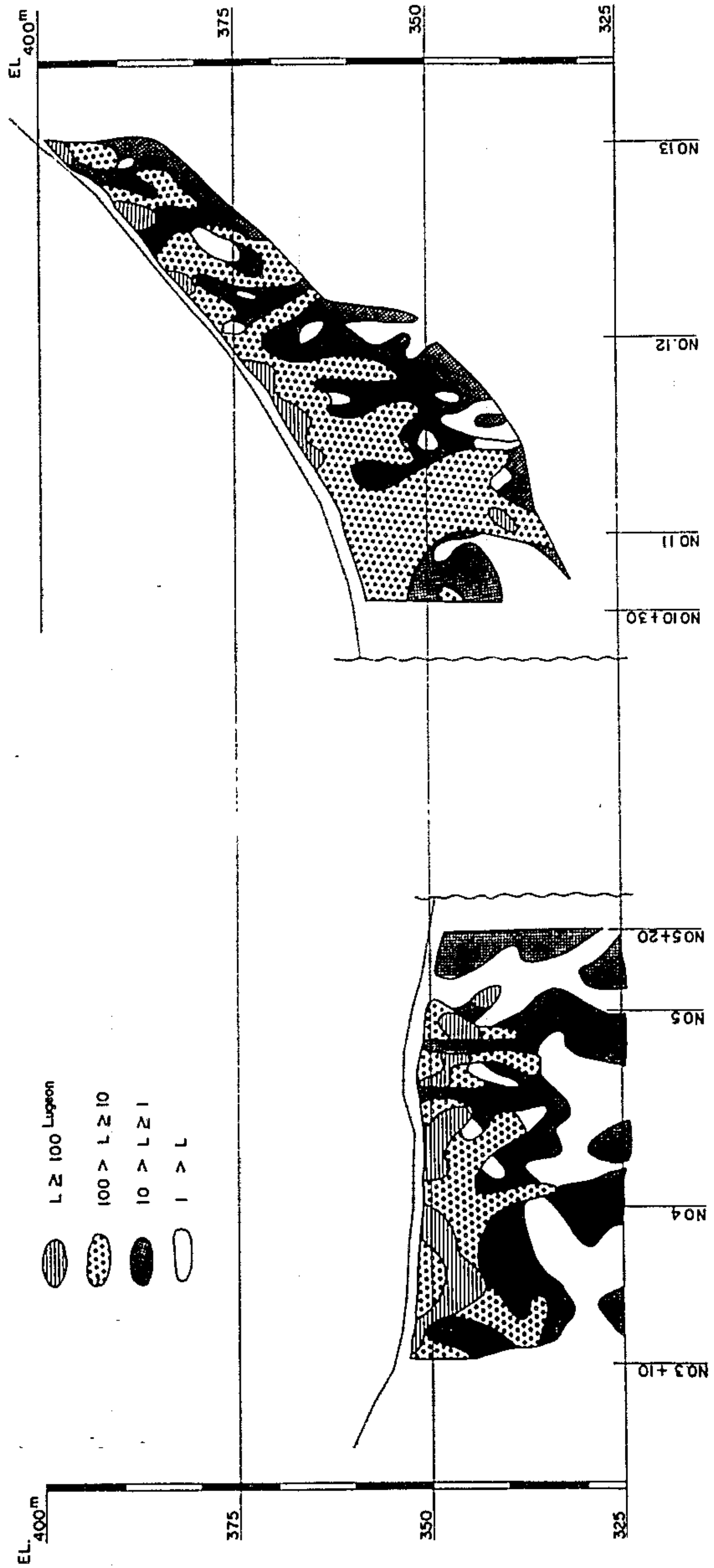


FIGURE C3-1 RESULTS OF PERMEABILITY TEST

FIGURE C3-2 LUGEON-MAP OF LEFT SADDLE DAMSITE

SCALE (H=1:1,000 V=1:500)



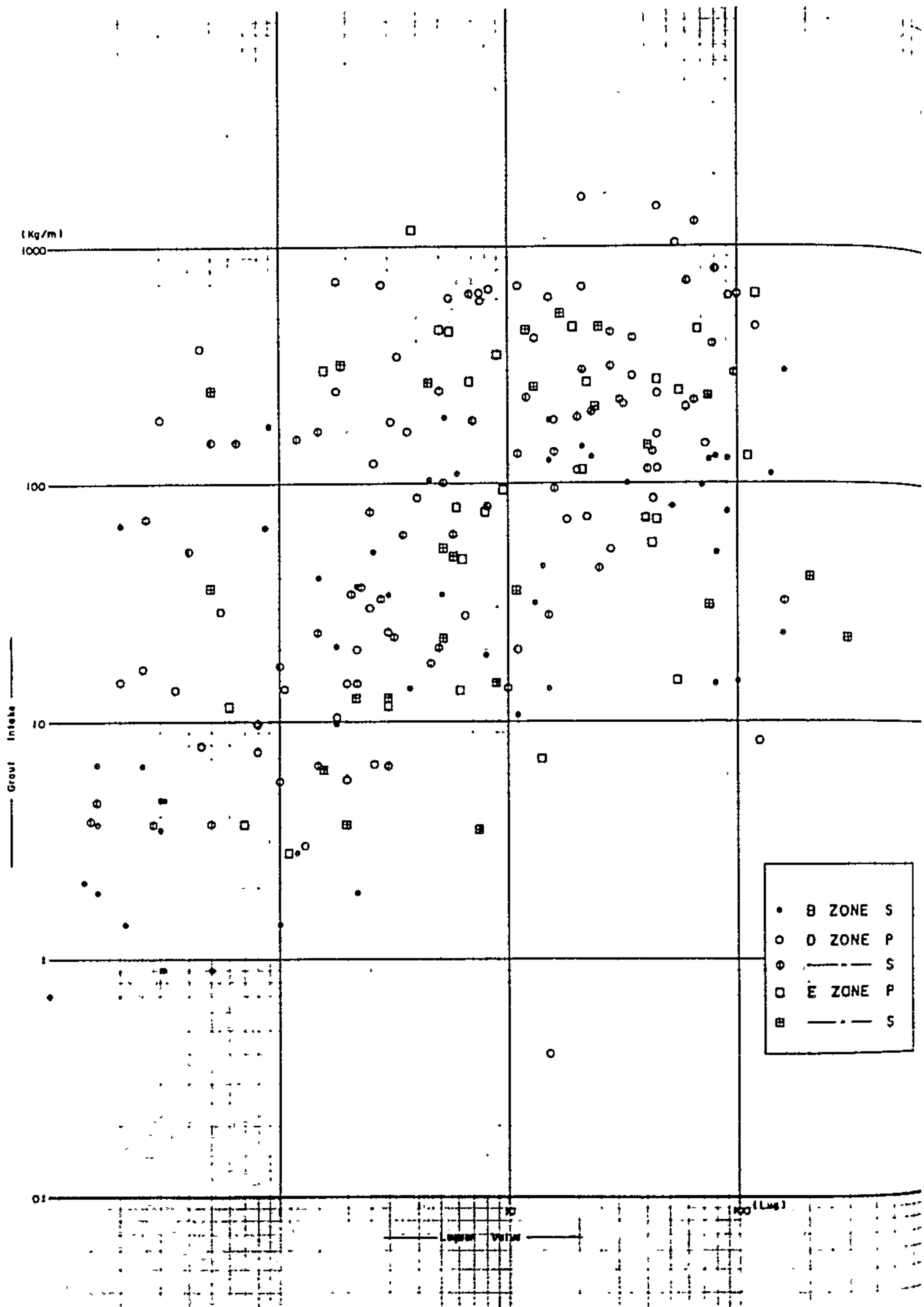


FIGURE C3-3 RELATIONSHIP BETWEEN PERMEABILITY AND GROUT-INTAKE

4. Results of the Geological Investigation

4-1. Introduction

The Government of Japan sent a First Survey Team to Thailand for 45 days, from 15 February to 31 March 1981, and a Second Stage Survey Team for 85 days, from 25 May to 19 August 1981. Through these two survey terms, geologists of the team conducted a data collection, grasping a geological and geomorphological condition of the site and additional geological investigation works.

At the chapter, the results of these geological investigation works are reported. The main subjects of geological investigations are a) field geological reconnaissance survey, b) drillings and in-situ tests, c) seismic exploration, d) bearing capacity tests and e) lateral loading tests in drilling holes.

4-2. Geological Reconnaissance

a) Reservoir area

The foundation geology of the reservoir area consists of a bedrock, diluvium and alluvium (river deposit and talus).

The bedrock consists of sandstone, sandy quartzite, slate and limestone.

The limestone is correlated with Rutburi-Limestone, permian in age, massive and hard limestone. The limestone distributes along the syncline existing to the east of the site, but in the investigated area the outcrops of it is restricted to a small isolated mountain with extremely steep slope, about 6 km north from the site. And the limestone only distributes on the elevation more than 500 m, where is enough high than the full water level of proposed dam.

The dominant bedrocks are sedimentary rocks correlated with Khaeng Krachan formation, carboniferous-devonian in age (see Table C 2-1). Sandstone and sandy quartzite are very hard and generally well bedded.

Sandstone is usually intercalated thin shale beds. Alternation of sandstone and shale is the rock phase heavily intercalated with shale beds, and the rock quality of the phase is rather hard but heavily bedded and cracked. The distribution of slate is sporadic in the area. Slate has a heavily schistosity and usually heavily altered.

The structure of the bedrock seems to be monoclinic structure with NNW-SSE or NW-SE strikes and dipping to NE as a total, but the bedrock is heavily folded and faulted parallel to or perpendicularly to the folding axis. Because of this situation the foundation has been cut into blocks and the blocks appears different dipps and strikes each other.

Diluvial deposits distribute in the right bank of the Mae Muang around the Right Saddle Damsite and in the left saddle area of the Doi Long around the Left Saddle Damsite. The deposits are rather thick and usually compacted.

Alluvium is widespread at immediate upstream of the Main Damsite along the Mae Kuang. The talus presents surrounding the small mountains and at foot of the mountainous area. The property of alluvium is mainly loose sand and sandgravel.

b) Core trench in Left Saddle Damsite

The core trench and outlet trench works are almost completed corresponding to the original design of R.I.D. in the Left Saddle Damsite. At these trenches, a geological reconnaissance and sketching were conducted.

The bedrock consists of sandstone and shale alternation and slate but slate is dominant, especially at the outlet trench almost all of the bedrock is slate. The slate has heavy schistosity and heavily altered by folding (see Picture P-1). The alternation of sandstone and slate or sandstone bed intercalated are generally hard but cracked.

Picture P-1 Slate (core trench)

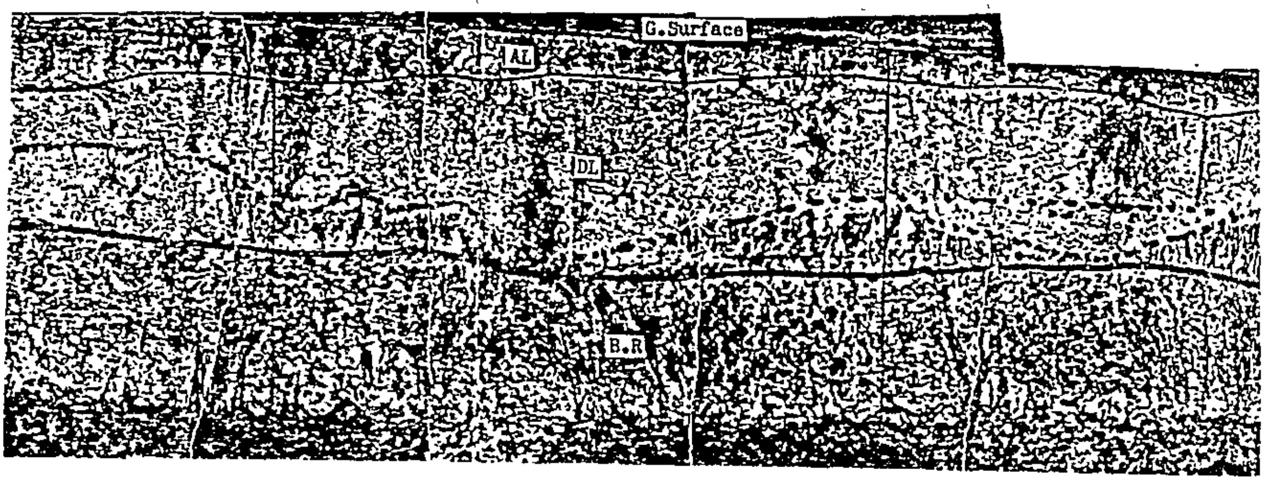
A certain part of geological sketching is shown as Figure C 4-1. It is taken from the core trench. As shown in the illustration, so many faults, sheared zones with width ranging from 1 to more than 20 meters, or a large hard rock-mass (more than four meters diameter) involved into a fault are observed. Figure C 4-2 is a "Schmidt Net" (equal area net) projected dipps and strikes of these faults and sheared zones. The net and an observation of the core trench suggest that these many faults form a fault comprex as a total, and a direction and dip are judged from the net as N33°W, 80°E to vertical.

Farther in the trenches, heavy altered zones presumed to be affected by hydrothermal alteration are observed here and there, and at these altered zones even a sandstone which is very hard originally is altered into a fragile phase, sometimes easily scratched by wooden peg.

The exposed rock surface is heavily weathered in comparison with the one immediate after an excavation. This means the rock surface exposed to the air is easily and rapidly weathered, certainly because the rock has been affected by hydrothermal alteration heavily or slightly. In this connection, the time-lag between an excavation of the trench and an embanking of core zone should be reduced at the actual construction time.

An overburden in the trenches are usually 5 to 6 meters in depth and at somewhere 8 meters in depth, and mainly consists of well compacted diluvial deposits. An alluvial deposit destributes thinly at the top of the overburden as a top-soil, but at a gully it is rather thick (see Picture P-2).

Picture P-2 Overburden (trench)



4-3. Drillings and Permeability Tests

The investigation drillings and in-situ tests were conducted in three damsites. The quantity of drilling works and tests are shown in Table C 4-1.

Table C 4-1 Bill of Quantity for Drilling Works

Site	Hole No. (hole)	Depth (m)	2/ S.P.T (time)	3/ P.T (time)	Location
Left Saddle Damsite	1/ LAD - 1	36	-	-	on ℄ dam, right abutment
	LAD - 2 4/	35	-	6	on core trench, center
	LAD - 3 4/	35	-	6	on core trench, left side
Sub-total	3	106	0	12	
Main Damsite	MAD - 1	50	4	7	on ℄ dam, river bed, center
	MAD - 2	50	12	7	on ℄ dam, river bed, left side
	MAD - 3	30	9	(3)	on ℄ dam, river bed, right side
Sub-total	3	130	25	17	
Right Saddle Damsite	RAD - 1	28	5	3	on ℄ dam, river bed, left side
	RAD - 2	28	4	2	on ℄ dam, river bed, center
	RAD - 3	28	10	2	on ℄ dam, river bed, right side
	RAD - 4	28	15	2	on ℄ dam, river bed, right side
	RAD - 6	20	1	2	upstream, river bed, center
Sub-total	5	132	35	11	
Total	11	368	60	40	

1/: inclined hole (45°), drilled by R.I.D.
2/: Standard Penetration Test
3/: Permeability Test
4/: from the bottom of core trench

The locations of these drilling holes were selected to compensate the long distance of previous drilling holes, or at the points where the foundation seemed to have some geological problems estimated from the results of seismic exploration.

Among these drilling holes only LAD-1 hole was inclined hole and conducted by R.I.D. The other drilling holes were drilled vertically using NX sized core-barrel (about 75 m/m).

As an in-situ test, a standard penetration test at an overburden and a pressure permeability test at a rock formation were performed except in an inclined hole.

The results of these investigaiton drilling were arranged as a geological loggs and attached in the end of the report, and they are briefly described in following clause according to the summarized charts (see Figure C 4-3 (1) to Figure C 4-3 (3)).

* Left Saddle Damsite

At the Left Saddle Damsite three additional drillings were carried out. The results of the drillings also show that a slate is highly dominant and a sandstone beds slightly distribute at depths on right abutment as a foundation rock. The rock quality is generally poor like as the R.Q.D. (Rock Quality Designation) of the foundation rock was judged as almost zero (0) except a sandstone existing at the depths.

At the time, the upmost cares had been taken to catch the drilling cores, so the core recovery percentage was improved than the previous one but a full core recovery was also not achieved (there were some core-lacks at where presumed to be fault-clay or heavily sheared zone). However these core-lacks were due not only to a rock quality but to a drilling technique certainly.

At the site a standard penetration test was not performed because two holes were drilled form the bottom of core trench and another was drilled as inclined hole. Permeability tests were carried out in two vertical holes and the results indicated rahter high permeability coefficients ranging from 20 to 70 lugeons in general and more than 100 lugeons in considerable parts.

* Main Damsite

The river deposit of the site has developed extensively and thickly (ranging from 12 to 16 m in depth). The properties of the deposit are sandy or sandgravelly and rather loose. The N-values of the deposit are less than 10 at an upper part and nearby the groundwater level, and about 20 or more at the sand or sandgravel layers.

The bedrock consists of mainly sandstone (including a sandy-quartzite) and few thin slate or shale beds intercalated. The quality of the bedrock is generally good and R.Q.D. of the drilling cores are usually more than 50% except the MAD-3 hole which drilled through a wide sheared zone.

The foundation of the site has rahter high permeability coefficients of about 70 lugeons as an average except a sound shale bed, nevertheless the quality of it is rather good.

* Right Saddle Damsite

At the site the overburden extends thinly in left side and very thickly in right side. The depth of overburden is 6, 7 meters in left side but about 17 meters in right side. These tendency is just same to the results of previous investigation which performed along an arched damaxis. The overburden consists of mainly sand but containing much clayey components at right side, and it is generally compacted

The foundation was occupied mainly by sandstone with good quality and few shale interbedded. However RAD-4 hole at right side of damaxis drilled through thick altered zone (argillizated zone) and it suggests there exists a fault zone nearby the hole.

The bedrock of the site shows lower permeability than the others but it also ranges from 10 to 30 lugeons and more than 100 lugeons locally.

As shown in the figures, at the drilling holes in the Right Saddle damsite and at the hole in the Main damsite the lateral loading tests were carried out, and the results shall be described after.

4-4. Seismic Exploration

The seismic exploration survey were conducted by the team and by R.I.D. (the Right Saddle damsite and Spillway site). Total quantity of the exploration is 15 lines, about 5.8 kilometers (see Table C 4-2). The locations of each observation lines were shown in attached "Location Map".

The analyzing results of the seismic exploration were arranged as attached sheets "Analyzing Chart of Seismic Exploration", and briefly described in this clause.

Table C 4-2 Quantity of Seismic Exploration

Site	Line (Line)	Length (m)	Remarks
	A - Line	770	on ℄ Dam
	B - Line	330	
Left Saddle Dam	C - Line	330	
	D - Line	220	
Sub-total	4	1,650	
	A - Line	650	on ℄ Dam
	B - Line	330	
Main Dam	C - Line	330	
	D - Line	330	
Sub-total	4	1,640	
	A - Line	660	on ℄ Dam (new axis)
	B - Line	330	
Right Saddle Dam	C - Line	330	
	D - Line	220	
Sub-total	4	1,540	
	S - Line	330	on ℄ Spillway
Spillway	M - Line	550	extended from Main Dam
	E - Line	110	
Sub-total	3	990	
Total	15	5,820	

* Left Saddle Damsite

The foundation of the site has analyzed mainly as three layered structure and in some restricted part it analyzed as four layered or two layered structure. These velocity layers are farther classified into two sub-layers respectively, and the classification of the velocity layers including a correlation with geology is arranged as follows;

Layer	Sub-layer	Velocity		Geology
- The I layer	I-1	V = 0.4 - 0.55 km/sec		Top soil (alluvium)
	I-2	V = 0.7 - 0.8	"	Diluvium, embankings
- The II layer	II-1	V = 1.0 - 1.2	"	compacted diluvium, heavily weathered rock
	II-2	V = 1.5 - 1.6	"	weathered rock
- The III layer	III-1	V = 2.7 - 3.0	"	cracked or soft bedrock
	III-2	V = more than 3.5	"	sound bedrock
- Low-velocity-zone		V = 1.5 - 2.2	"	sheared or altered zone

The I layer distributes thinly at the top of the foundation and the thickness of the II layer is also small (nearly 10 m). At the core trench (A-Line), the foundation consists of contrastive two velocity layers, overburden and bedrock, and the elastic wave velocity of the overburden is abnormally high (certainly because of the affection of grout mixture).

More than a half part of the bedrock is occupied by the III-2 layer, and it indicates the bedrock is rather hard. In spite of that, the bedrock of the site should be disturbed heavily judging from the facts that nearly ten zones of low-velocity-zones are discovered along the damaxis and the III-1 layer correlated with soft or heavily cracked rock are scattered throughout the foundation. The distribution of the III-2 layer indicates the bedrock of the site is rather good than the appearance of it observed in the trench.

* Main Damsite

Almost all part of the Main damsite has analyzed as a three layered structure, and only a few part has analyzed as a two layered. These layers had farther classified into sub-layers from their elastic wave velocity. These classification of velocity layers is correlated with each representative geology as shown below;

- The I layer	I-1	V = 0.4 - 0.5 km/sec	—— top soil
	I-2	V = 0.6 - 0.7 "	—— gravelly soil, diluvium
- The II layer	II-1	V = 1.0 - 1.2 "	—— overburden under water
	II-2	V = 1.4 - 1.2 "	—— ditto but gravelly weathered rock
- The III layer	III-1	V = 2.6 - 2.8 "	—— shale, slate
	III-2	V = 3.0 - 3.3 "	—— cracked s.s, alternation
	III-3	V = morethan 3.6 "	—— sound sandstone
- Low-velocity-layer		V = 1.5 - 2.2 "	—— fault

The I layer is generally thin (less than 5 m). The II layer which means a river deposit is very thickly extending (usually more than 10 m and 20 m in maximum depth), but the one which means a weathered rock distributes not so thickly (10 m in maximum thickness) at both abutments.

As a base-velocity-layer, the layer of lower velocity (III-1) distributes at both abutments and the layer of middle and high velocity (III-2, III-3) distribute in the riverbed area. Among them, the III-3 layer indicates the rock quality is very hard and few cracked.

Two large scaled low-velocity-zones are discovered at the foot of both abutments and some other low-velocity-zones are found out in the site.

* Right Saddle Damsite

Nearly a half of the site has analyzed as a three layered structure and another half has analyzed as a four layered structure. Usually the three layered structure has lacked the II layer.

These four layers are classified into some sub-layers, and these layers are correlated with representative geology respectively as follows;

- The I layer		V = 0.35 - 0.5 km/sec	—— top soil
- The II layer	II-1	V = 0.6 - 0.7 "	—— diluvium
	II-2	V = 1.0 - 1.4 "	—— compacted diluvium, heavily weathered rock
- The III layer		V = 1.8 - 2.2 "	—— weathered rock
- The IV layer	IV-1	V = 2.9 - 3.1 "	—— heavily cracked rock
	IV-2	V = 3.4 - 3.5 "	—— cracked s.s, alternation
	IV-3	V = more than 3.8 "	—— hard sandstone
- Low-velocity-zone		V = 1.8 - 2.2 "	—— fault, altered zone

The thickness of the I layer is generally small but at somewhere it reaches to 5 or 6 meters. The II layer regarded as a diluvium distributes thinly at the left bank(nearly 5 m) and very thickly (15 m in maximum thickness) at the right bank of the riverbed. The III layer underlies below the II layer in the riverbed but underlies directly below the I layer at the both abutments (the II layer is lacked). The thickness of the III layer is generally large, about 20 meters in average and about 30 meters in maximum thickness.

Among the base-velocity-layers (the IV layer), the layers with higher velocity (IV-2,IV-3) distribute along the damaxis. This situation indicates the quality of the bedrock is generally good, but it also indicates the bedrock under the part from center to right side end of the riverbed has been disturbed hardly simultaneously, because altogether four wide low-velocity-zones concentrate to the part. Aside from the part, some low-velocity-zones are discovered at the left abutment, the left side of the riverbed, downstream of the damaxis and so on.

* Spillway

At the site, almost all observation lines have analyzed as a four layered structure and only few part is analyzed as a five layered structure. These velocity layers are correlated with a certain geological conditions respectively as shown below.

- The I layer	V = 0.35 - 0.5 km/sec	—— top soil
- The II layer	V = 0.8 - 1.0 "	—— talus, heavily weathered rock
- The III layer	V = 1.6 - 2.0 "	—— weathered rock
- The IV layer	V = 3.1 - 3.3 "	—— cracked sandstone
(- The V layer)	V = more than 4.2 "	—— massive hard sandstone
- Low-velocity-zone	V = 1.5 - 2.2 "	—— fault

The I layer covers the top of the foundation very thinly. The II layer distributes at the mountain slopes of upstream and downstream side, and the thickness is 4, 5 meters in general and 10 meters in maximum. The thickness of the III layer is generally large, about 20 meters in average and more than 30 meters in maximum thickness. Most of the IV layer which is an usual base-velocity-layer of the site indicates 3.3 km/sec of elastic wave velocity and it means a common cracked sandstone. Farther, at the base of the ridge the V layer (V>4.2 km/sec) underlies below the IV layer and the layer seems to be a massive and very hard sandstone or quartzite.

Altogether five low-velocity-zones are discovered along the center line of spillway (S-line), and many low-velocity-zones are existing along the M-line which means an extention of the Main Damaxis.

The observation line for the spillway (S-line) was a little shifted from the center line of proposed spillway, and the result of analysis was projected to the center line based on the depth of each layer.

4-5. Bearing Capacity Tests

At the core trench of the Left Saddle damsite, the bearing capacity tests, so-called a jack tests were planned and conducted targeting to the bedrock, especially to an altered zones. However the tests had completed only at two points among planned 6 points because they had started from June when was already in wet season. The rest of the tests are expected to be conducted by R.I.D. The location of these test points are shown in Table C 4-3 (at the Table ST.0 means a point of elevation 400 m. at the left abutment).

Table C 4-3 Location of Bearing Capacity Tests

Tests No.	Location	Target Geology
No.1	ST. 0 + 80 m.	Sheared Zone
No.2	ST. 0 + 240 m.	Altered Zone
No.3	ST. 0 + 265 m.	Sound Rock
No.4	ST. 0 + 276 m.	Sheared Zone
No.5	ST. 0 + 300 m.	Sheared Zone
No.6	ST. 0 + 420 m.	Sound Rock

The tests were carried out using a loading plate of 30 cm diameter and repeated loading method. The loading plan adopted is shown as Figure C 4-4. Farther the maximum load was decided as 20 tons from the consideration for over loading material and for the design load by embankment (10 kg/cm^2, about 7 tons converted to the loading plate), but in these tests performed actually the load could not get to a planned maximum load because of heavy subsidence of the loading plate.

The analyzid charts are shown in Figure C 4-4 (1) to Figure C 4-4 (2). The result of No.1 test shows that both of the critical pressure and the failure-strength are extremely low, about 9.6 kg/cm^2 and about 14 kg/cm^2 respectively. The result is derived from that the target point of the test was heavily altered and sheared zone, and it indicates even the critical pressure of the point is less than the design load.

The No.2 test targetting a weathered sandstone indicates a rather high critical pressure of about 22 kg/cm^2 which means about twice times of the design load. The result suggests the weathered sandstone has a bearing capacity for the dam at least, but the value is not enough for dam foundation (usually a critical pressure of dam foundation is required a value more than three times of the design load).

4-6. Lateral Loading Tests

At the time of the Second Stage Survey, the lateral loading tests in drilling hole were conducted. The instrument for the test was carried from Japan by the team. The instrument was adapt for a drilling hole of 66 m/m diameter which is the most popular drilling size in Japan, but at the site all drilling holes had been drilled using a NX sized core-barrel (about 75 m/m), so the testing was rather difficult (at some holes the lateral load could not get enough).

The results of the test, "stress-strain curve', are shown in Figure C 4-5 (1) to Figure C 4-5 (6) and each physical values got from the charts are listed in Table C 4-4.

Table C 4-4 Results of Lateral Loading Test

No.	Hole	Depth (m)	Geology	1/ C.P (kg/cm^2)	2/ K (kg/cm^3)	3/ E (kg/cm^2)
No.1	RAD - 1	8.00	Sandstone	74.5	2,240	11,400
No.2	RAD - 2	11.00	Slaty Shale	71.5	5,136	27,200
No.3	RAD - 3	17.65	weathered SS	-	1,500	7,570
No.4	RAD - 4	18.10	Sandstone	-	3,160	16,080
No.5	RAD - 6	6.50	weathered SS	35.0	1,190	6,690
No.6	MAD - 3	11.40	Gravels	15.5	200	1,130

1/: Critical Pressure (kg/cm^2)

2/: K - Value (kg/cm^3)
coefficient of subgrade reaction

3/: Elastic Constant (kg/cm^2)

From a consideration of these values, the bedrocks irrespective of sandstone or shale have enough high physical values like as more than 70 kg/cm^2 of critical pressure, more than 3,000 kg/cm^3 of K-value and also more than 10,000 kg/cm^2 of elestic constant. While the weathered zone of the bedrocks shows an inferior physical property as a rock like as less than 2,000 kg/cm^3 of K-value, in several thousands kg/cm^2 order of elastic constant and a critical pressure nearly a half value of the sound rock's one. However, these values indicate that they are enough tough for the load by embanking at the site even if they were weathered.

Farthermore, these values of sound rocks got by the tests are presumed to be less about one order as a values of sound rock distributed in the site, and these results are also presumed to be derived from the situation that they were cracked heavily and slightly disturbed by drilling.

At the MAD-3 hole, the sand-gravel layer had been tested and the result indicates the layer has been well compacted.

FIGURE C 4-1 GEOLOGICAL SKETCH OF CORE TRENCH (a part)

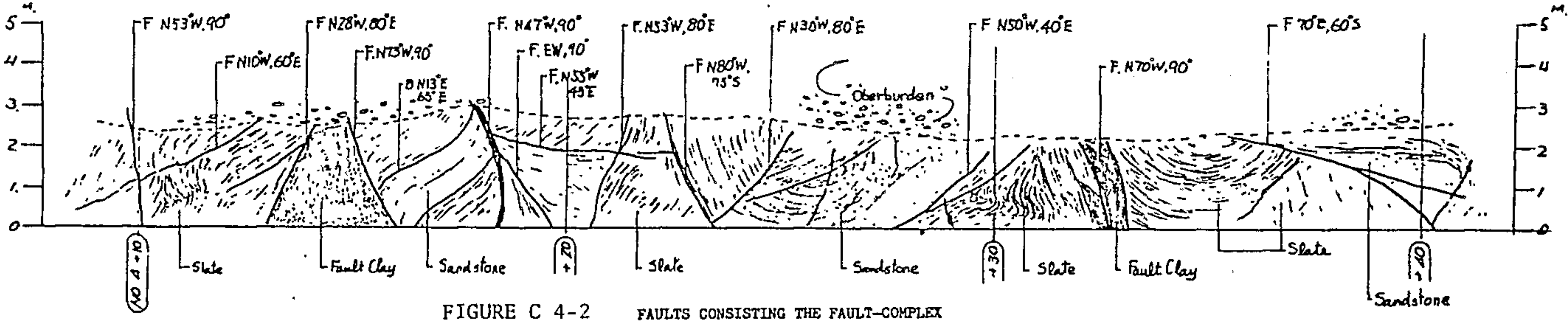
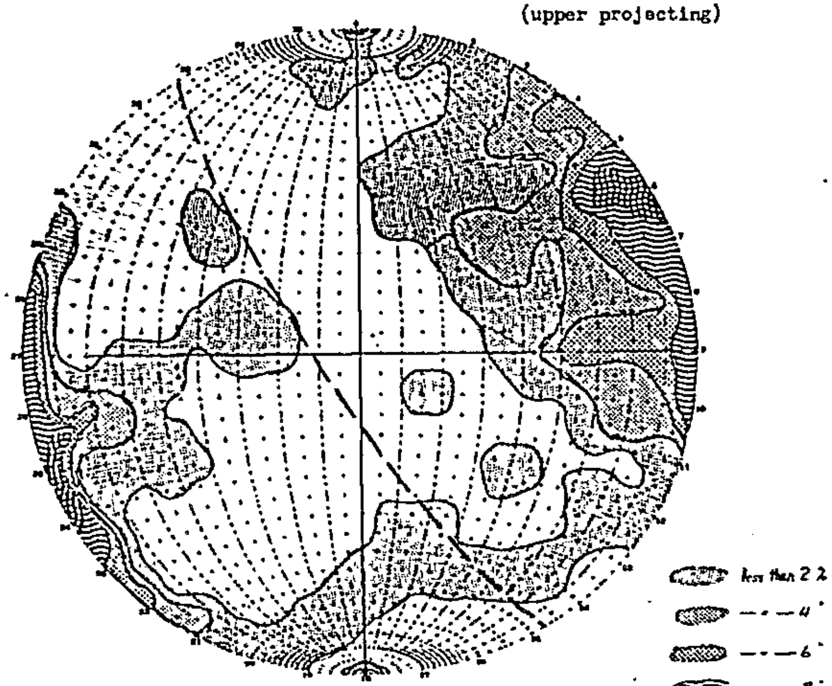


FIGURE C 4-2 FAULTS CONSISTING THE FAULT-COMPLEX

(upper projecting)



Reproduced from chart prepared by the
United States Department of Interior Geological Survey

EQUAL AREA NET - MERIDIONAL PROJECTION OF THE HEMISPHERE

LEFT SADDLE DAM

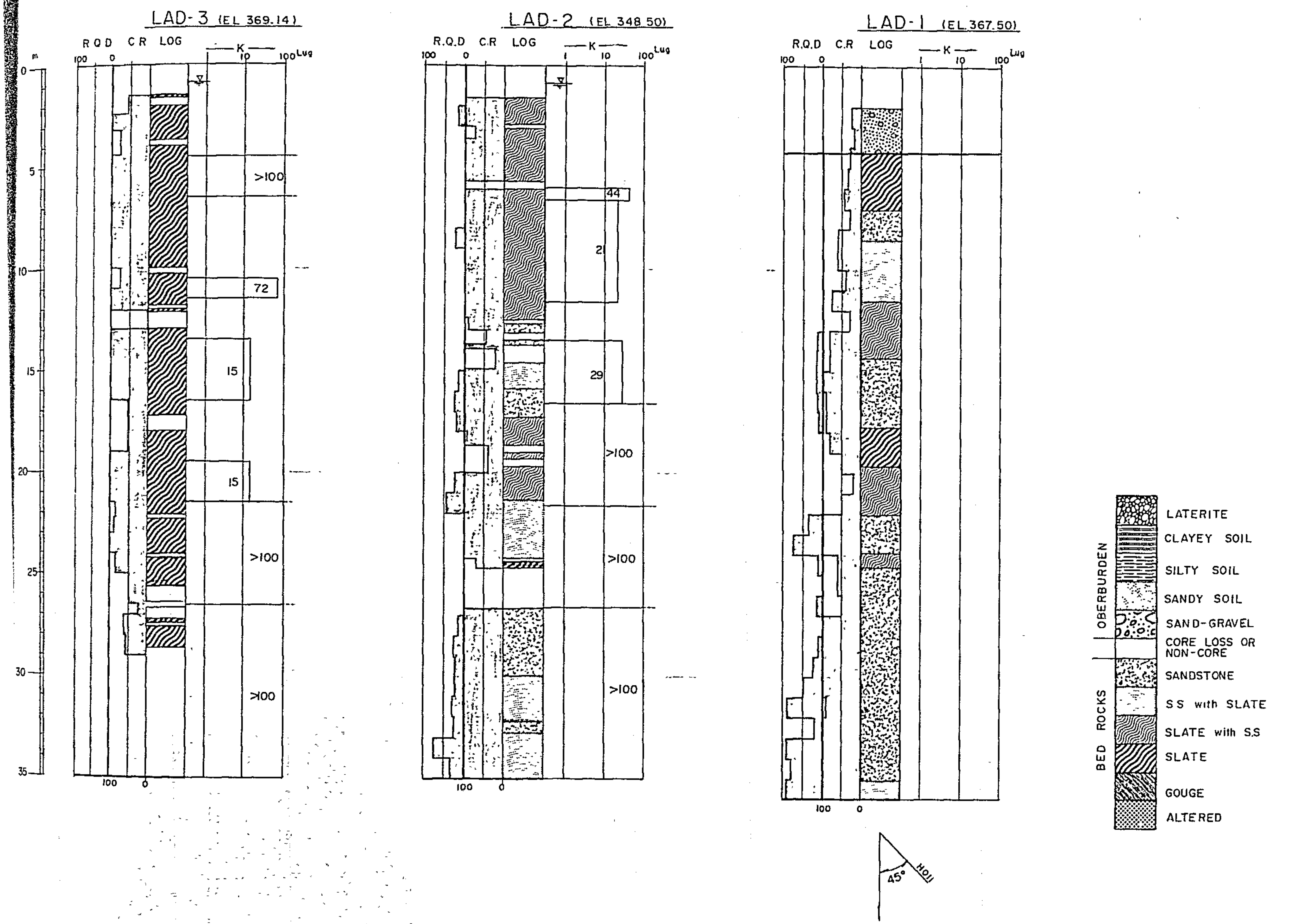


FIGURE C4-3(1) GEOLOGICAL LOG OF BORE HOLE (LEFT SADDLE DAM)

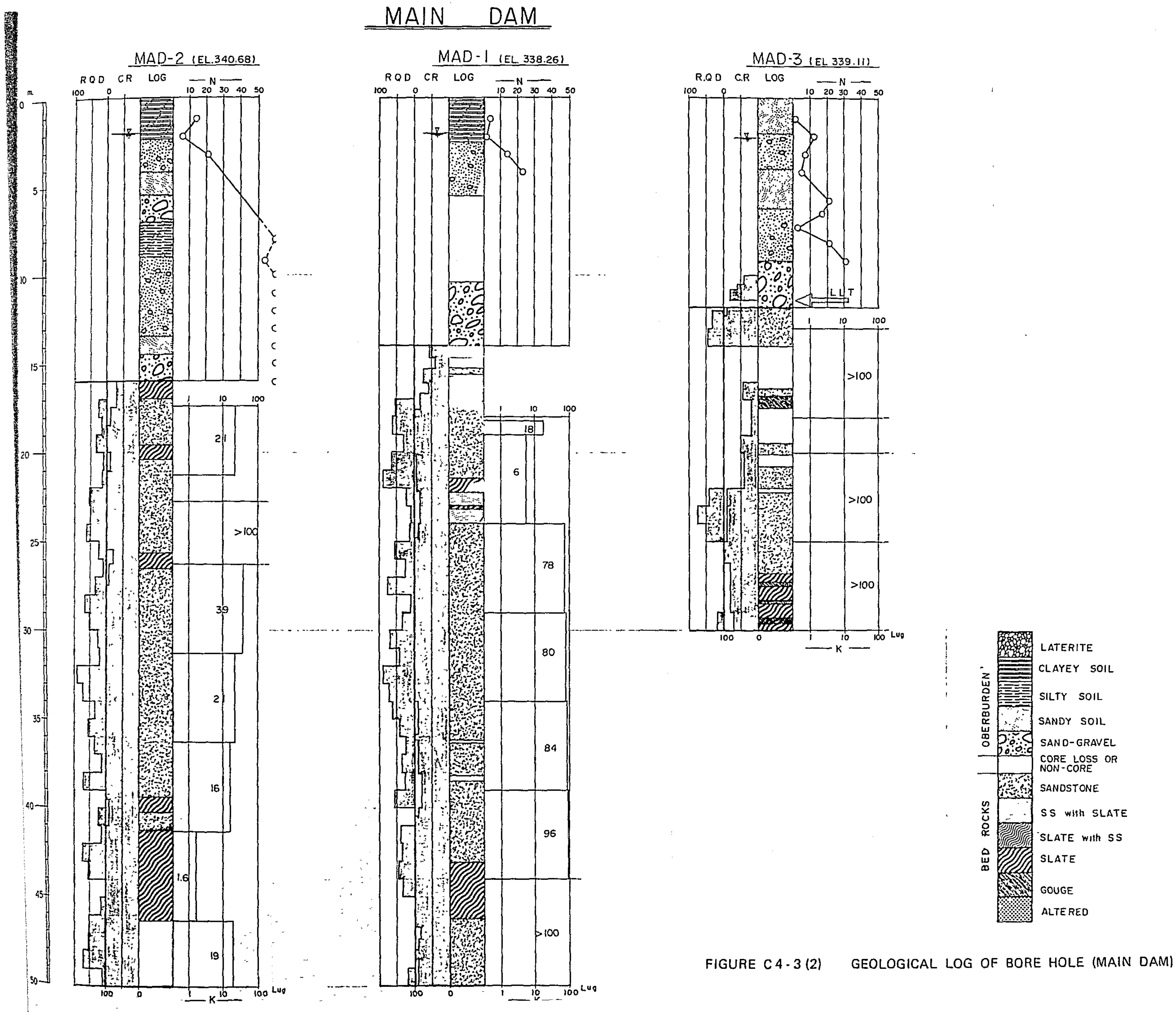


FIGURE C4-3(2) GEOLOGICAL LOG OF BORE HOLE (MAIN DAM)

RIGHT SADDLE DAM

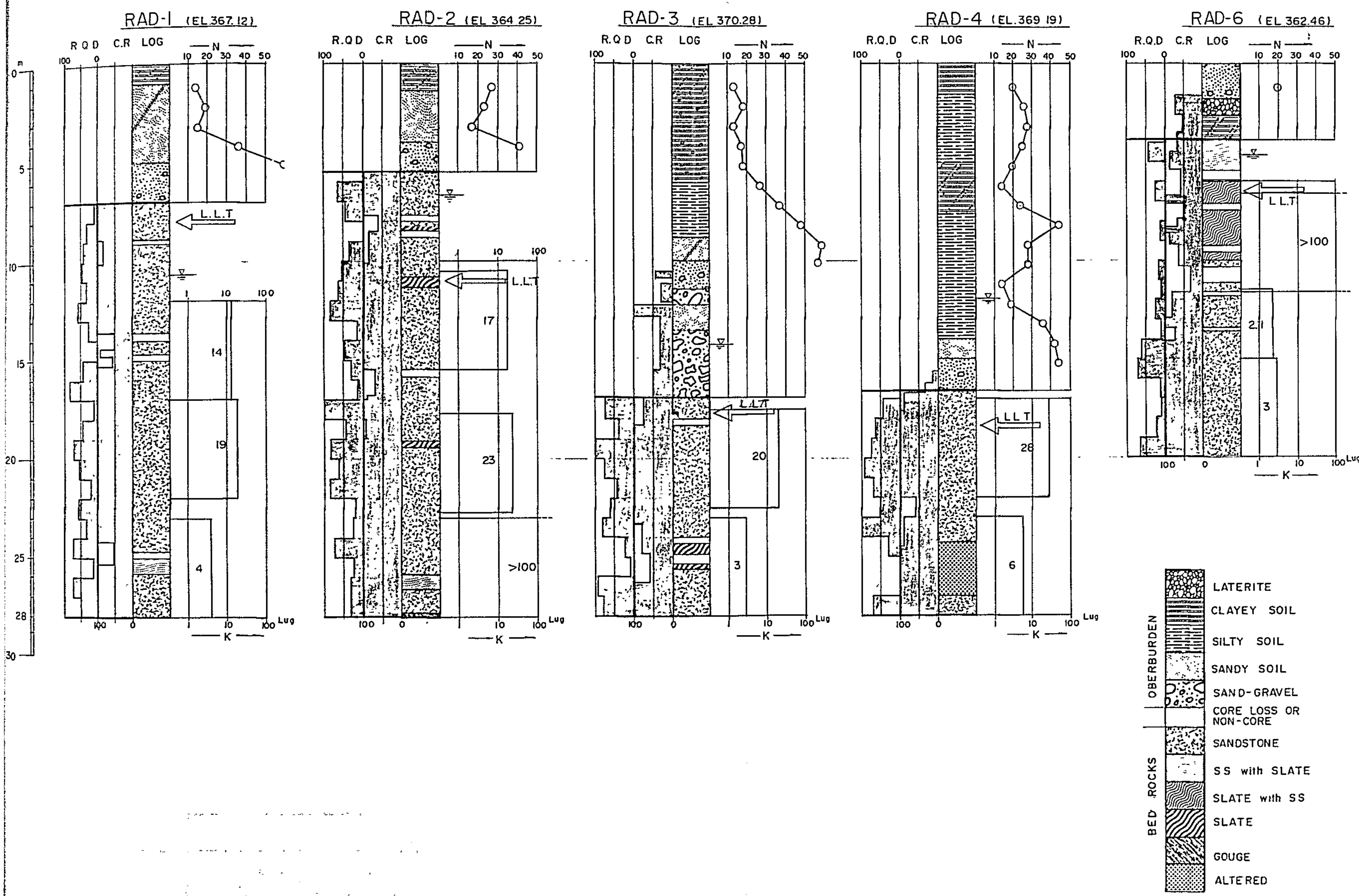
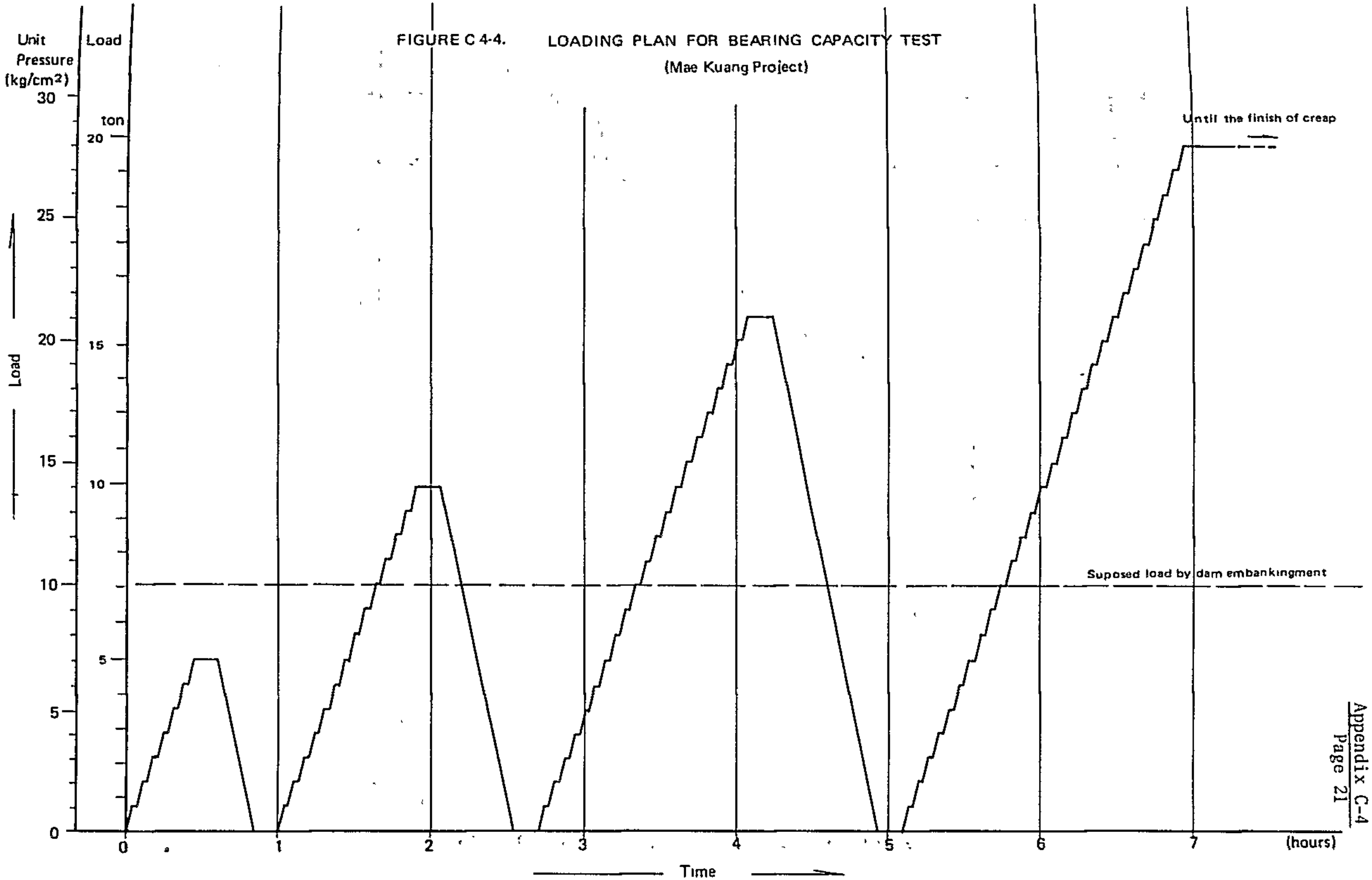


FIGURE C4-3(3) GEOLOGICAL LOG OF BORE HOLE (RIGHT SADDLE DAM)

FIGURE C 4-4. LOADING PLAN FOR BEARING CAPACITY TEST
(Mae Kuang Project)



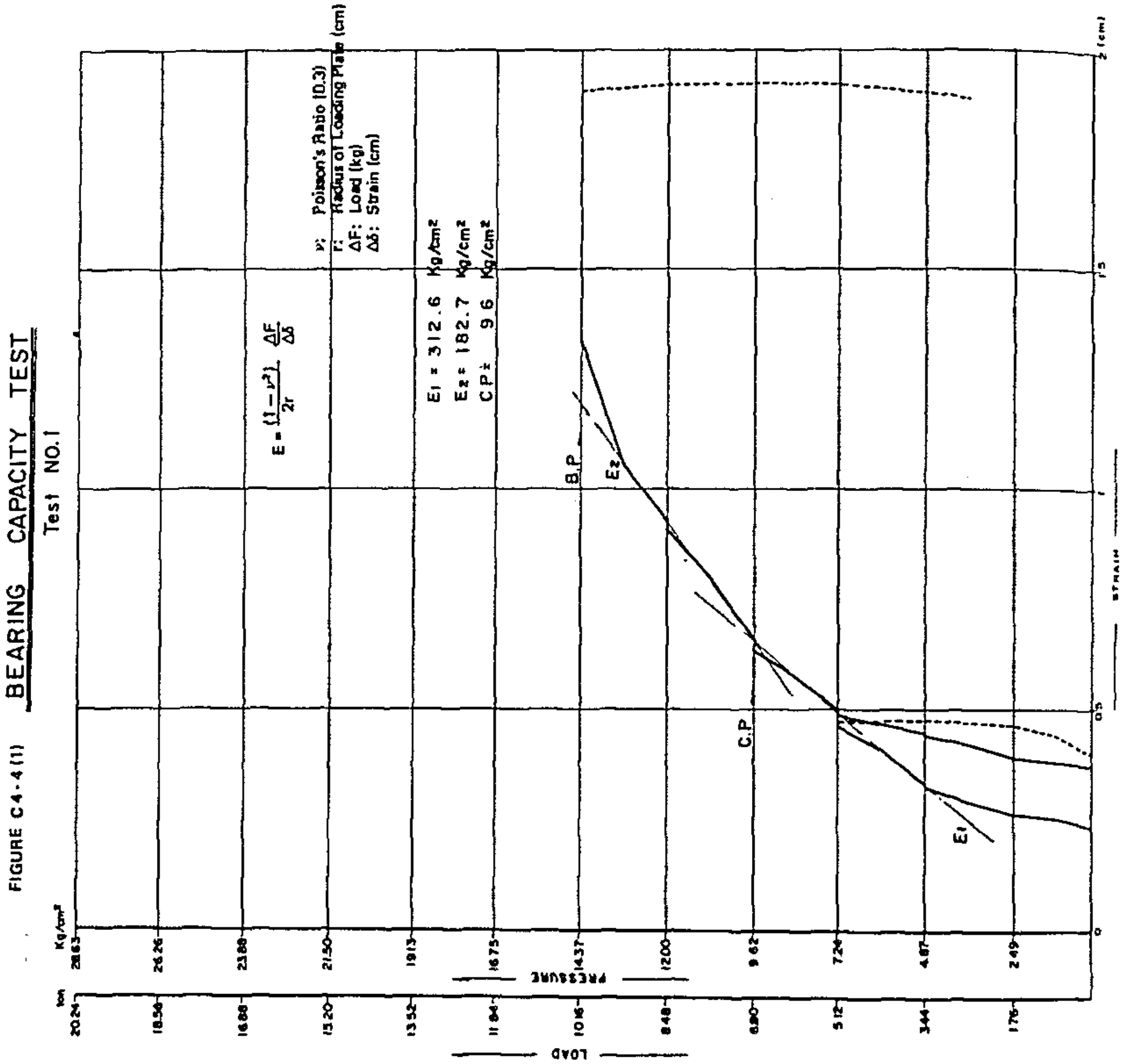


FIGURE C4-4(1)
BEARING CAPACITY TEST
Test NO.1
E = (1 − ν²)/2r · ΔF/Δδ
ν: Poisson's Ratio (0.3)
r: Radius of Loading Plate (cm)
ΔF: Load (kg)
Δδ: Strain (cm)
E1 = 312.6 Kg/cm²
E2 = 182.7 Kg/cm²
CP= 9.6 Kg/cm²
B.P
E2
C.P
E1
Kg/cm²
28.63
26.26
23.88
21.50
19.13
16.75
14.37
12.00
9.62
7.24
4.87
2.49
PRESSURE
ton
20.24
18.56
16.88
15.20
13.52
11.84
10.16
8.48
6.80
5.12
3.44
1.76
LOAD
0
0.5
1
1.5
2 (cm)
STRAIN

FIGURE C4-4(2) BEARING CAPACITY TEST
Test NO.2

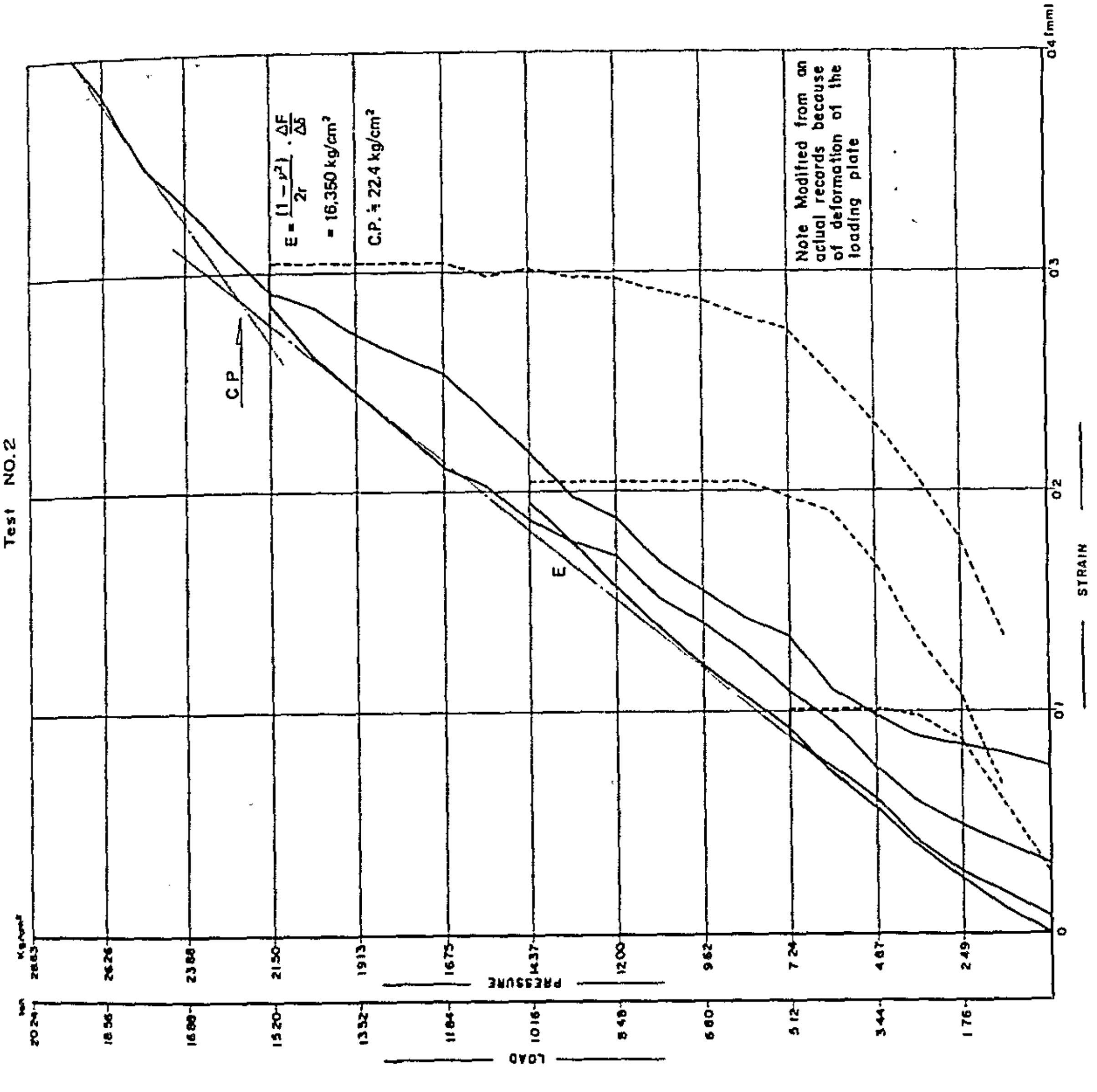
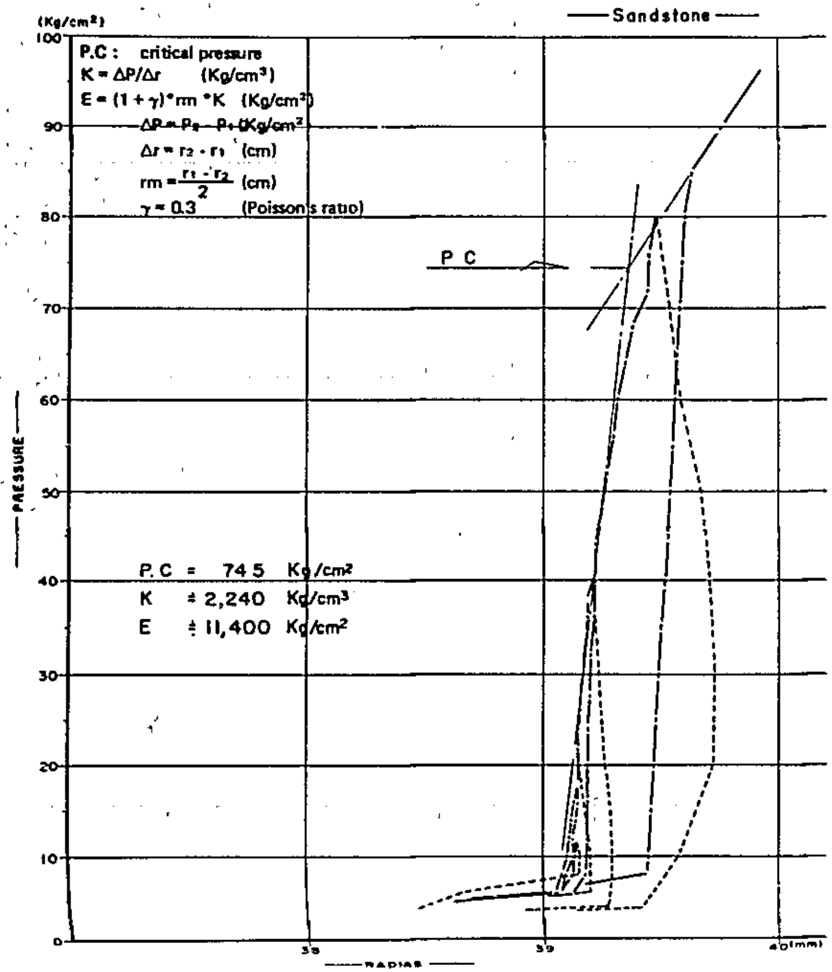


FIGURE C4-5(1) RESULTS OF LATERAL LOADING TEST (1) AND (2)



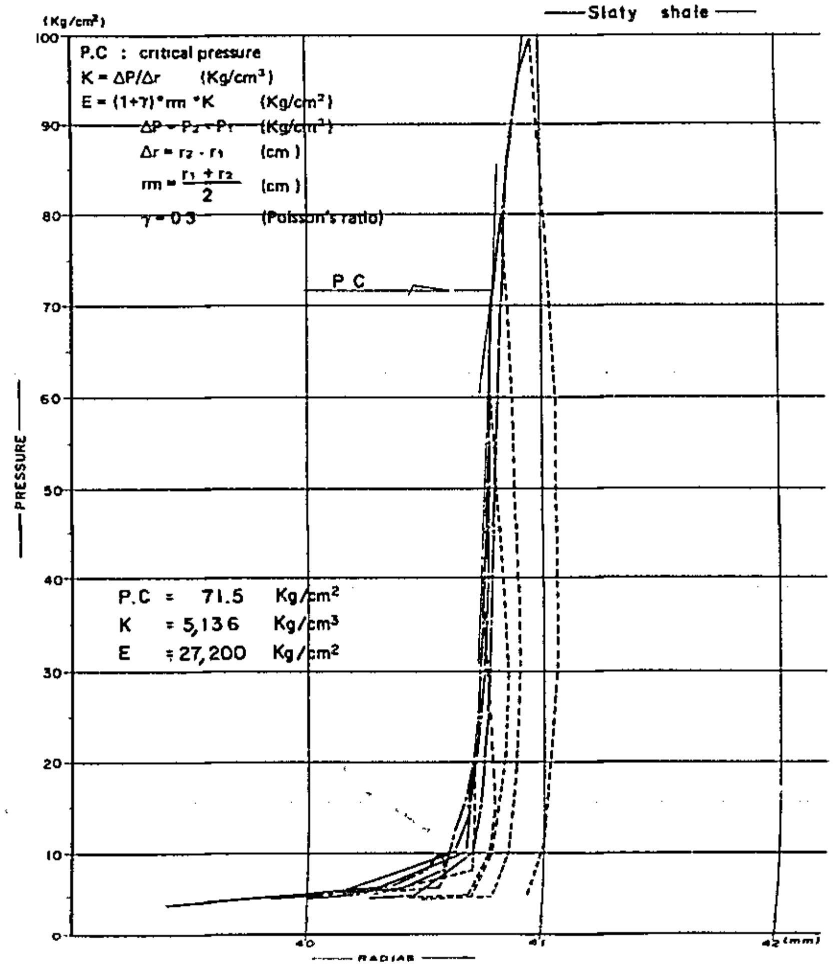
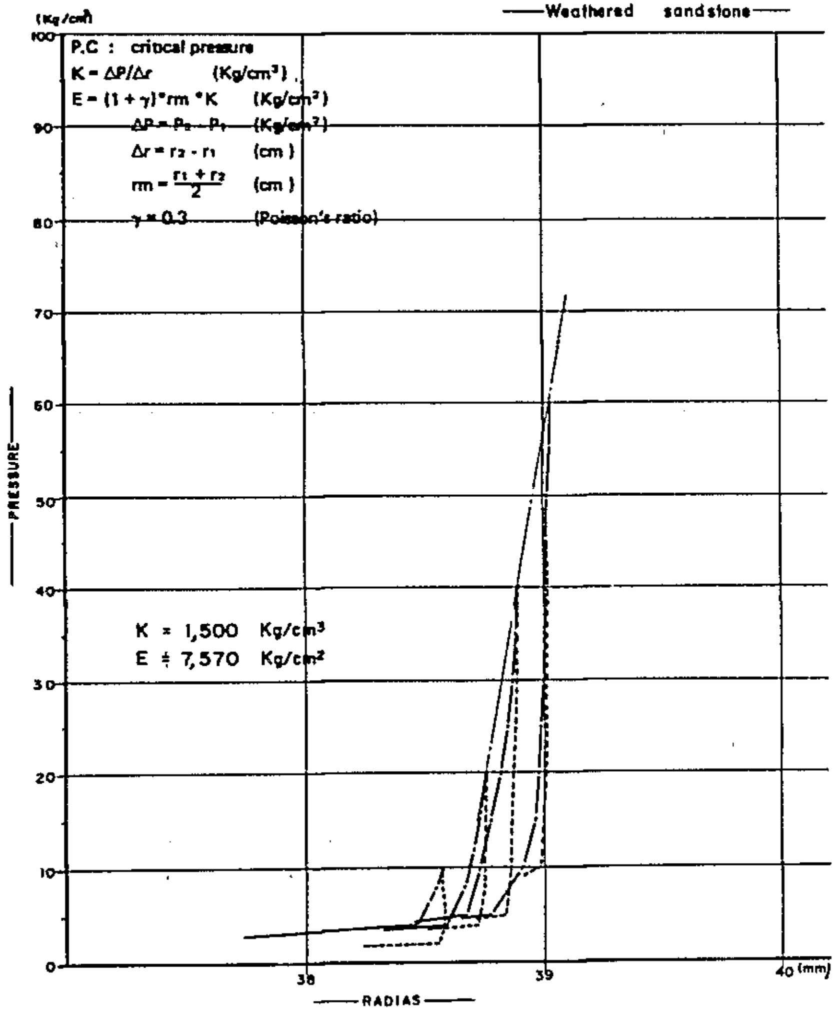


FIGURE C4-5 (2) RESULTS OF LATERAL LOADING TEST (3) AND (4)

RAD-3 (17.65m)



RAD-4 (18.10m)

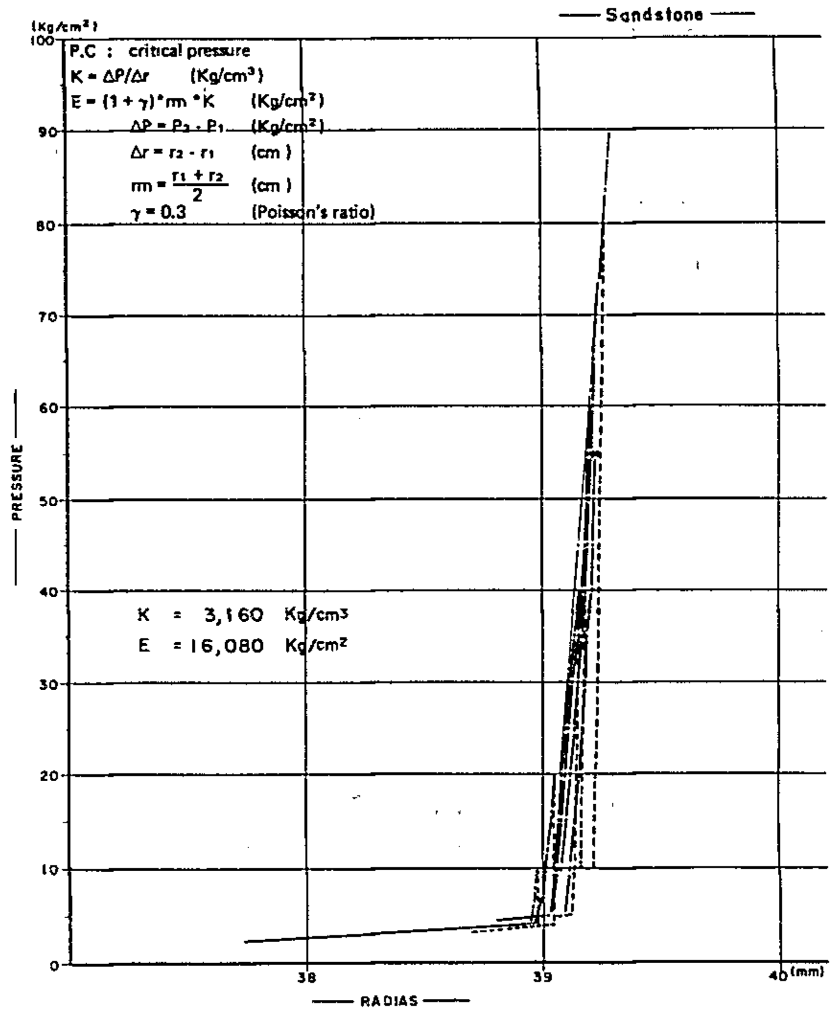
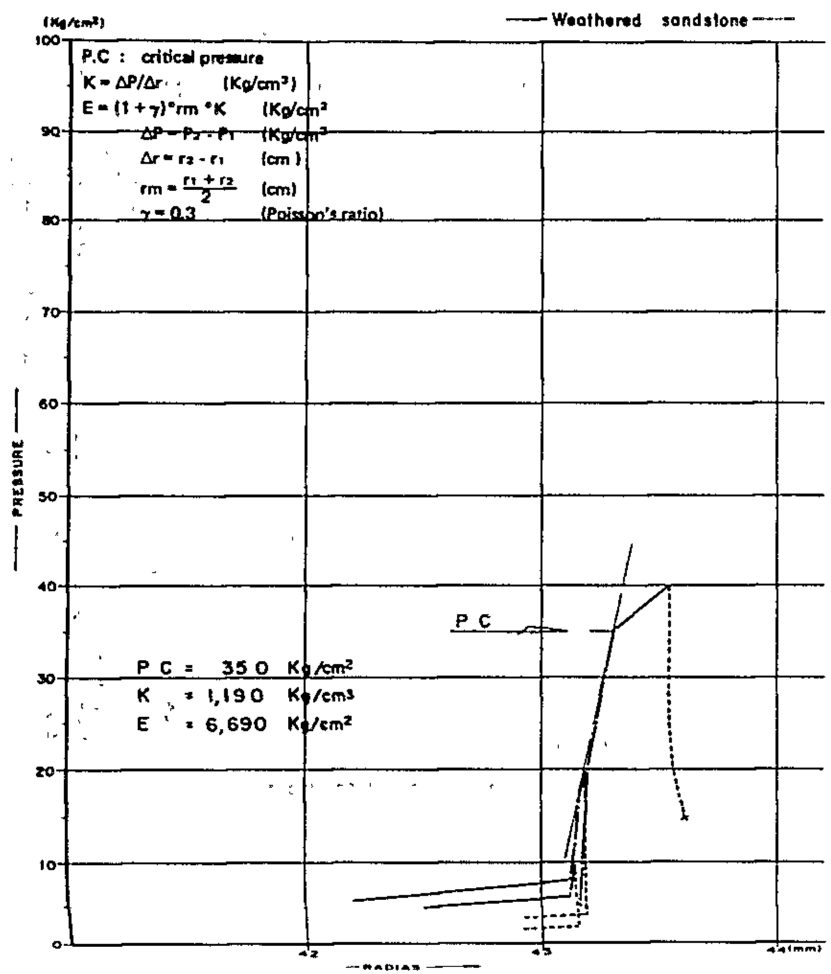
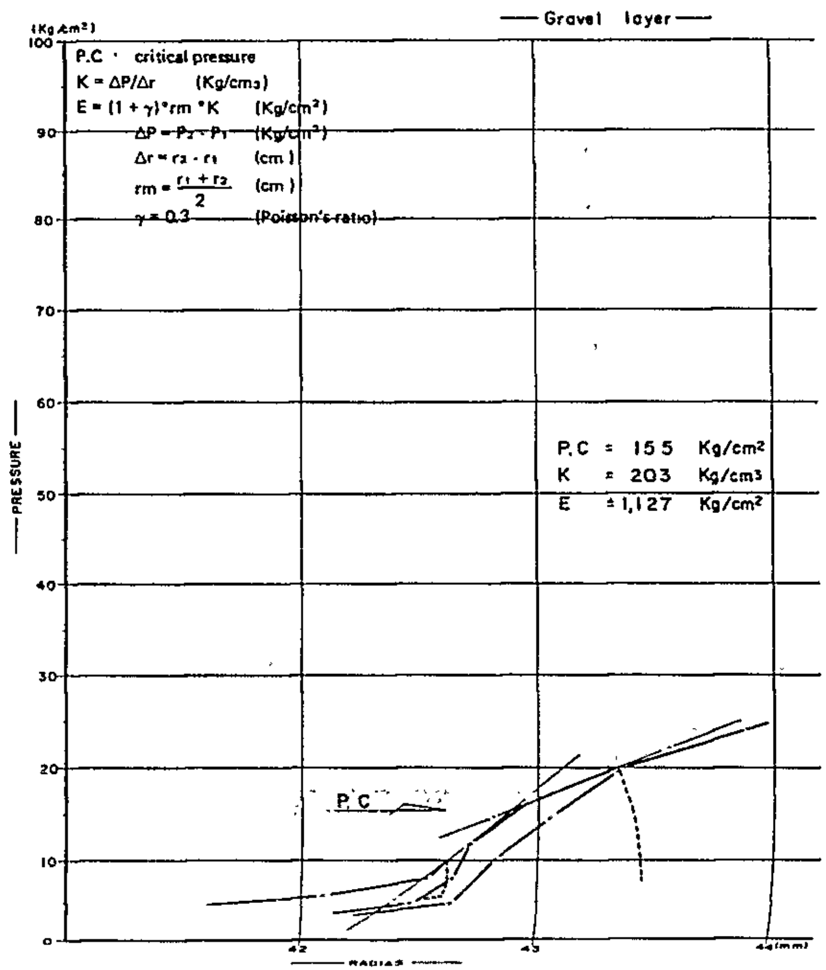


FIGURE C4-5(3) RESULTS OF LATERAL LOADING TEST (5) AND (6)





5. Geology of the Damsites

5-1. Introduction

In this chapter, the geological conditions of each damsite are described and considered generally based on the results of investigations and studies explained already in chapter 3 and 4. The description is conducted orderly as a) topography, b) overburden, c) bedrock, d) geological structure, e) permeability and f) bearing capacity (only at the Left Saddle damsite) for every site.

The attached sheets "Geological Profiles" of each site are very useful for understanding of geological conditions.

5-2. Left Saddle Damsite

a) topography

The Left Saddle damsite is set between the small isolated mountain (Doi Long) situated at left bank of the Mae Kuang and the mountain range which restricts on east of the Chiang Mai basin (see Figure C 5-1).

The topographic situation of the site is wide (about 370 m), and plain saddle. The saddle is presumed to be originated from an old river route of the Mae Kuang, and formed after shifting of the route by erosion of a surface water toward both original downstream and upstream. The upstream side of the saddle has been eroded slightly but the downstream side of the saddle has been eroded heavily and it slightly appears that there was an old river route because the Mae Kuang after shifted to the present position situated at high elevation than the original downstream site.

The damaxis is located nearby a longitudinal center of the saddle where the both mountain slopes just protrude to the center, and the axis is crossed by two streams (or gullies) which stream down to the reservoir side.

The elevaiton of the riverbed (bottom of the saddle) is 335 m and Height-Span Ratio at EL. 400 m is about 14.4. The riverbed is almost plain but the mountain slopes of both banks are steep (maximum inclination is about 30 degrees).

At the site, the excavation of an outlet trench and the most of a core trench have been completed (on Augst 1981) according to the plan of R.I.D.

b) overburden

The thickness of overburden along the damaxis is generally thin, about 7, 8 meters at center of the riverbed and only 4,5 meters at both side of the riverbed and abutments. However, at upstream or downstream area the depth of overburden reaches locally to 15 meters.

The overburden distributing at the riverbed consists of mainly sand and sandgravel, and is generally well compacted (0.8 - 1.2 km/sec of elastic wave velocity) except a top soil. The overburden existing at right side of the saddle contains much clayey components and it seems to be residual soil formed by weathering. At both abutments, the overburden is also sandy and it seems to be a talus mainly, and a residual soil.

These overburdens at the site are generally well compacted except a talus but have high permeability coefficients, therefore, these should be cut off at least at the core zone.

c) bedrock

The bedrock of the Left Saddle damsite consists of slate and alternation of slate and sandstone, and contains some sandstone beds intercalated.

By the seismic exploration, the elastic wave velocity of the bedrock ranging from 3.2 - 3.5 km/sec was got and the value indicates that the rock is considerably hard. However, the seismic exploration discovered many low-velocity-zones simultaneously along the damaxis, and the results of drilling or the observation of trenches indicate that the bedrock of the site had been disturbed heavily.

As described in the chapter 4 (4-2.b), the bedrock observed at the core trench had been cut or sheared by many faults and heavily altered by hydrothermal alteration along these faults. The results of drillings also showed the geological condition of the foundaiton is very inferior. At the most of drilling holes, core recovery percentages were very poor and R.Q.D. of the cores are nearly zero even if the cores were recovered.

d) geological structure

The geological structure of the site seems to be a monoclinic structure with NW or NNW of strikes and 60° - 80° NE of dips from a total view, but local variation is heavy as shown in the trenches. These local variation of geological structure is derived from the fact that the foundation of the region had been heavily folded originally and farther cut into blocks by numerous faults large or small scaled. Many faults and sheared zones observed at core trenches form a fault complex as a whole, and the fault complex is presumed to be an extension of a tectonic line which controls a geography of the region. The trending of the fault complex at the site is measured as N33°W, 80°E - 90°, and the trending is just same to the one of the linear-structure which is a characteristic of the topography around the site.

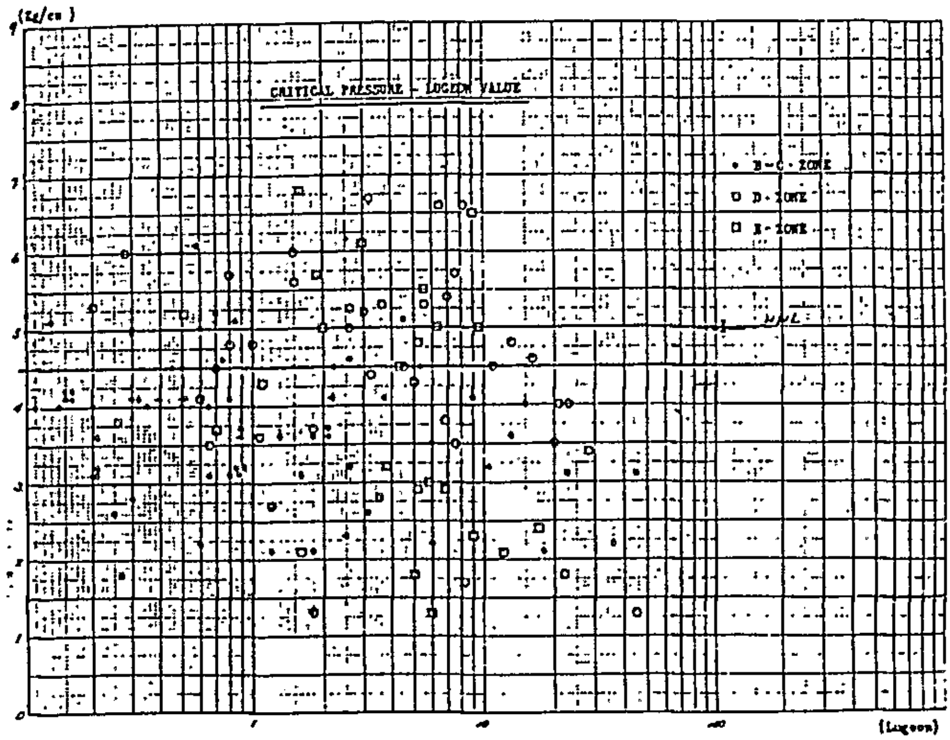
The trending of the fault complex and the tectonic line also consists with the general strike of the bedrock around the site and farthermore it consists with the direction of syncline existing to east of the site. These facts suggest that the extreme linear structure which cahracterizes the topography around the site was derived mainly from the folding of the bedrock and the tectonic lines parallel to the folding axis.

e) permeability

The results of permeability tests carried out in additional drilling holes indicate the permeability coefficients of the bedrock range from 20 to 100 lugeons but the previous data indicate the permeability of the bedrock ranges widely from less than one lugeon to some hundreds lugeons. These permeability coefficients are roughly classified into some groups corresponding to a geological conditions. They are, a group indicating less than one lugeon which is correlated with a heavily sheared or altered zone mainly and a sound rock rarely, a group ranging from 2 to 10 lugeons which is correlated with a common sound bedrock, a cracked bedrock or an alternation phase which belongs to a permeability group ranging from 20 to 50 lugeons and a group indicating higher permeability coefficients more than 80 lugeons which is correlated with a sheared bedrock or weathered rock. Like these classification the permeability of the bedrock mainly depends upon the quality of the rock and has no concerning with the depth except the uppermost part of the foundation.

The pressure-intake curves got by the permeability tests show that critical pressures of permeability groups indicating the lowest lugeon value and the highest lugeon value are remarkably low. The relationship between critical pressure and permeability is shown in Figure C 5-2. The figure is derived form the Figure C 3-1 and dotted by the data indicating obvious critical pressure. The figure indicates the most of critical pressures should be less than the water head of proposed reservoir if it has filled up.

Figure C 5-2 Relationship between Critical Pressure and Permeability



f) bearing capacity

The bearing capacity tests in the site were conducted at only two points, and from them any conclusive consideration concerning to the bearing capacity of the foundation as a total could not get because of too small quantity.

From the results of these two tests only following facts are revealed. The heavily altered or completely sheared zone are difficult to bear the load by embanking, and the bedrock even if it was weathered or altered has an enough bearing capacity for the load by earth-fill type dam provided it appears just rock.

After that, to grasp a physical or elastic property of every graded sheared zones is an urgent subject. Anyhow at the site there are many heavily sheared zones and also heavily altered zones, so the foundation treatment, especially for improvement of these sheared or altered zones should be conducted sufficiently.

5-3. Main Damsite

a) topography

The Main dam was proposed to dam up the main flow of the Mae Kuang between two small mountains which restrict the mouth of the Mae Kuang valley to the Chiang Mai basin.

The Mae Kuang coming down generally westward or southwestward attacks the small mountain (Doi Long), and goes around the mountain to north, then flows down to south passing through the damsite.

The wideness of the riverbed is about 400 meters at the dam-axis and just upstream of the axis the river has a broad flood plane about 1.3 km^2 in acreage, which is available as a big storage pocket. The riverbed trends NW-SE direction as a whole but the present river channel flows down to ESE crossing the riverbed. The width of the channel is about 30 meters at damaxis (not in flood season).

The riverbed is very plain and contains some marshs, but the slopes of both abutments are extremely steep (30° in average, 40° in max.). The elevation of the riverbed is 337 meters at the dam-axis and Height-Span Ratio at EL. 400 meters is about 10.2.

b) overburden

The depth of overburden in the riverbed is generally large, about 15 meters in average and reaching to 20 meters in maximum depth at the point where seems to be an old river channel. The depth of overburden at both abutments is very thin as only a few meters.

The overburden in the riverbed is a river deposit and composed of sandy soil or sandgravels except the parts nearby the ground surface. The deposit is generally loose, and N-value is nearly 10 at a sandy soil and nearly 20 at a sandgravel. Farther-more, a clayey soil at the parts nearby the ground surface and a sandy soil nearby a groundwater table indicate very low N-value less than 5. These river deposit is presumed to have a high per-meability from its component. Beside, the river deposit shows some small scaled cycles of sedimentaiton derived from a shifting of river channel.

The overburden existing at both abutment are mainly talus and only small parts of them are presumed to be an in-situ residual soil by weathering. The talus is rather loose deposit containing an angular or sub-angular gravels.

c) bedrock

The bedrock of the site consists of mainly sandstone and shale or slate beds intercalated.

The quality of a sandstone is very hard and tough, and too siliceous to call as sandstone (perhaps it shall be called as sandy quartzite) but at the papers it is called simply as sandstone. The slate has a heavy schistosity but the quality is generally as sound as indicating some R.Q.D. in its drilling cores except a hole near-by the sheared zone.

The result of the seismic exploration indicates the elastic wave velocity of the bedrock ranging from 2.6 to 4.0 km/sec. The bedrock in the riverbed has the highest and the middle (3.0 - 3.3 km/sec) elastic wave velocity, and the bedrock at both abutments have rather low elastic wave velocity. These distribution of velocity layers suggests the bedrock in the riverbed is generally good quality without crack or few cracked but the one at both abutments are cracked rock phase on the contrary. The fact that a weathered rock zone distributes mainly at both abutments but slightly at the riverbed also supports the matter mentioned above.

At the drilling holes conducted at this term, almost full core-recovery has been achieved except the MAD-3 hole which aims to research the sheared zone. And R.Q.D. of the drilling cores is nearly 50% in average. These situation also indicates the bedrock of the site is generally good quality.

d) geological structure

The geological structure of the Main damsite is presumed to be a monoclinic structure as a total with NW-SE strikes and dips to NE, from an observation of the outcrops at both abutments.

The seismic exploration discovered two wide low-velocity-zones at a foot of both abutments, and the one of them was conformed as a sheared zone. And some more sheared zones which is not enough large to be caught by the exploration are supposed to exist in the site also.

Two large faults with sheared zone discovered at beneath of both abutments are presumed to be not parallel but running like a V-shape opening toward upstream. In any rates, these faults are also derived from the tectonic line described before. The fault at a foot of the right abutment was searched by drilling as mentioned above. The drilling hole has penetrated through about 7 meters of completely sheared zone (at where the core was lacked), sandstone bed altered into fragile phase by hydrothermal alteration and up to heavily crushed slate and fault-clay.

Farthermore these faults are presumed to affect mainly to the bedrocks at both abutments from the situation of bedrock mentioned above.

e) permeability

The permeability coefficients obtained by the tests are classfied into three groups, one is a low permeability group with less than 6 lugeons, one is a middle permeability group ranging from 15 to 40 lugeons and another one is a high permeability group with more than 80 lugeons. These groups are correlated with a sound slate and massive sandstone, a common sandstone in the site and with alternations, cracked sandstone and sheared zone respectively.

Among them a middle and high permeability groups are dominant in the site, therefore, the bedrock at the Main damsite is estimated to have considerably high permeability as a whole.

In addition to that, the groundwater table at the riverbed is very high and the ground surface is swamped locally.

5-4. Right Saddle Damsite

a) topography

The Right Saddle dam has planned at the saddle between the nameless small mountains which are southern one of two isolated mountains restricting the mouth of the Mae Kuang valley and one of the mountain range at right bank of the Mae Kuang.

At first R.I.D. proposed an arched dam axis based on the trends of both abutments because at the right bank of the saddle the ridge extends to southeast and at the left bank of the saddle the ridge from the small mountain protrudes toward north. However, from a consideration for farther exact topography and for embanking operation, the axis was changed to a straight line.

The eastern side of the saddle (reservoir side) opens extensively with very gentle slope to the broad flood plain just upstream of the Main dam, and the western side of the saddle is a composition of a right bank of the Huai Mae Sataeng which is a tributary of the Mae Kuang at farther downstream.

The riverbed (saddle) is generally plain having a gentle slope less than 5 degrees and the both abutments have a rather steep slopes but the slopes are usually less than 20 degrees, far gentle in comparison with the other damsites. The elevation of the riverbed is 363 meters, Height-Span Ratio is about 17.3 at EL. 400 meters.

b) overburden

The depth of the overburden varies from a right side to a left side of the site. That is to say, the depth of overburden at left side is thin, 6 or 7 meters, but the depth at right side reaches to about 15 meters. The depth of overburden at both abutments are very thin, only about 3 meters.

The property of overburden at riverbed is generally sandy and containing gravels at lower part. The overburden at subsurface and at a part from the center to right bank of the damaxis are composed of clayey or silty soils and these are generally well compacted, the N-value ranges from 20 to 30 excepting the uppermost part and to more than 40 in lower part. These well compacted layer are presumed to be a diluvium. And this situation of deep deposit at right side of the riverbed is presumed to be derived from the bedrock condition which shall be described in following clause. The overburden distributed at the both abutments are mainly weathered and residual soils.

The drilling hole drilled at downstream of the site revealed a laterite bed about one meter thick at about two meters depth, but obvious outcrops of laterite has not found out at the site.

c) bedrock

The bedrock of the Right Saddle damsite consists of mainly sandstone as same as the Main damsite and a few thin slate beds intercalated.

The sandstone is very hard and tough (and also silicious). Generally it has cracks but drilling cores are recovered as a connected colum and R.Q.D. of the cores is more than 50% in average. However, at the right side of the riverbed, the zone heavily altered into fragile or argillizated phase by hydrothermal alteration is discovered by the drilling hole RAD-4. This zone is presumed to be subjected by large scaled fault complex being explained later.

The sound sandstone indicates an elastic wave velocity ranging from 3.7 to 4.1 km/sec and the weathered phase has about 2.0 km/sec of elastic wave velocity. At the site this weathered zone distributes extensively and deeply in contrast with other damsites. Even in the weathered phase the rock quality is hard in itself, nevertheless it is cracked heavily and most of the cracks are opened.

A slate intercalated in a sandstone is generally more sound and hard than the one distributed in other site, but the quality is far inferior than a sandstone.

At the bedrock the lateral loading tests were conducted and the result showed the bedrock irrespective of rock kind or weathering has enough strength for the load by filled type dam.

d) geological structure

The bedrock of the site is presumed to have dips and strikes of 45°-60°NE, NW-SE direction from a reconnaissance and an observation of drilling core, but obvious outcrops are lacked. However, the topographic trend of left abutment is a little different to the one of right abutment, and this situation suggests that there should be at least one of tectonic lines crossing the site. This suggestion is supported by the result of seismic exploration that four low-velocity-zones concentrate in a part about 200 meters wide at right side of the riverbed and they are presumed to form a fault complex similar to the one passing the Left Saddle damsite. But the trending of the fault complex is not yet grasped.

The spot where the depth of overburden is abnormally deep as mentioned above just consists with a spread of the fault complex, and it means a deep erosion had occured just along the altered zone by the fault complex. And the distribution of deep weathered rock zone seems to have a concerning to the complex zone.

e) permeability

The permeability coefficients of the bedrock resulted by the permeability tests carried out in the term are classified into three groups from their ranging as low, middle and high permeability group.

The low permeability group has a permeability coefficients ranging from 3 to 6 lugeons, the middle group has a values from 15 to 30 lugeons and high group has a values more than 100 lugeons. These classification is adaptable to the results of previous investigation conducted by R.I.D. These permeability classes are correlated with a rock quality because the almost all bedrock of the site consists of sandstone only. That is, sound and crackless sandstone has a low permeability, a common sandstone dominant in the site has a middle permeability and a cracked sandstone has a high permeability.

Beside, a differency for a permeability coefficient between a weathered rock and sound rock has not been recognized from the results of this time investigation, but it is not certain because the most of drilling had not been drilled up to enough depth through a sound rock zone.

5-5. Spillway

a) topography

The proposed spillway has set at the small mountain situated at right bank of the Mae Kuang.

The small isolated mountain is composed of two summits arrranging north to south and a ridge extending to northeast from the northern summit. The left abutment of the Right Saddle dam clings to the northern slope of the north summit and the northeastern end of the ridge is the right abutment of the Main dam.

The spillway is planned at a small saddle situated nearby the end of the ridge, vertically to a trending of the ridge. The distance between the spillway axis and the right bank crest of the

Main dam is about 220 m. The elevation of the small saddle which means a top in a profile along the center line of the spillway is about 420 meters. The mountain slopes of both sides are extremely steep, generally 35° and about 50° at maximum inclination (but a center line of the spillway is not completely vertical to the slope).

The upstream slope of the ridge leads to a very gentle slope front of the Right Saddle dam and the downstream slope leads to a vast and completely plain flood plane formed by the Mae Kuang.

b) overburden

A top of the ridge higher than EL. 400 m has no or a few overburden but at a slopes of both sides the overburden distribute rather thickly, 7 or 8 meters in depth. And at the flood plane the depth of overburden becomes very large (15 m in average).

The overburden material at a top of the ridge is a residual soil by weathering but the one distributed at a slope consists of mainly talus deposit. These are sandy and compacted generally, and the talus contains gravels. The flood plane deposit is composed of sand, sandgravel and rarely clayey soil. The N-value of the deposit is more than 20 except the uppermost part where the N-value is less than 10 (up to 2, 3 meters from a ground surface).

c) bedrock

The ridge also consists of a sandstone and thin slate beds intercalated rarely.

A sandstone is hard and silicious but cracked generally. Especially at a weathered rock zone distributed thickly (15 -20 m in thickness), the rock is heavily cracked because an elastic wave velocity of the rock in rather low ranging from 1.5 to 1.8 km/sec. At a base of the ridge a sound rock which indicates 3.3 km/sec of elastic wave velocity distributes underlying a weathered rock zone and at farther depths a very hard and massive rock which has an elastic wave velocity of more than 4.3 km/sec is underlying.

At the ridge total five zones of low-velocity-zones were discovered by the seismic exploration, and these are certainly faults running parallel to a trending of the ridge. The very thick weathered zone is presumed to be derived from these faults.

d) permeability

At the site, data concerning to a permeability are only derived from the previous investigation. The data indicate permeability of the bedrock is low ranging from 1 to 10 lugeons nevertheless the target zones were heavily cracked weathered sandstone. However, these coefficients were obtained using a gravity method, and the permeability coefficients of the bedrock are certainly ranging from 20 to 80 lugeons and more than 100 lugeons locally as same as the situation of the other sites from a consideration for an elastic wave velocity and a results of drillings.

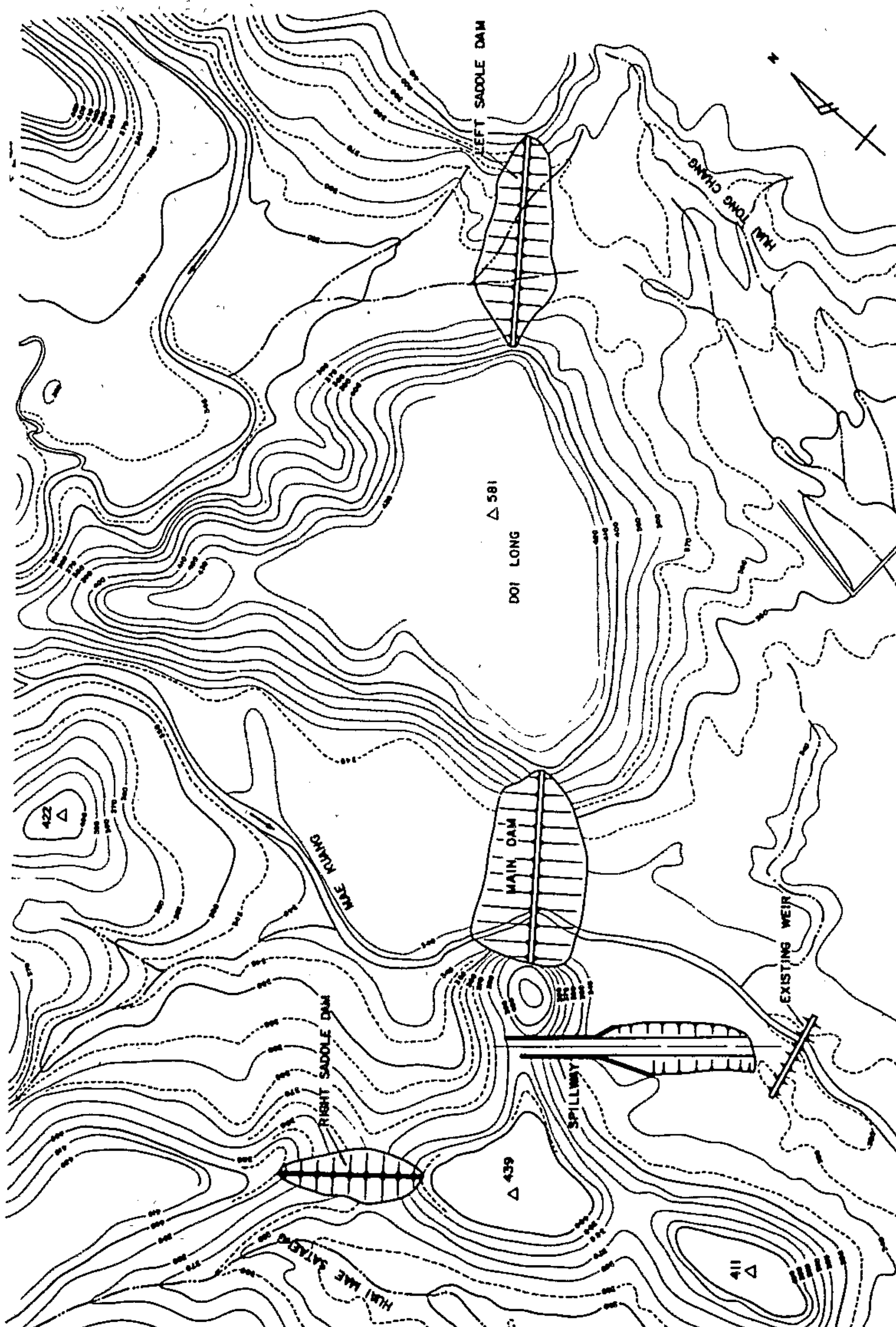


FIGURE C5-1 TOPOGRAPHY OF PROPOSED DAMSITE