JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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THE REPUBLIC OF INDONESIA

FEASIBILITY STUDY
ON
THE WARSAMSON HYDROELECTRIC POWER DEVELOPMENT PROJECT
IN
THE REPUBLIC OF INDONESIA

FINAL REPORT

SUPPORTING REPORT

VOLUME-IV GEOLOGICAL INVESTIGATION

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INTRODUCTION

This is the report on the geological investigation performed for the Feasibility Study on Warsamson Hydroelectric Power Development Project in the Republic of Indonesia. This report presents the results of the investigation, the interpretation of the ground and the engineering analysis. The present investigation was financed by Japan Government through Japan International Cooperation Agency (JICA) and P.T. Pondasi Kisocon Raya performed the investigation under the instruction from Pacific Consultants International, the representative of JICA.

The project site is located at the "bird head" of Irian Jaya at about 31 km to the east of Sorong city toward Makbon village. Figure 0-1 shows the location map of the site.

The objective of the present investigation is to obtain geological information of the ground at the site and the availability of borrow materials. The information will be used by the client to select the appropriate dam site and to design the proposed structures.

According to the Contract Document from the client, the scopes of the works in the present investigation cover the following items:

(1) To perform exploratory drilling.
(2) To execute standard penetration tests.
(3) To carry out field permeability tests.
(4) To conduct field density tests (Sand cone tests).
(5) To carry out seismic refraction survey.
(6) To perform laboratory tests on rock core samples, disturbed soil samples and concrete aggregate samples.
(7) To submit a factual and interpretation report on the results of the investigation.

This report consists of four chapters and six appendices. Chapter 1 outlines the detail of the field ground investigation and Chapter 2 describes the laboratory tests. The interpretation of the ground condition is given in Chapter 3 and the results of engineering analysis is summarized in Chapter 4. The appendices provide the methods of the field ground investigation, the borehole logs, the detailed results of field and laboratory tests and the photographs of the field activities including core samples.

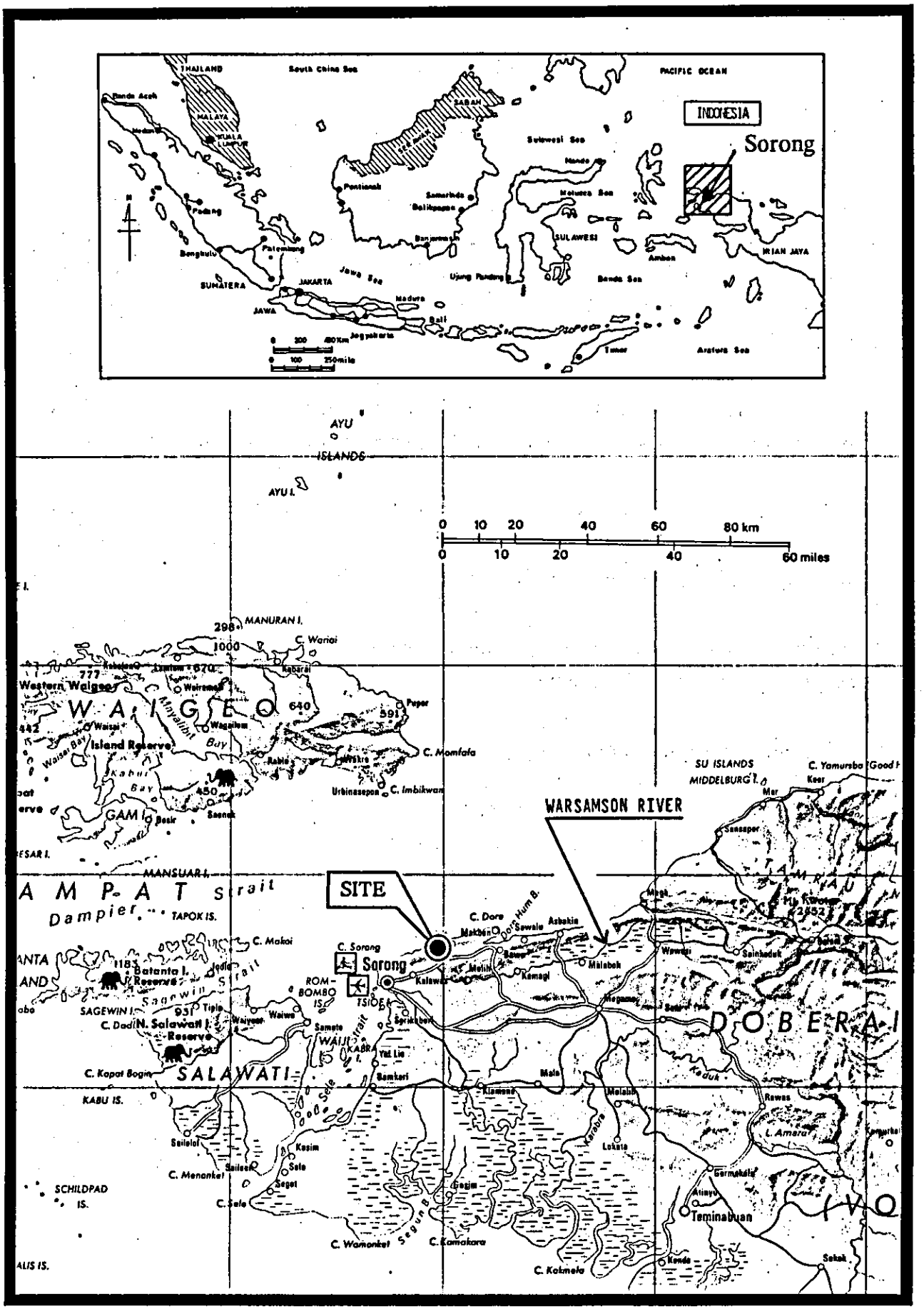


Figure 0-1 Location Map of the Site

CHAPTER 1

FIELD GROUND INVESTIGATION

1.1 Access to the Site

The dam sites and power house area are located at the down stream part of Warsamson river about 2 km south from the estuary. The saddle dam area is situated along the road heading toward Makbon village between 31 km and 34 km milestones from Sorong. Figures 1-1 and 1-2 show the locations of the two sites.

The project sites were accessible by car and followed by walking. From Sorong, land transport was required to travel along the road toward Makbon village and alight at the milestone of 31 km. Four wheel drive cars were generally necessary to travel the unpaved road at the last few kilometers, especially after heavy rains. From the 31 km milestone, the dam sites and the power house area can be reached on foot following a foot path inside the tropical rain forest with hilly terrain. The foot path is approximately 1.5 km but it requires 1 to 1.5 hours to travel due to heavy terrain. The saddle dam sites are situated close to the south side of the road and readily accessible by car.

1.2 Mobilization

Four rotary type drilling rigs and other equipments were mobilized from Bandung to Jakarta by land transport and then to Sorong by sea transport. With low frequency of sea transport and the heavy terrain of the sites which required manual transport of the equipment, approximately one month (November 10 to December 7, 1994) was required to mobilize all the equipments to the drilling sites.

1.3 Execution and Quantity of Field Work

The drilling at the first borehole was started on December 8, 1994 and all the field works were completed on January 22, 1995. The field works executed in the present investigation are listed below:

(1) Performed exploratory drilling at 12 locations with a total length of 355m.
(2) Executed standard penetration tests with a total number of 36.
(3) Carried out Lugeon tests at 5m interval with a total number of 44.
(4) Performed constant head and falling head permeability test at 5m interval with a total number of 21.
(5) Conducted field density tests at 5 locations.

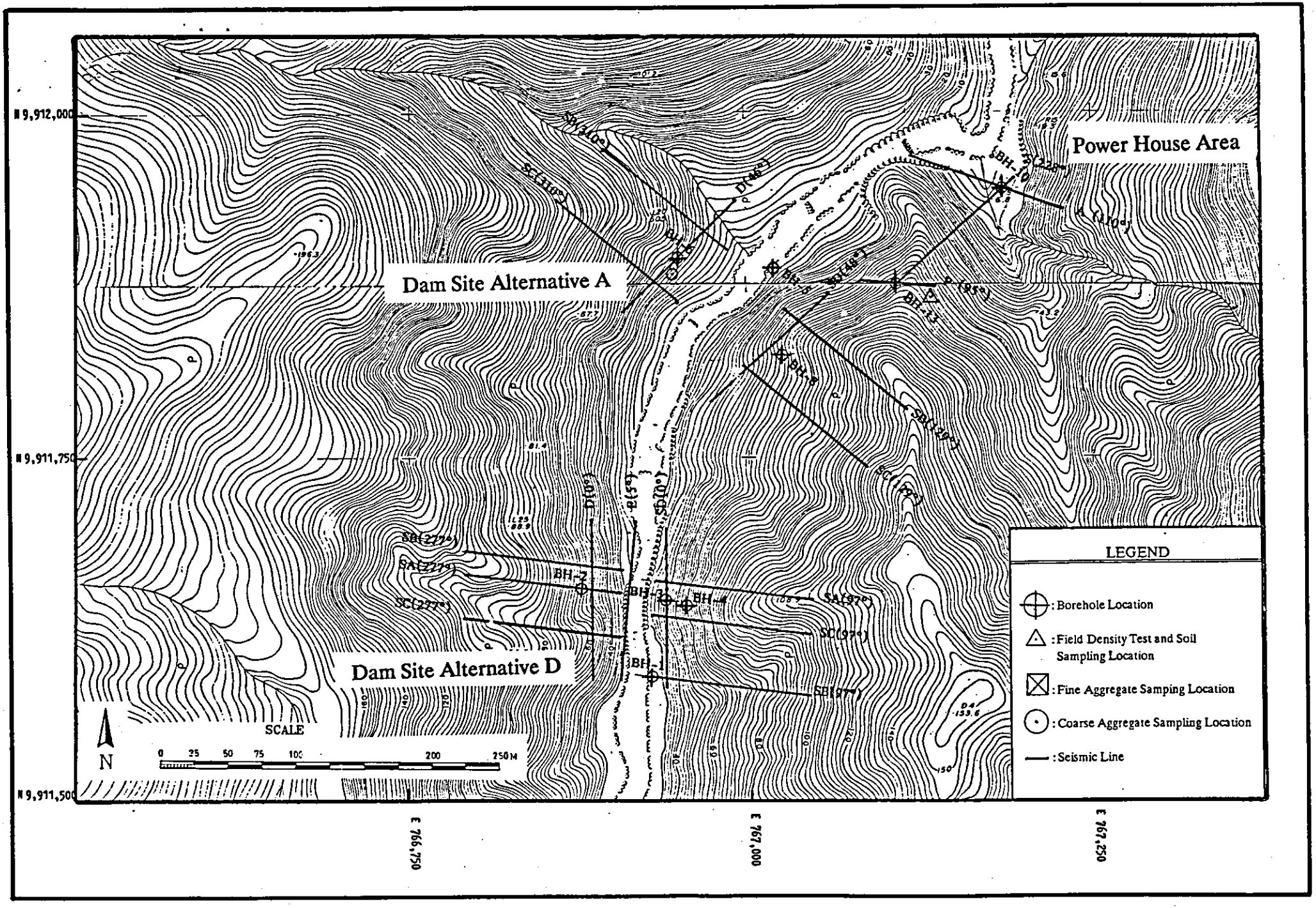


Figure 1-1 Geological Investigation at Dam Site Alternatives and Power House Area

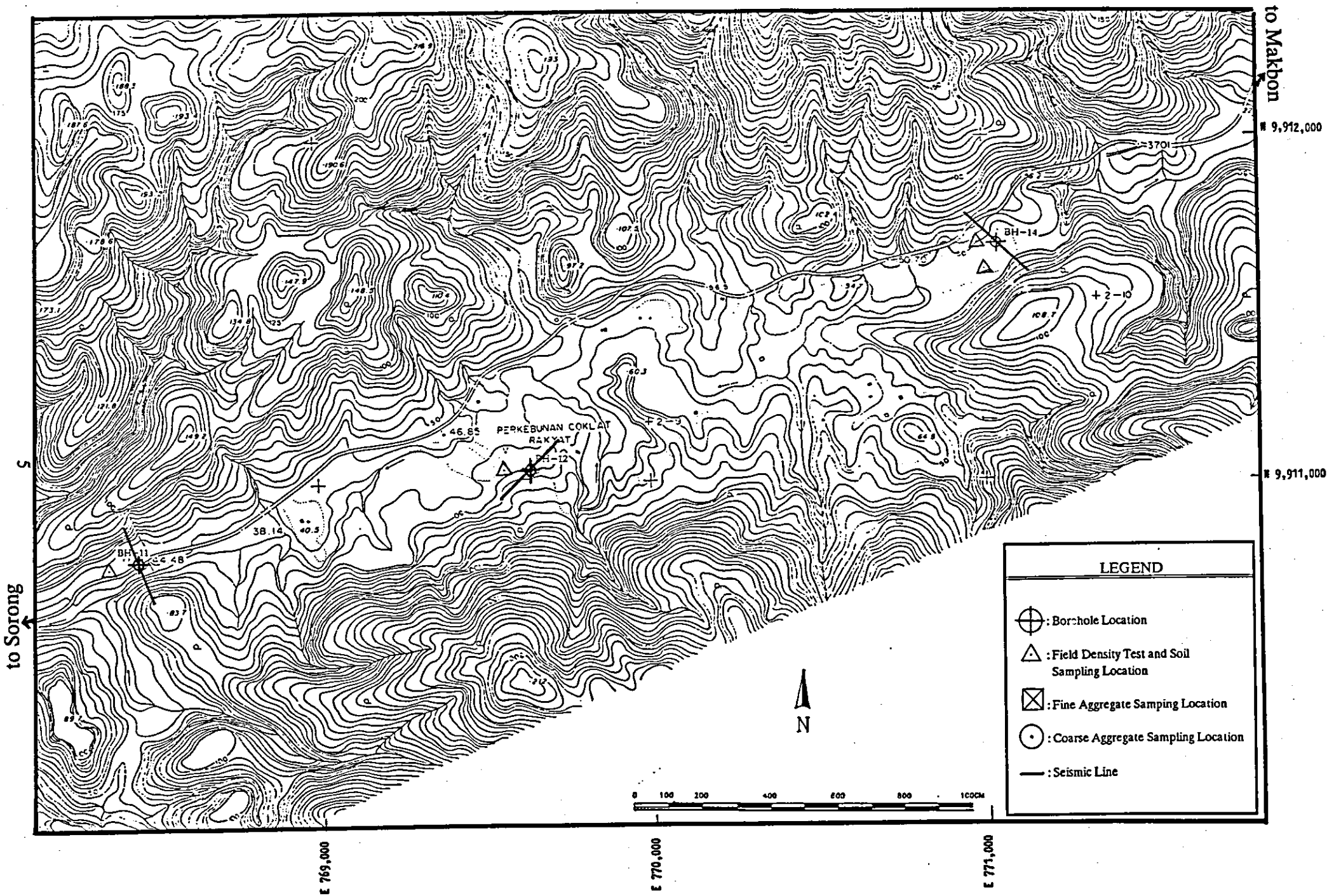


Figure 1-2 Geological Investigation at Saddle Dam Areas

(6) Carried out seismic refraction survey along 24 lines with a total length of 2.7 km.

Table 1-1 summarizes the quantity of the field works and Appendix E shows the photographs of the field work activities.

1.4 Positioning Survey

The locations of the boreholes and the seismic lines were positioned based on the existing polygon points which were identified from the contour maps (scale 1 : 500) produced by P.T. Aerokarto Indonesia. Table 1-2 lists the coordinates and the ground elevations of the borehole locations. Figures 1-1 and 1-2 show the locations of the boreholes and seismic lines.

1.5 Exploratory Drilling

Twelve boreholes were sunk in the present geological investigation. Four boreholes (BH-1 to BH-4) are located at dam site alternative D and three boreholes (BH-5, BH-6 and BH-8) are at dam site alternative A. Two other boreholes (BH-10 and BH-13) are located at power house area and the last three boreholes (BH-11, BH-12 and BH-14) are at saddle dam area.

Coring method was used to sink the borehole with the procedure as described in Appendix A.1. The retrieved core samples were kept in core boxes for identification. Casing pipes were used to prevent the borehole wall from collapsing.

Two boreholes BH-7 and BH-9 which were originally planned to be sunk at dam site alternative A and power house, respectively, were canceled by the client during the course of the drilling. Additional boreholes BH-13 and BH-14 were sunk at the upper portion of the power house and at the saddle dam area. The total drilling depth in the present investigation is 355m which consists of:

Borehole	Area	Drilling Depth
BH-1	dam site alternative D	70m
BH-2	dam site alternative D	15m
BH-3	dam site alternative D	15m
BH-4	dam site alternative D	15m
BH-5	dam site alternative A	70m
BH-6	dam site alternative A	20m

Table 1−1 Total Quantities of Field Works Performed

Area	Borehole No.	Drilling Depth (m)	Standard Penetration Test (nos)	Lugeon Test (nos)	Field Permeability Test		Field Density Test (nos)	Seismic Refraction Survey
					Constant Head (nos)	Falling Head (nos)		
Dam site alternative D	BH−1 (inclined 30 deg. from vertical)	70	−	14	−	−	−	1,035 m (9 lines)
	BH−2	15	−	2	−	−	−	
	BH−3	15	1	2	−	−	−	
	BH−4	15	−	2	−	−	−	
Dam site alternative A	BH−5 (inclined 40 deg. from vertical)	70	−	14	−	−	−	690 m (6 lines)
	BH−6	20	−	3	−	−	−	
	BH−8	15	1	1	1	1	−	
Power house	BH−10	20	−	3	−	−	−	285 m (3 lines)
	BH−13	20	2	1	2	1	1	
Saddle dam	BH−11	40	5	−	6	2	1	230 m (2 lines)
	BH−12	30	4	2	3	−	1	230 m (2 lines)
	BH−14	25	24	−	−	5	2	230 m (2 lines)
Total		355	37	44	12	9	5	2,700 m (24 lines)

Table 1–2 Coordinates and Ground Elevations of Borehole Locations

Area	Borehole No.	Coordinates (m)		Elevation (m)
		Easting	Northing	Z
Dam site alternative D	BH–1	766,927.250	9,911,590.615	30.020
	BH–2	766,876.343	9,911,654.722	55.920
	BH–3	766,937.500	9,911,646.150	40.000
	BH–4	766,953.076	9,911,642.219	60.610
Dam site alternative A	BH–5	767,016.541	9,911,881.019	18.060
	BH–6	766,948.819	9,911,894.507	35.780
	BH–8	767,025.184	9,911,824.059	59.910
Power House	BH–10	767,185.090	9,911,943.730	4.220
	BH–13	767,108.844	9,911,875.200	70.000
Saddle Dam	BH–11	768,320.084	9,910,725.011	44.600
	BH–12	769,700.133	9,911,208.343	48.780
	BH–14	770,975.500	9,911,650.411	48.580

BH-8	dam site alternative A	15m
BH-10	power house	20m
BH-11	saddle dam	40m
BH-12	saddle dam	30m
BH-13	upper power house	20m
BH-14	saddle dam	25m

All the boreholes were sunk vertically, except boreholes BH-1 and BH-5 which were sunk with inclination of 30 degrees and 40 degrees, respectively, to the vertical for the purpose of investigating the ground condition across the river bed. Appendix B presents the drilling logs and Appendix F shows the photograph of the soil core samples.

1.6 Standard Penetration Test

The purpose of the standard penetration test (SPT) is to determine relative density or consistency of the ground and to obtain disturbed soil samples for identification.

In the present investigation, the SPTs were mainly performed in the completely weathered rock in BH-14 at 1m interval. SPTs were also conducted in the weak and highly weathered rock in other boreholes. A total of 37 SPTs was executed with detailed quantity at each borehole as summarized in Table 1-1. Appendix B presents the results of the SPTs in the drilling logs.

The SPT hammer used in the present investigation was a free-fall type with a hammer weight of 63.5 kg and a falling height of 760mm. The method of the test is described in Appendix A.2.

1.7 Field Permeability Test

To determine the permeability of the rock formations, Lugeon tests, constant head and falling head permeability tests were carried out in the present investigation. The Lugeon tests were performed in the intact rock formation with low permeability while the falling head and the constant head permeability tests were performed in the highly weathered rock formations. The method of the tests are described in Appendix A.3.

A total of 44 Lugeon tests, 17 constant head and 9 falling head permeability tests was conducted in all the boreholes at 5m interval. Table 1-1 presents the quantity of the tests performed in each borehole, Table 1-3 summarizes the results of the Lugeon tests and Table 1-4 summarizes the results of the falling head and constant head tests. The results of

Table 1−3 Results of Lugeon Tests

No	Borehole No	Ground Elevation (m)	Testing Depth (m)	Test Elevation (m)	Lugeon Value (Lugeon)
1	BH−1	30.02	1.0 to 5.0	29.02 to 25.02	1.70
2			5.0 to 10.0	25.02 to 20.02	2.20
3			10.0 to 15.0	20.02 to 15.02	3.80
4			15.0 to 20.0	15.02 to 10.02	4.40
5			20.0 to 25.0	10.02 to 5.02	1.60
6			25.0 to 30.0	5.02 to 0.02	2.20
7			30.0 to 35.0	0.02 to −4.98	1.80
8			35.0 to 40.0	−4.98 to −9.98	1.30
9			40.0 to 45.0	−9.98 to −14.98	1.70
10			45.0 to 50.0	−14.98 to −19.98	2.40
11			50.0 to 55.0	−19.98 to −24.98	2.60
12			55.0 to 60.0	−24.98 to −29.98	2.40
13			60.0 to 65.0	−29.98 to −34.98	1.20
14			65.0 to 70.0	−34.98 to −39.98	2.30
15	BH−2	55.92	5.0 to 10.0	50.92 to 45.92	0.20
16			10.0 to 15.0	45.92 to 40.92	0.32
17	BH−3	40.00	6.0 to 10.0	34.00 to 30.00	0.27
18			10.0 to 15.0	30.00 to 25.00	0.12
19	BH−4	60.61	5.0 to 10.0	55.61 to 50.61	0.70
20			10.0 to 15.0	50.61 to 45.61	0.45
21	BH−5	18.06	2.0 to 5.0	16.06 to 13.06	2.80
22			5.0 to 10.0	13.06 to 8.06	1.40
23			10.0 to 15.0	8.06 to 3.06	2.80
24			15.0 to 20.0	3.06 to −1.94	7.00
25			20.0 to 25.0	−1.94 to −6.94	230.00
26			25.0 to 30.0	−6.94 to −11.94	2.20
27			30.0 to 35.0	−11.94 to −16.94	20.00
28			35.0 to 40.0	−16.94 to −21.94	7.20
29			40.0 to 45.0	−21.94 to −26.94	10.70
30			45.0 to 50.0	−26.94 to −31.94	12.00
31			50.0 to 55.0	−31.94 to −36.94	8.40
32			55.0 to 60.0	−36.94 to −41.94	2.10
33			60.0 to 65.0	−41.94 to −46.94	1.70
34			65.0 to 70.0	−46.94 to −51.94	2.30
35	BH−6	35.78	5.0 to 10.0	30.78 to 25.78	1.20
36			10.0 to 15.0	25.78 to 20.78	0.90
37			15.0 to 20.0	20.78 to 15.78	3.90
38	BH−8	59.91	10.0 to 15.0	49.91 to 44.91	4.40
39	BH−10	4.22	5.0 to 10.0	−0.78 to −5.78	2.60
40			10.0 to 15.0	−5.78 to −10.78	5.20
41			15.0 to 20.0	−10.78 to −15.78	2.60
42	BH−12	48.78	5.0 to 10.0	43.78 to 38.78	0.20
43			10.0 to 15.0	38.78 to 33.78	0.35
44	BH−13	70.00	16.5 to 20.0	53.50 to 50.00	4.00

Table 1−4 Results of Constant Head and Falling Head Permeability Tests

No.	Borehole No.	Ground Elevation (m)	Test Depth (m)	Test Elevation (m)	Permeability k (cm/sec)
1	BH−8	59.91	4.5 to 5.0	55.41 to 54.91	5.23E−05
2			9.0 to 10.0	50.91 to 49.91	9.29E−04
3	BH−11	44.60	3.5 to 4.0	41.10 to 40.60	1.51E−04
4			9.5 to 10.0	35.10 to 34.60	2.20E−03
5			14.5 to 15.0	30.10 to 29.60	7.85E−04
6			19.5 to 20.0	25.10 to 24.60	5.25E−04
7			20.0 to 25.0	24.60 to 19.60	1.30E−04
8			30.0 to 30.0	14.60 to 14.60	2.42E−04
9			30.0 to 35.0	14.60 to 9.60	2.57E−06
10			30.0 to 40.0	14.60 to 4.60	1.36E−06
11	BH−12	48.78	15.0 to 20.0	33.78 to 28.78	7.84E−06
12			15.0 to 25.0	33.78 to 23.78	2.16E−06
13			15.0 to 30.0	33.78 to 18.78	1.75E−06
14	BH−13	70.00	4.5 to 5.0	65.50 to 65.00	8.94E−05
15			9.5 to 10.0	60.50 to 60.00	4.22E−04
16			14.5 to 15.0	55.50 to 55.00	8.86E−04
17	BH−14	48.58	5.0 to 5.0	43.58 to 43.58	1.95E−04
18			10.0 to 10.0	38.58 to 38.58	9.93E−07
19			15.0 to 15.0	33.58 to 33.58	2.08E−05
20			20.0 to 20.0	28.58 to 28.58	2.67E−05
21			25.0 to 25.0	23.58 to 23.58	6.83E−04

the tests are also indicated in the drilling logs in Appendix B. Appendix C.1 presents the detailed results of the field permeability tests.

1.8 Field Density Test

The sand cone tests were performed to determine the density of the soil in its natural state at the proposed borrow pit areas. Appendix A.4 describes the test method. A total of 5 tests was carried out, i.e., one test each close to the boreholes BH-11, BH-12 and BH-13 and two tests at the location of BH-14. Table 1-1 shows the quantity of the tests performed in each borehole location. The tests results are presented in Table 2-3 in Chapter 2. Appendix C.2 presents the detailed results of the sand cone tests.

1.9 Sampling for Laboratory Test

Rock core samples, disturbed soil samples and concrete aggregate were collected from the sites for laboratory tests. Table 1-5 lists the samples retrieved for laboratory tests. Some of the sampling locations which are close to the drilling locations are indicated in Figures 1-1 and 1-2.

Rock Core Sample

The following 15 rock core samples were obtained from the core boxes for the laboratory tests to determine index and mechanical properties:

Borehole	Area	Sample Depth
BH-1	dam site alternative D	3.08 - 3.33m
		17.00 - 17.25m
BH-2	dam site alternative D	4.60 - 4.90m
		12.65 - 12.95m
BH-4	dam site alternative D	2.35 - 2.52m
		7.70 - 7.95m
BH-5	dam site alternative A	2.75 - 3.00m
		18.08 - 18.38m
BH-6	dam site alternative A	4.00 - 4.25m
		6.70 - 6.90m
BH-8	dam site alternative A	9.70 - 9.90m
BH-10	power house	4.77 - 5.00m
		5.00 - 5.25m
BH-12	saddle dam	3.00 - 3.30m
BH-13	upper power house	16.86 - 17.00m

Table 1–5 List of Samples Collected for Laboratory Tests

Location	Sample No.	Depth (m)	Type of Samples				Remark
			Rock Core (nos)	disturbed Soil (nos)	Fine concrete aggregate (nos)	Coarse concrete aggregate (nos)	
BH–1		3.08 – 3.33	1	–	–	–	
		17.00 – 17.25	1	–	–	–	
BH–2		4.60 – 4.90	1	–	–	–	
		12.65 – 12.95	1	–	–	–	
BH–4		2.35 – 2.52	1	–	–	–	
		7.70 – 7.95	1	–	–	–	
BH–5		2.75 – 3.00	1	–	–	–	
		18.08 – 18.38	1	–	–	–	
BH–6		4.00 – 4.25	1	–	–	–	
		6.70 – 6.90	1	–	–	–	
BH–8		9.70 – 9.90	1	–	–	–	
BH–10		4.77 – 5.00	1	–	–	–	
		5.00 – 5.25	1	–	–	–	
BH–12		3.00 – 3.30	1	–	–	–	
BH–13		16.86 – 17.00	1	–	–	–	
BH–11			–	1	–	–	
BH–12			–	1	–	–	
BH–13			–	1	–	–	
BH–14			–	2	–	–	
Beach at Makbon	SP–1		–	–	1	–	– on land (5m from shoreline)
	SP–2		–	–	1	–	– taken from shoreline
	SP–3		–	–	1	–	– in water (100m from shoreline)
Warsamson estuary	SP–4		–	–	1	–	
BH–6	Near BH–6		–	–	–	1	
One kilometer south from Warsamson estuary	Limestone		–	–	–	1	
Warsamson estuary	Estuary Conglomerate		–	–	–	1	
Total			15	5	4	3	

Disturbed Soil Sample

A total of five disturbed soil samples was collected from all the sand cone test locations, i.e., one sample each close to the boreholes BH-11, BH-12 and BH-13 and two samples at the location of BH-14. The disturbed soil samples were tested in the laboratory to determine the suitability of the soil for fill material.

Concrete Aggregate Samples

Seven concrete aggregate samples were collected and were sent to laboratory to investigate the suitability for concrete material. Three fine aggregate samples were taken from the beach of Makbon village and one fine aggregate sample from the estuary of Warsamson river. Three coarse aggregate samples were retrieved at the location near BH-6, at the Warsamson estuary and at the bank of the Warsamson river about 1 km from the estuary.

1.10 Seismic Refraction Survey

The purpose of the seismic refraction survey is to determine the stratification of the ground based on the difference of the wave propagation properties. The method of the test is described in Appendix A.5. A total survey length of 2,700m (24 lines) was conducted with details as below:

Location	Line No	Azimuth	Length
site D left bank	SA	277 degrees	115m
	SB	277 degrees	115m
	SC	277 degrees	115m
	D	0 degrees	115m
	E	5 degrees	115m
site D right bank	SA	97 degrees	115m
	SB	97 degrees	115m
	SC	97 degrees	115m
	SD	180 degrees	115m
site A left bank	SB	310 degrees	115m
	SC	310 degrees	115m
	D	46 degrees	115m
site A right bank	SB	129 degrees	115m
	SC	129 degrees	115m
	SD	48 degrees	115m
power house	S	228 degrees	115m
	A	110 degrees	115m

	P	95 degrees	55m
saddle dam (BH-11)	S (2 lines)	46 degrees	2 x 115m
saddle dam (BH-12)	A	226 degrees	115m
	S	46 degrees	115m
saddle dam (BH-14)	SA	317 degrees	115m
	S	137 degrees	115m

Figures 1-1 and 1-2 present the survey lines plotted on the topographic maps. The calculation sheets and the T-X graphs are given in Appendix C.3.

1.11 Geological Mapping

During the investigation period, a geological mapping was conducted to identify the rock types and the extent of the rock. The survey covers the following areas: (a) along the Warsamson river between km 31 milestone and the estuary, (b) along the road heading to Makbon between the Warsamson bridge and the borehole BH-14 and (c) from W-02 bench mark at approximately N 9,913,000m and E 769,000m to the south until the road at the saddle dam area. The results of the mapping are presented in Figure 3-3 and are discussed further in Chapter 3.

CHAPTER 2

LABORATORY TESTS

According to the Contract Document and subsequent instructions from the client, the soil and rock samples were subjected to the following laboratory tests:

(1) Rock core samples:

- Specific gravity and absorption	(ISRM Doc. No. 2)
- Ultrasonic velocity test	(ISRM Doc. No. 4)
- Unconfined compression test	(ISRM Doc. No. 7)
- Indirect tensile strength test	(ISRM Doc. No. 8)

(2) Soil samples:

- Specific gravity	(ASTM D 854)
- Grain size analysis	(ASTM D 422)
- Atterberg limits (LL and PL)	(ASTM D 423 and 424)
- Compaction test	(ASTM D 678 and 1557)
- Permeability test	(ASTM D 2434)

(3) Fine aggregate samples:

- Specific gravity and absorption	(ASTM C 127)
- Grain size analysis	(ASTM C 136)
- Alkali Reactivity test	(ASTM C 289)
- Sulphate soundness test	(ASTM C 88)
- Crushing test	(ASTM C 417)
- Organic impurities	(ASTM C 40)
- Mud and clay content	(JIS A 1137)
- Chloride content	(ST. CHEM 203A)

(4) Coarse aggregate samples:

- Specific gravity and absorption	(ASTM C 127)
- Grain size analysis	(ASTM C 136)
- LA abrasion test	(ASTM C 131)
- Alkali Reactivity test	(ASTM C 289)
- Sulphate soundness test	(ASTM C 88)
- Chloride content	(ST. CHEM 203A)

Table 2-1 summarizes the total quantities of the laboratory tests performed in the present geological investigation. Tables 2-2 to 2-5 present the test results. Appendix D provides the detailed results of the laboratory tests.

Table 2–1 Total Quantities of Laboratory Tests Performed

No.	Type of Test	Type of Samples				Total
		Rock Core (nos)	Disturbed Soil (nos)	Concrete Aggregate		
				Fine (nos)	Coarse (nos)	
1	Specific gravity and absorption	15	–	–	–	15
2	Ultrasonic velocity test	15	–	–	–	15
3	Unconfined compression test	15	–	–	–	15
4	Indirect tensile strength test	14	–	–	–	14
5	Specific gravity	–	5	–	–	5
6	Grain–size analysis	–	5	–	–	5
7	Atterberg limits (LL and PL)	–	5	–	–	5
8	Compaction test	–	10	–	–	10
9	Permeability test	–	5	–	–	5
10	Specific gravity and absorption	–	–	4	3	7
11	Grain–size analysis	–	–	4	3	7
12	Alkali reactivity test	–	–	4	3	7
13	Sulphate soundness test	–	–	3	3	6
14	Crushing test	–	–	3	–	3
15	Organic impurities	–	–	4	–	4
16	Mud and clay content	–	–	4	–	4
17	Chloride content test	–	–	4	3	7
18	Los Angeles abrassion test	–	–	–	3	3

Table 2–2 Results of Laboratory Tests on Rock Core Samples

Project : WARSAMSON HEPP FEASIBILITY STUDY

Borehole No.	BH – 1		BH – 2		BH – 4		BH – 5		BH – 6		BH – 8	BH – 10		BH – 12	BH – 13
Sample Depth	3.08 m ~ 3.33 m	17.00 m ~ 17.25 m	4.60 m ~ 4.90 m	12.65 m ~ 12.95 m	2.35 m ~ 2.52 m	7.70 m ~ 7.95 m	2.75 m ~ 3.00 m	18.08 m ~ 18.38 m	4.00 m ~ 4.25 m	6.70 m ~ 6.90 m	9.70 m ~ 9.90 m	4.77 m ~ 5.00 m	5.00 m ~ 5.25 m	3.00 m ~ 3.30 m	16.86 m ~ 17.00 m
Rock Mechanical Properties Determination															
Wet Density, t/m3	2.37	2.57	2.71	2.80	2.51	2.37	2.81	2.77	2.77	2.82	2.46	2.56	2.62	2.56	2.46
Natural Water Content, %	0.43	2.62	1.18	0.38	1.03	1.35	1.00	0.45	0.17	0.47	1.16	2.28	1.50	1.10	1.80
Saturated Density, t/m3	2.40	2.60	2.72	2.82	2.57	2.51	2.84	2.80	2.80	2.84	2.56	2.61	2.66	2.59	2.54
Absorpt. Sat. Water Content, %	1.56	3.65	1.60	0.96	3.47	6.11	2.11	1.35	1.32	1.23	5.19	4.50	3.06	2.45	5.19
Dry Density, t/m3	2.36	2.51	2.68	2.79	2.48	2.33	2.78	2.76	2.77	2.81	2.43	2.50	2.58	2.53	2.41
Degree of saturation, %	27	72	74	40	30	22	47	33	13	38	22	51	49	45	35
Porosity, %	3.69	9.15	4.28	2.68	8.60	14.49	5.86	3.73	3.64	3.46	12.62	11.24	7.91	6.18	12.53
True Specific gravity	2.45	2.76	2.80	2.87	2.72	2.77	2.95	2.86	2.87	2.91	2.78	2.81	2.81	2.69	2.76
Void ratio	0.04	0.10	0.05	0.03	0.09	0.17	0.06	0.04	0.04	0.04	0.14	0.13	0.09	0.07	0.14
Ultrasonic velocity test															
Compression wave velocity, m/sec	3133	3102	3185	3142	3600	3085	2333	2678	3375	2815	1740	3040	3456	3185	3696
Shear wave velocity, m/sec	1566	1551	1858	1692	1661	1542	1354	1566	1800	1671	949	1636	1481	1858	1540
Poisson's ratio	0.33	0.33	0.24	0.30	0.36	0.33	0.25	0.24	0.30	0.23	0.29	0.30	0.39	0.24	0.40
Young's modulus, kg/cm2	1.55E+05	1.89E+05	2.32E+05	2.08E+05	1.89E+05	1.53E+05	1.29E+05	1.69E+05	2.34E+05	1.94E+05	5.71E+04	1.77E+05	1.60E+05	2.19E+05	1.63E+05
Shear Modulus, kg/cm2	5.82E+04	7.08E+04	9.36E+04	8.02E+04	6.92E+04	5.73E+04	5.16E+04	6.79E+04	8.97E+04	7.88E+04	2.22E+04	6.85E+04	5.75E+04	8.83E+04	5.82E+04
Indirect tensile strength test															
Tensile strength, kg/cm2	36	37	56	45	49	35	28	51	59	94	88	44	39	35	–
Unconfined compression test															
Compressive strength, kg/cm2	467	636	663	619	385	953	279	580	975	672	649	475	389	823	239
Strain at failure, %	0.6	0.4	0.8	0.8	0.6	0.6	0.7	0.8	1.1	0.9	0.5	0.4	0.6	0.7	0.4

Table 2–3 Results of Laboratory Tests on Disturbed Soil Samples

	Sample Designation*					Remark
	BH–11	BH–12	BH–13	BH–14	BH–14A	
Condition of Sample	Disturbed	Disturbed	Disturbed	Disturbed	Disturbed	
Natural Water Content**, %	15	17	14	16	17	
Specific Gravity	2.70	2.78	2.68	2.60	2.76	
Wet density (Insitu)** , t/m3	1.58	1.53	1.58	1.59	1.62	
Dry density** , t/m3	1.37	1.31	1.38	1.37	1.38	
Natural void ratio	0.97	1.12	0.94	0.89	1.00	
Degree of saturation, %	42	42	40	46	47	
Atterberg limits						
Liquit limit, %	65	66	61	97	94	
Plastic limit, %	39	24	42	29	44	
Plasticity Index, %	26	42	19	68	50	
Grain size analysis						
Gravel, %	0	3	1	2	1	
Sand, %	8	22	32	3	8	
Silt, %	54	48	39	67	55	
Clay and colloid, %	38	27	28	28	36	
Permeability cm/sec	2.6x10–4	1.5x10–4	1.6x10–4	8x10–4	5.4x10–4	
Maximum dry density, t/m3	1.31	1.53	1.36	1.21	1.45	Standard Proctor
Optimum moisture content, %	36	23	32	37	27	
Maximum dry density, t/m3	1.36	1.60	1.42	1.29	1.53	Modified Proctor
Optimum moisture content, %	34	19	30	34	24	

Note: * The samples were taken close to the location of the designated boreholes
** Result of field density test

Table 2–4 Results of Laboratory Tests on Fine Concrete Aggregate Samples

Test Description	Makbon			Warsamson	Requirement
	SP – 1	SP – 2	SP – 3	SP – 4	
Bulk Specific Gravity	2.35	2.34	2.07	2.54	
Bulk Specific Gravity (Saturated–Surface Dry)	2.44	2.44	2.40	2.60	Not less than 2.5
Apparent Specific Gravity	2.6	2.6	3.08	2.70	
Absorption, %	4.11	4.40	15.71	2.21	Not more than 3%
Fraction passing sieve, %					
9.6 mm	100	97	100	100	100
4.8 mm	100	86	100	100	90–100
2.4 mm	100	78	100	99	80–100
1.2 mm	99	57	100	93	50–90
0.6 mm	90	33	100	58	25–65
0.3 mm	55	28	99	14	10–35
0.15 mm	13	18	96	1	2–10
Alkali Reactivity					
Rc, mmol/l	170	187	277	170	Sc < Rc
Sc, mmol/l	84	66	63	102	
Soundness, %	6.33	8.60	–	9.99	Not more than 10 %
Organic Impurities	Brighter	Brighter	Brighter	Brighter	Brighter than Standard colour No 3
Silt & Clay, %	4.1	4.2	37.8	1.3	Less than 5 %
Hardness Index	2.18	2.78	–	1.16	
Chloride Content, %	0.05	0.06	0.18	0.01	

Table 2–5 Results of Laboratory Tests on Coarse Concrete Aggregate Samples

Test Description	Near BH–6	Limestone	Estuary Conglomerate	Requirement
Bulk Specific Gravity	2.60	2.62	2.44	
Bulk Specific Gravity (Saturated–Surface Dry)	2.64	2.66	2.55	Not less than 2.5
Apparent Specific Gravity	2.69	2.72	2.74	
Absorption, %	1.24	1.38	4.51	Not more than 3%
Alkali Reactivity				
Rc, mmol/l	170	96	277	Sc < Rc
Sc, mmol/l	35	42	96	
Soundness, %	1.17	2.23	2.65	Not more than 12%
Abrassion Loss, %	17.80	29.60	37.70	Not more than 40%
Chloride Content, %	undetected	0.004	undetected	

CHAPTER 3
INTERPRETATION OF GROUND CONDITIONS

3.1 General Topography

The Warsamson River basin, including its surrounding area, can be classified to two typical topographies which are (1) intermontane valleys and (2) rugged hills. Figure 3-1 indicates their distributions.

(1) Intermontane Valley

The most upstream part of the Warsamson River is near the foot of Tamrau Range, located some 100km east of Sorong town. After that, the stream meanders toward west in a wide and gentle intermontane valley, called "Warsamson Valley". The elevation of the ground near the river is in a range of 50m to 100m and the slopes of the bank are generally gentle. This intermontane valley area is bounded by mountain range at its north and south. Further north of the mountain range is the Dore Hum valley running parallel with the Warsamson river. The proposed saddle dam is located in this Dore Hum Valley. A large portion of this intermontane valley will serve as a reservoir pond for the proposed dam.

(2) Rugged Hills

The Warsamson River, meandering in the intermontane valley abruptly changes its direction at about 15km east of Sorong town and cuts through rugged hills into a deep gorge en route to the Pacific Ocean to the north. Cascades and waterfalls have developed at several places in the lower part of the gorge. The rugged hills constitute a part of mountains surrounding the intermontane valleys. The slope angle of the bank is 30° to 60° at the dam site alternatives in the gorge.

3.2 Geological Background

On the basis of the "Geology of the Sorong Sheet area, Irian Jaya" published by the Geological Research and Development Center (1990), the Warsamson River basin and its surrounding area can be divided into three geological formations, i.e., Tamrau Block, Sorong Fault System and Kemum Block, as shown in Figure 3-2.

The proposed dam site will be located in the Tamrau Block while most parts of the reservoir area in the upper stream will be situated within the Sorong Fault System with minor part within the Kemum Block.

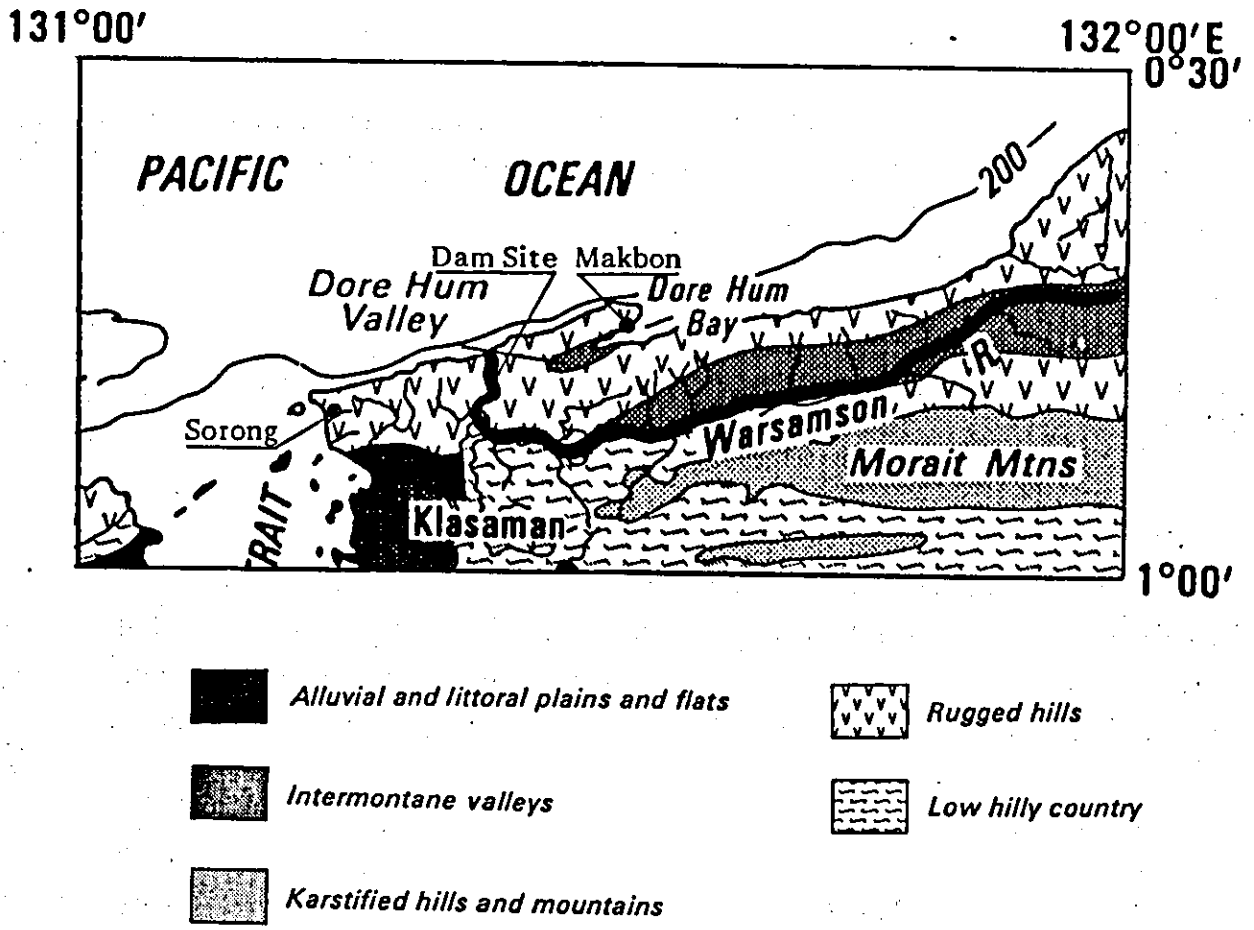
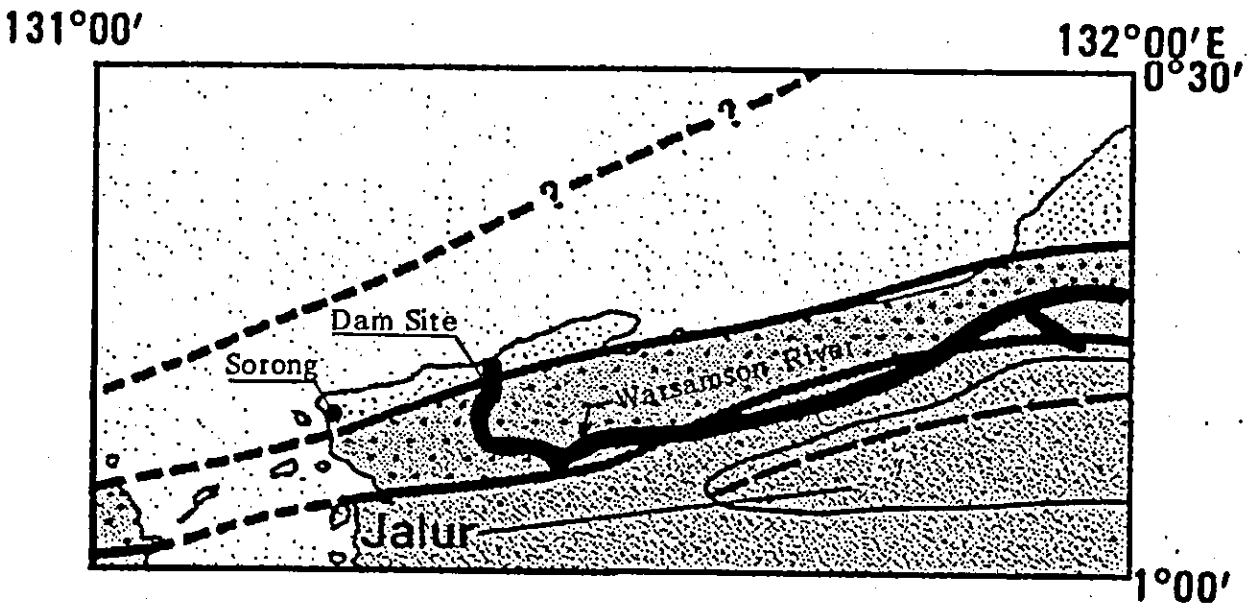


Figure 3-1 Warsamson River Basin and Topography



Legends	Discription	Age
	Kemum Block *(Blok Kemum)*	Siluro–Devonian to Holocene
	Tamrau Block *(Blok Tamrau)*	Miocene
	Sorong Fault System *(Sistem Sesar Sorong)*	Late Miocene to Quaternary

Figure 3–2 Warsamson River Basin and Geological Formation
(Reproduced from "Geology of the Sorong Sheet Area, Irian Jaya", published by the Geological Research and Development Center, 1990)

In the Tamrau Block, the major formation encountered at the site is Miocene Dore volcano (Tmdo) consisting of andesitic to basaltic volcanic, volcanoclastic rocks. Other than these, carbonate rock was also confirmed near the estuary and is probably a member of Koof Formation (Tmko) or Segawin Limestone (Tmsa) deposited in the Miocene epoch.

The Sorong Fault System is a melange zone comprising fragments of clastic sedimentary rocks, carbonate, granite and ultramafic and volcanic rock ranging in size from pebbles to blocks of several kilometers long. The fragments owe their present relative configurations to the movement of the Sorong Fault System between the Late Miocene and Quaternary. The type of rocks outcropped at the site are shale, tuff, conglomerate and siltstone. To be noted is that such rocks contain fragment of limestone, considerably varying in size and quantity depending on the location.

The Kemum Block comprises clastic sedimentary rocks, metamorphic rocks, intrusive rocks, carbonates and surficial deposits ranging in age from Siluro-Devonian to Holocene. This formation was not confirmed in the present investigation.

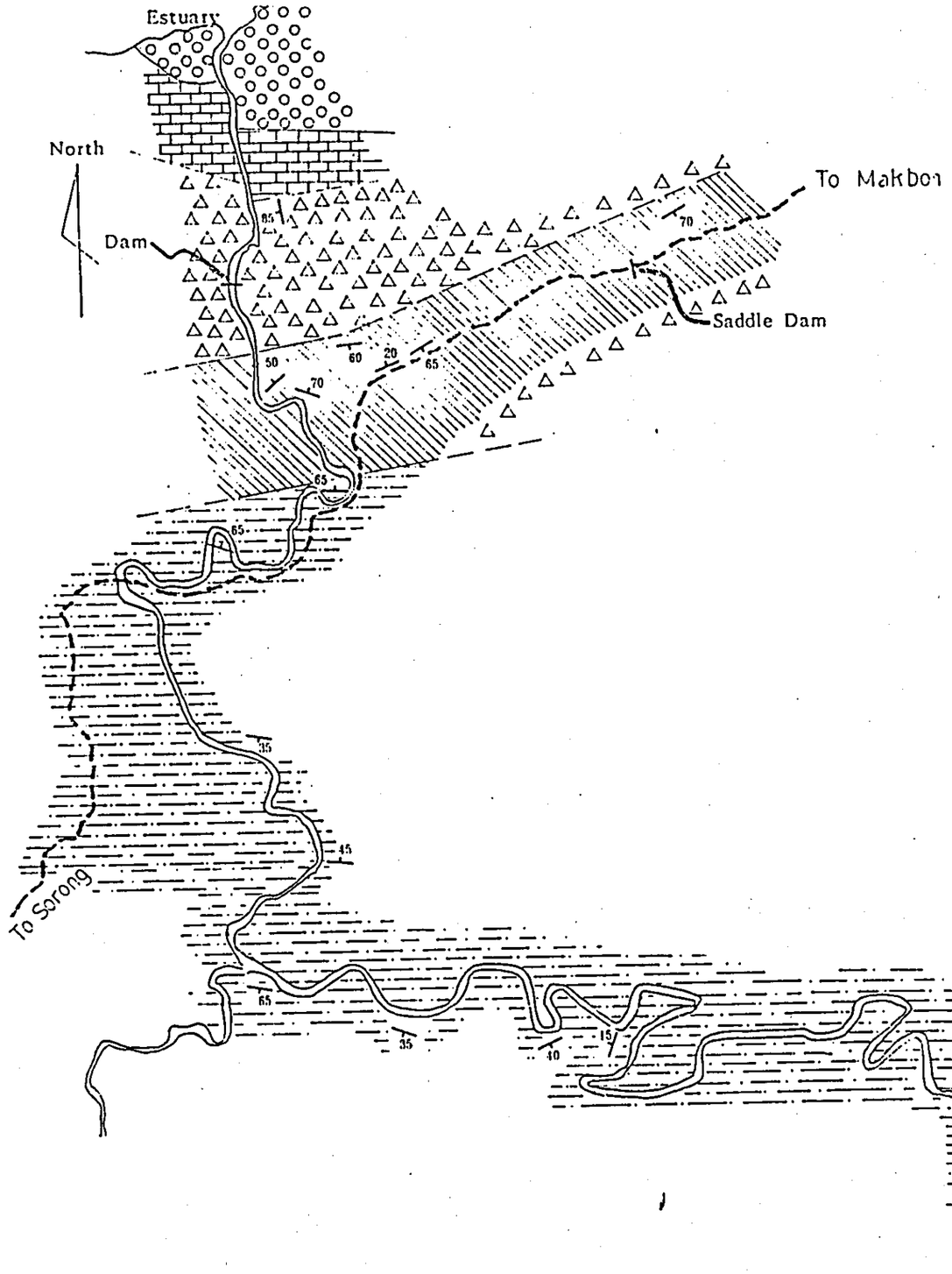
3.3 Stratification

Figure 3-3 presents the results of our geological reconnaissance survey performed mainly along the river and road. As can be seen in the figure, we divided the river basin into five geological zones for geotechnical study purpose from the north to south as below :

(1) Zone of Estuary Conglomerate
(2) Zone of Cliff Limestone
(3) Zone of Lava Breccia
(4) Zone of Weathered Shale
(5) Zone of Miscellaneous Sedimentary Rocks

(1) Zone of Estuary Conglomerate

Relatively well cemented conglomerate is cropped out at the estuary of the Warsamson River in the north coast of the rugged hills. We believe that it belongs to the Tamrau Formation (Tmdo) in the Miocene. Gravels contained in the conglomerate are of volcanic origin rocks such as andesite, basalt and diabase with diameters of 10 to 50mm. The matrix is fine grained, tuffaceous material.



Legends	Discription	Age
	Estuary Conglomerate	Miocene
	Cliff Limestone	Miocene
	Lava Breccia	Miocene
	Weathered Shale	Miocene
	Miscellaneous Sedimentary Rock	Late Miocene to Quaternary
	Road	
65	Strike and Dip	

Scale

0 4 km

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THE FEASIBILITY STUDY ON THE WARSAMSON HYDRO-ELECTRIC POWER DEVELOPMENT PROJECT SORONG, IRIAN JAYA

FIGURE 3-3
GEOLOGICAL MAP ALONG WARSAMSON RIVER

SCALE:
1 : 50000

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(2) Zone of Cliff Limestone

There are vertical cliffs of limestone at the right and left banks of the river in the south of the estuary conglomerate zone. The height of the cliff is 20 to 30m. The limestone is white or black and moderately crystallized with a lot of close spaced silica veins and, although not so weak as a fragment, is heavily weathered with many open joints, fissures and some cavities.

We believe that this limestone is a member of the Koof Formation (Tmko) or the Segawin limestone (Tmsa) which was found in the Dore Volcanic Formation near the project site with limited distribution at small and isolated area.

(3) Zone of Lava Breccia

Lava breccia is distributed at the south of the cliff limestone zone, forming the rugged hills with steep and narrow gorges that Warsamson River running through. The steepest and narrowest gorge is considered suitable to construct a concrete dam. Large andesite boulders (probably derived from this lava breccia) with diameter of greater than 3m were found at the upper portion of the mountain range at both sides of the Dore Hum Valley.

The lava breccia is dark grey with subangular fragments of basalt, andesite and diabase, containing medium spaced white silica veins with maximum thickness of 3mm. Occasionally, the fissures are open along the vein.

The lava breccia can be divided to the following 3 portions based on the results of the seismic refraction survey and the drilling logs.

	Seismic Wave Velocities	RQD
- Residual Soils	< 0.5 km/sec	0%
- Moderately Weathered Portion	0.5 - 2 km/sec	0-100%
- Slightly Weathered to Fresh Portion	> 3 km/sec	75-100%

The residual soils mainly contain materials of D class based on the classification proposed by the Central Research Institute of Electric Power Industry (CRIEPI) as indicated in Appendex G. The moderately weathered portion contains CL to CM materials while the slightly weathered to fresh portion contain CH materials with minor of CM materials.

Residual soils

Figures 3-4 and 3-5 indicate the geological sections along the dam sites D and A respectively. As shown in the figures, the top portion of lava breccia is completely weathered and has been changed into residual soils in places. The residual soils are clayey silt, sandy silt, silty sand and gravelly soils. The thickness of the residual soils confirmed at the borehole loca-

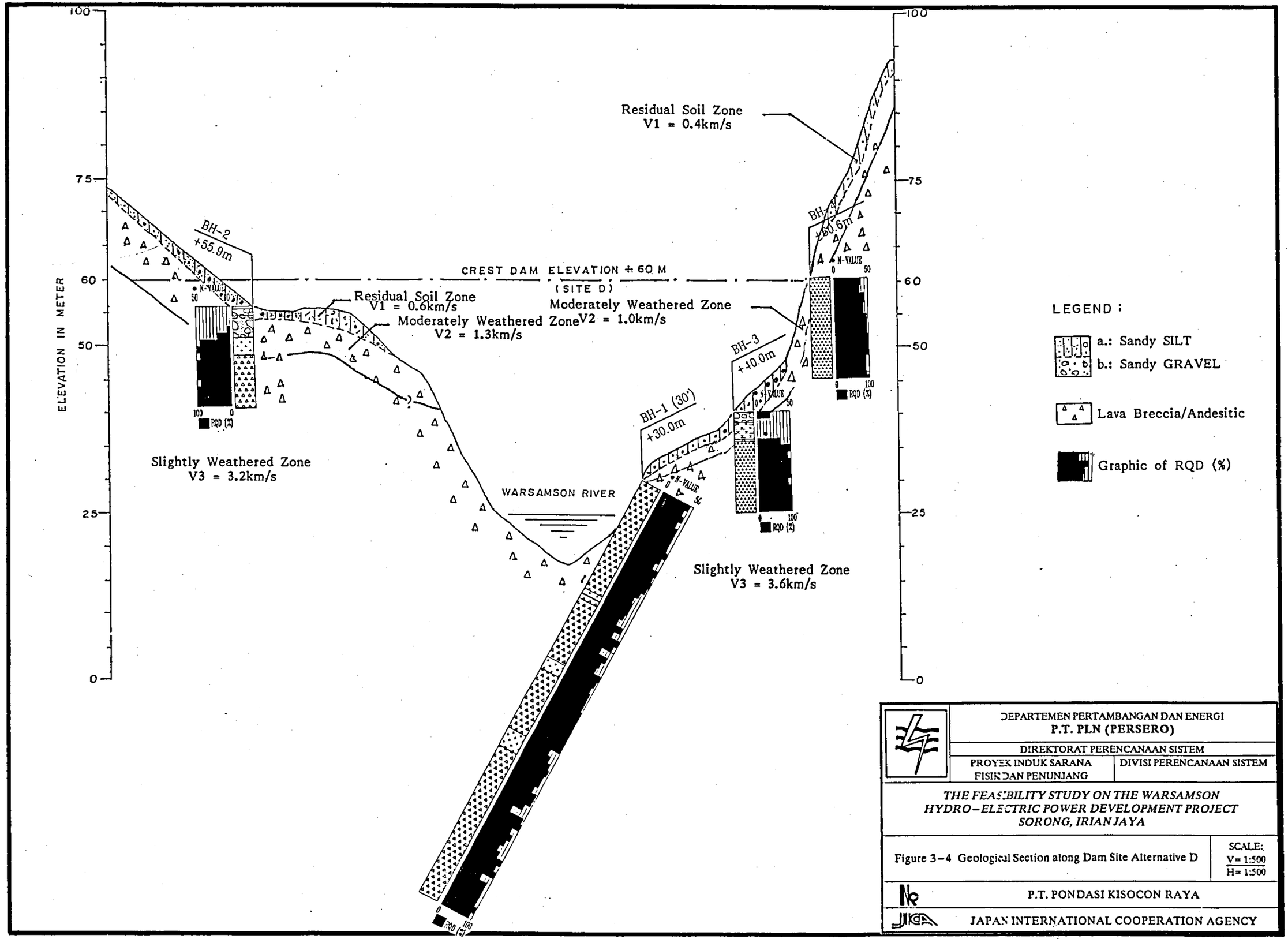

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Figure 3-4 Geological Section along Dam Site Alternative D

SCALE: V= 1:500 / H= 1:500

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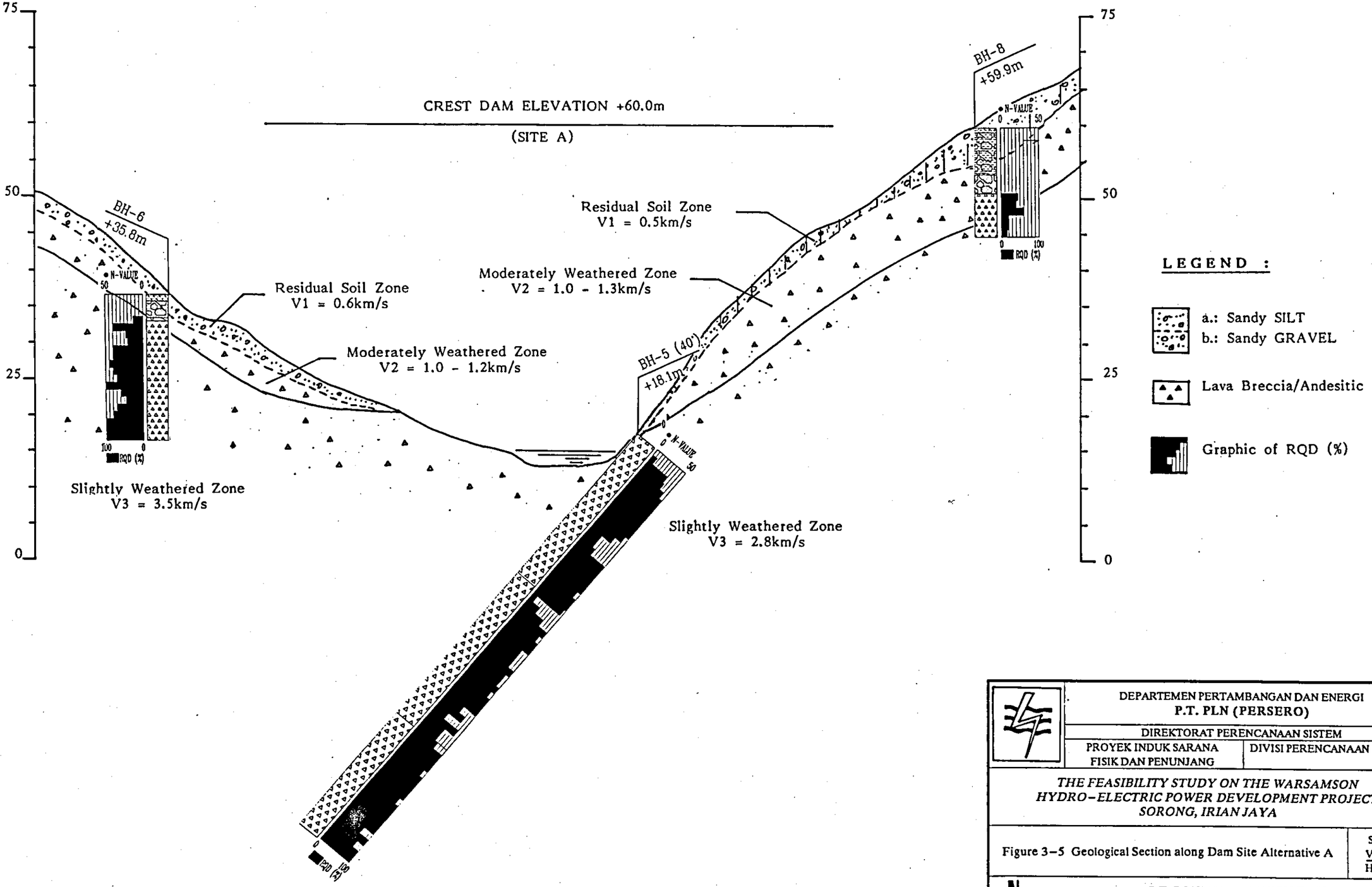

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THE FEASIBILITY STUDY ON THE WARSAMSON HYDRO-ELECTRIC POWER DEVELOPMENT PROJECT SORONG, IRIAN JAYA

Figure 3-5 Geological Section along Dam Site Alternative A

SCALE:
V= 1:500
H= 1:500

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tions is summarized as below :

	Borehole	Elevation (m)	Thickness of Residual Soils (m)
	BH-1	+30.0	-
Dam Site	BH-2	+55.9	5
Alternative D	BH-3	+40.0	4
	BH-4	+60.6	-
Dam Site	BH-5	+18.1	-
Alternative A	BH-6	+35.8	3
	BH-8	+59.0	7
Power House	BH-10	+4.2	6.5
Surge Tank	BH-13	+70.0	16.5

The thickness of the residual soil varies significantly from one location to another. However, there is a tendency that the thickness is larger at the boreholes at higher elevations.

There is no residual soil at BH-1 and BH-5 near the river side at lower portion of the hill while residual soils with thickness of 17m were revealed at BH-13 which is located at the middle flank of the hill at 70m above the mean sea level.

Moderately Weathered Portion

Moderately weathered portion of lava breccia is sandwiched by the top residual soils and fresh lava breccia underneath. Figure 3-6 indicates the total thickness of the residual soils and the moderately weathered portion of lava breccia. As can be seen in the figure, there is a tendency that the total thickness also increases at higher elevation. The thickness of this moderately weathered portion varies significantly from a minimum thickness of 1m to a maximum of 25m. It is noted that this moderately weathered portion is not homogeneous with a single seismic velocity. On the contrary, it consists of various materials with different degrees of weathering, fissures and weak zones. The seismic velocity obtained in this portion is an average velocity of waves which passes through many materials. Therefore, the weathering state of the rock defined by the RQD observed in the borehole at the respective seismic section does not necessarily agree with the weathering state defined by the seismic wave velocity.

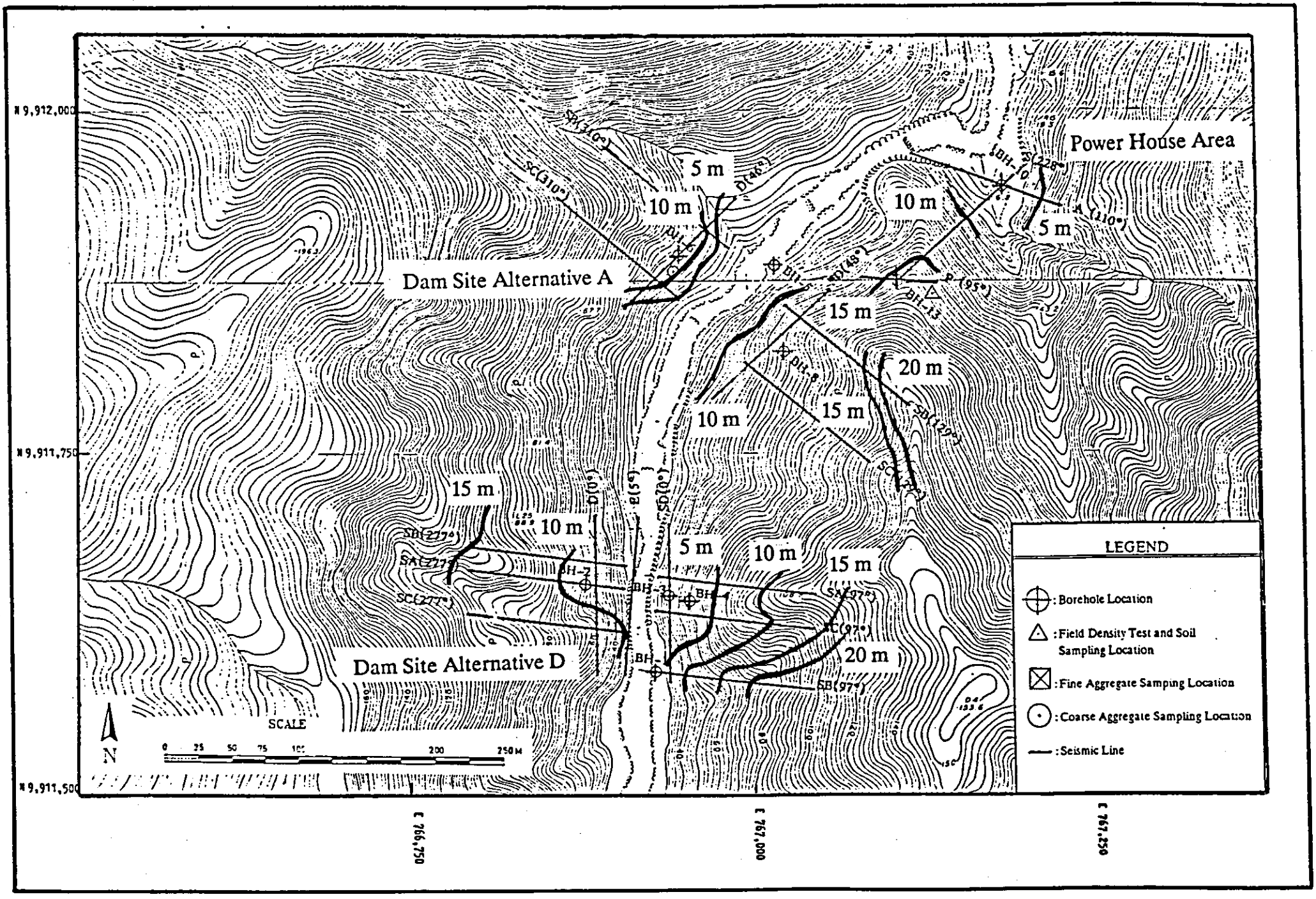


Figure 3–6 Contour Map Indicating The Thickness of Residual Soils and Moderately Weathered Lava Breccia

Slightly Weathered to Fresh Portion

The slightly weathered and fresh lava breccia is the most stable and sound layer which is suitable as foundation bearing layer for the proposed dam type. It is cropped out at the lower ridge of the mountain range and covered by thick top soils and moderately weathered portion at higher ridge of the mountain range. The RQD is excellent in a range of 75% to 100%.

(4) Zone of Weathered Shale

The highly weathered shale is the basic formation around the saddle dam area at Dore Hum Valley. The maximum thickness of the shale confirmed was 40m at the location of BH-11. The Pre-Feasibility study also confirmed the presence of the highly weathered shale at PB-1, 2, 3 and 4 which are located about 2km up stream from the dam site alternative D. The locations of the boreholes in the Pre-Feasibility Study are also indicated in Figure 3-7.

The shale is black to dark grey with many fissures, slicken sides and cleavages. The fragments are very weak and crushable with finger pressures or a light blow of hammer. SPT N-value is generally greater than 50 blows except at very top portion. Iron oxide stains the faces of fissures at the shallow portion within 10m from the ground surface.

It is noted that the shale in this Weathered Shale Zone often contains various sizes of limestone boulders. Some of the limestone boulders are outcropped on the slope of hills and on the beds of small drains and others are encountered in the boreholes. The limestone boulder encountered in BH-12 is 14m in size with excellent RQD of 80 to 100%, while they are highly weathered and fractured in the boreholes PB-1 to 4. These boulders were derived from Tamrau and Kemum Blocks, ages of which are from Late Cretaceous to Middle Miocene, although the shale itself of this melange zone was formed in Late Miocene to Quaternary.

(5) Zone of Miscellaneous Sedimentary Rocks

The zone of miscellaneous sedimentary rocks is located at the south of the Weathered Shale Zone and covers the most area of reservoir portion of the Warsamson River. This zone, together with the Weathered Shale Zone, is included in the Sorong Fault System which is a melange zone assembling various types of rocks, deriving from the adjacent zones.

The rocks confirmed along the river include conglomerate, tuff, mudstone, siltstone, sandstone and, sometimes, carbonate rocks. Mostly, they are highly weathered and a light blow of hammer is able to crush them into pieces. The predominant rock type in this zone is

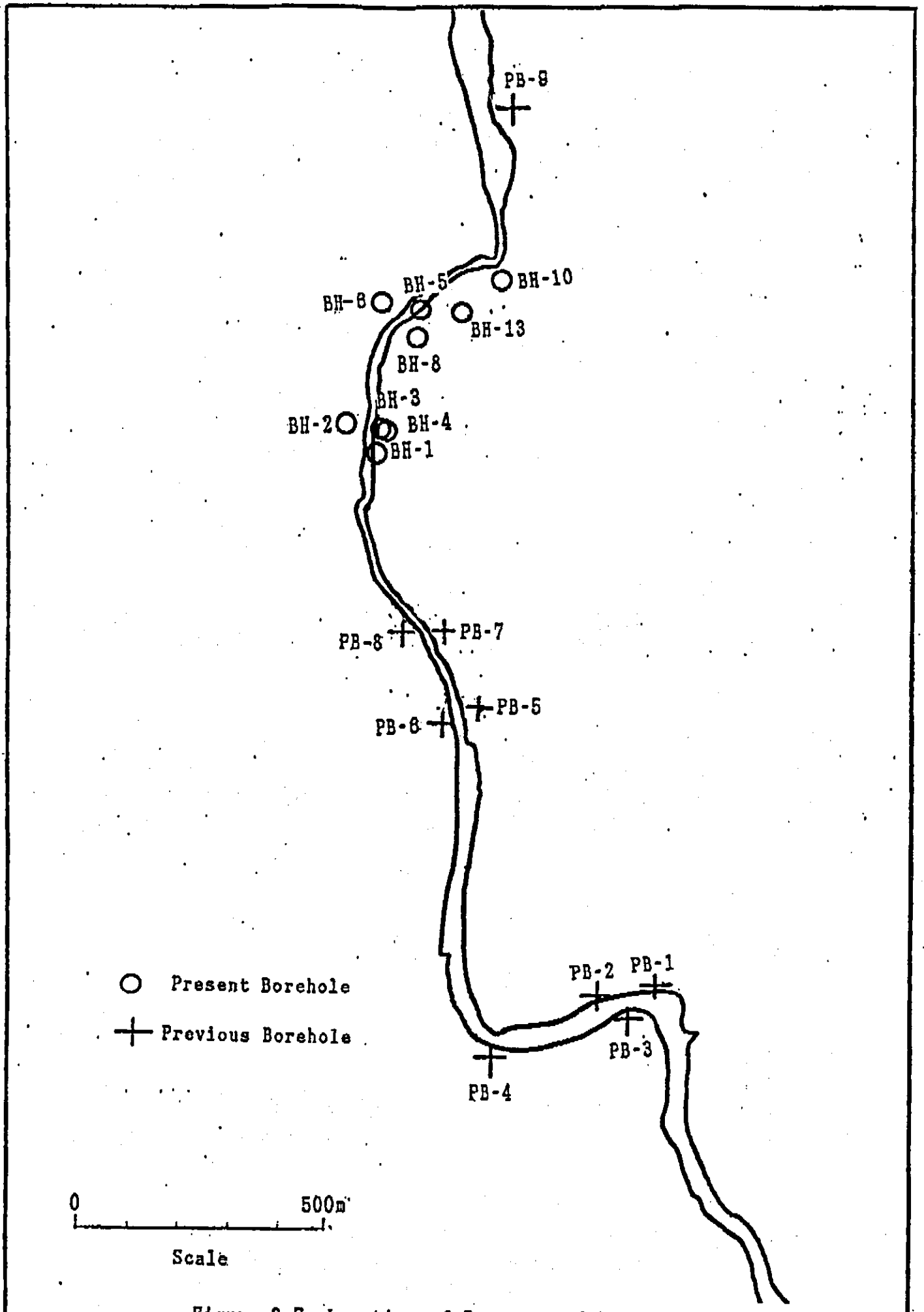


Figure 3-7 Location of Present and Previous Boreholes

tuffaceous or calcareous mudstone.

Outcrops of limestone are often noticed as boulders with random dips, strikes, shape and size. Usually the outcrop is isolated and is too small to map.

3.4 Engineering Properties

This section discusses the engineering properties of the ground based on the results of the present and previous (Pre Feasibility Study) investigations. Table 3-1 summarizes the engineering properties of the materials encountered in the investigation.

(1) Rock Quality Designation (RQD)

In general, the RQD of the lava breccia at the alternative dam sites is fair to excellent while it is poor to very poor at the perimeter area adjacent to other geological zones as shown in Figure 3-8. Location of this section is shown in Figure 3-9.

The lava breccia has a good to excellent RQD, ranging mostly from 75% to 100% at BH-1 to BH-4 at the dam site alternative D and at PB-6 to PB-8 at approximately 500m south from site D. At the dam site alternative A, the RQDs are rather low, ranging from 50 to 100% at BH-5 and BH-6 and 10% to 50% at BH-8.

At the perimeter area, RQDs are poor and ranging from 0 to 50% at BH-10, PB-5 and PB-9. The RQDs of the shale are generally very poor. However, excellent RQD is observed at the limestone boulders which are frequently embedded in the shale at BH-12.

(2) Index Properties

The unit weight varies from 2.5 to 2.8 g/cm^3 for the fresh to slightly weathered portion of lava breccia and 2.4 to 2.7 g/m^3 for the moderately weathered portions. The porosity is 2 to 8% for the fresh to slightly weathered portion and 4 to 13% for the moderately weathered portion.

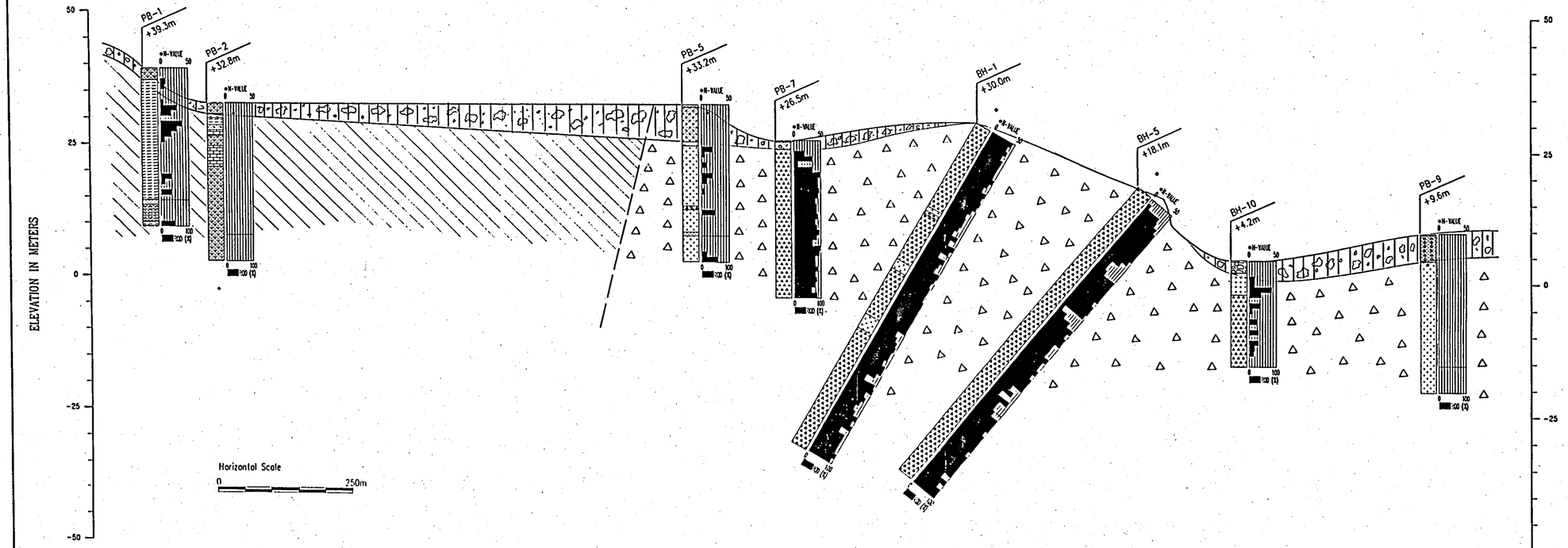
(3) Dynamic Properties

The dynamic properties of the lava breccia were obtained from the laboratory ultra sonic wave velocity measurements. The compressive wave velocity of the rock core extracted from the fresh to slightly weathered portion is almost the same as the insitu compressive wave velocity measured at the site by the seismic survey.

Table 3–1 Engineering Properties of the Ground

Items	Estuary Conglomerate	Cliff Limestone	Lava Breccia (1) Residual Soils	Lava Breccia (2) Moderately Weathered Portion	Lava Breccia (3) Fresh to Slightly Weathered Portion	Weathered Shale	(Limestone Boulder in Shale)	Miscellaneous Sedimentary Rock
Thickness (m)	–	–	0 – 17	0 – 5	> 60	>40	14	–
RQD	–	–	0	0 – 100	70 – 100	0	0	0 (Except Limestone)
Rock Cored Sample								
– Unit Weight, g/cm3	(2.55)	(2.66)	(1.53)	2.4 – 2.7	2.5 – 2.8	–	(2.56)	–
– Water Content, %	(4)	(2)	(17)	1 – 2	1 – 3	–	(1)	–
– Porosity, %	(11)	(4)	(49)	4 – 13	2 – 8	–	(6)	–
– Specific Gravity	(2.74)	(2.72)	(2.68)	2.8	2.8 – 2.9	–	(2.69)	–
– Wave Velocity, km/sec	–	–	–	1.7 – 3.7	2.3 – 3.4	–	(3.18)	–
– Shear Wave Velocity, km/sec	–	–	–	0.9 – 1.9	1.3 – 1.8	–	(1.86)	–
– Poisson's Ratio	–	–	–	0.24 – 0.33	0.24 – 0.33	–	(0.24)	–
– Dynamic Young Modulus, kg/cm2	–	–	–	60,000 – 230,000	130,000 – 230,000	–	(219,000)	–
– Dynamic Shear Modulus, kg/cm2	–	–	–	22,000 – 94,000	51,000 – 90,000	–	(88,000)	–
– Tensile Strength, kg/cm2	–	–	–	35 – 88	28 – 94	–	(35)	–
– Compressive Strength, kg/cm2	–	–	–	240 – 660	280 – 950	–	(823)	–
– Young Modulus, kg/cm2	–	–	–	60,000 – 130,000	40,000 – 160,000	–	(118,000)	–
Seismic Wave Velocity, km/sec	–	–	< 0.5	0.5 – 2.0	3.0 – 4.3	0.8 – 2.5	?	–
Coefficient of Permeability, cm/sec	–	–	$10^{-3} - 10^{-5}$	$10^{-2} - 10^{-4}$	$10^{-3} - 10^{-6}$	$10^{-3} - 10^{-4}$	$10^{-4} - 10^{-5}$	–

Notes : ( ) Only one result is available.



LEGEND

- Sandy-Silt & Gravel
- Lava Brecia/Andesitic
- Wheathered Shale
- PB-1 : Borehole (Pra FS-1991)
- BH-1 : Borehole (FS-1994)
- 2.6 Lugeon Value (Lu)

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FIGURE 3-8
GEOLOGICAL SECTION ALONG WARSAMSON RIVER

SCALE:
V = 1 : 500
H = 1 : 25000

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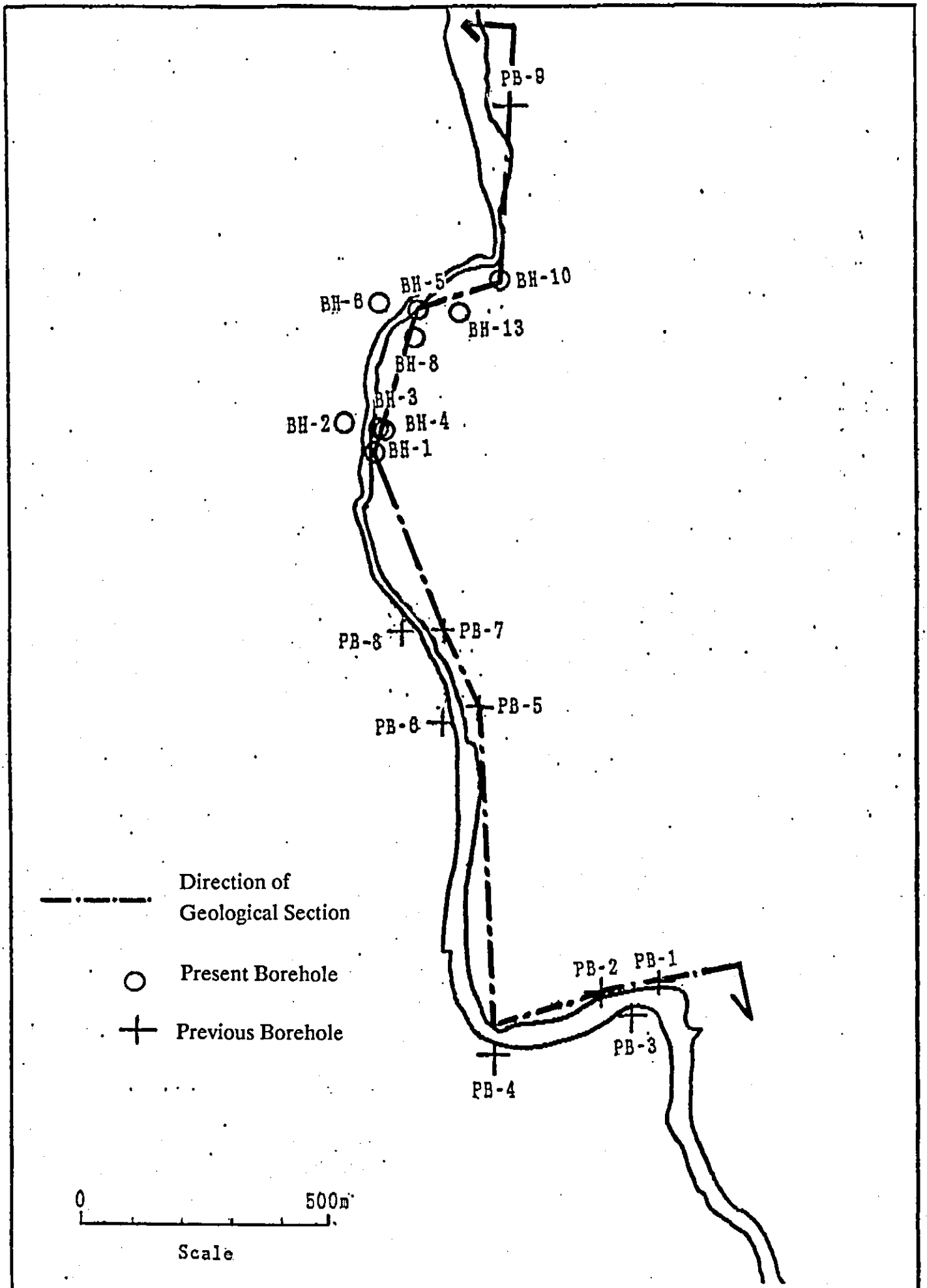


Figure 3-9 Location of Geological Section along Warsamson River

(4) Static Properties

The unconfined compression strength of the lava breccia is 200 to 1000 kg/cm^2 which is within the reasonable range estimated from compressive wave velocity. The brittleness ratio of the lava breccia, which is defined as the unconfined compressive strength over the tensile strength, is 7 to 27 that is also in a common range for this type of rock. The cohesion of rocks decreases with the higher ratio of brittleness. For the comparison, the brittleness ratio of steel with large cohesion is 1.

As always the case for other types of rocks, no correlation could be established between RQD and the engineering properties obtained from laboratory tests.

(5) Seismic Wave Velocity

Figure 3-10 presents the seismic wave velocity of the base rocks around the site. As shown in the figure, the insitu seismic wave velocities of the fresh to slightly weathered lava breccia are in the same order with the ones obtained at the laboratory through the rock core specimens. This indicates that the rock mass is in the same condition as the rock core specimens without discontinuities. The excellent RQD supports this interpretation. For this reason, the presence of faults is unlikely in the fresh to slightly weathered portion although the wave velocities are sometimes ups and downs in the time distance curves that can be interpreted as faults. We took the average velocity instead of taking high velocity plus weak zone.

We notice from the T-X graph in saddle dam area close to the borehole BH-14 in Appendix 4.2.6 that there is a zone with relatively lower velocity than the surrounding zones. The propagation of the wave may probably be affected by the nature of highly wheathered and completely fractured of the weathered shale.

(6) Permeability

<u>Zone of Lava Breccia</u>

Figures 3-11 and 3-12 show the Lugeon profiles at the dam sites alternative D and A respectively. The coefficients of permeability converted from the Lugeon values are summarized below:

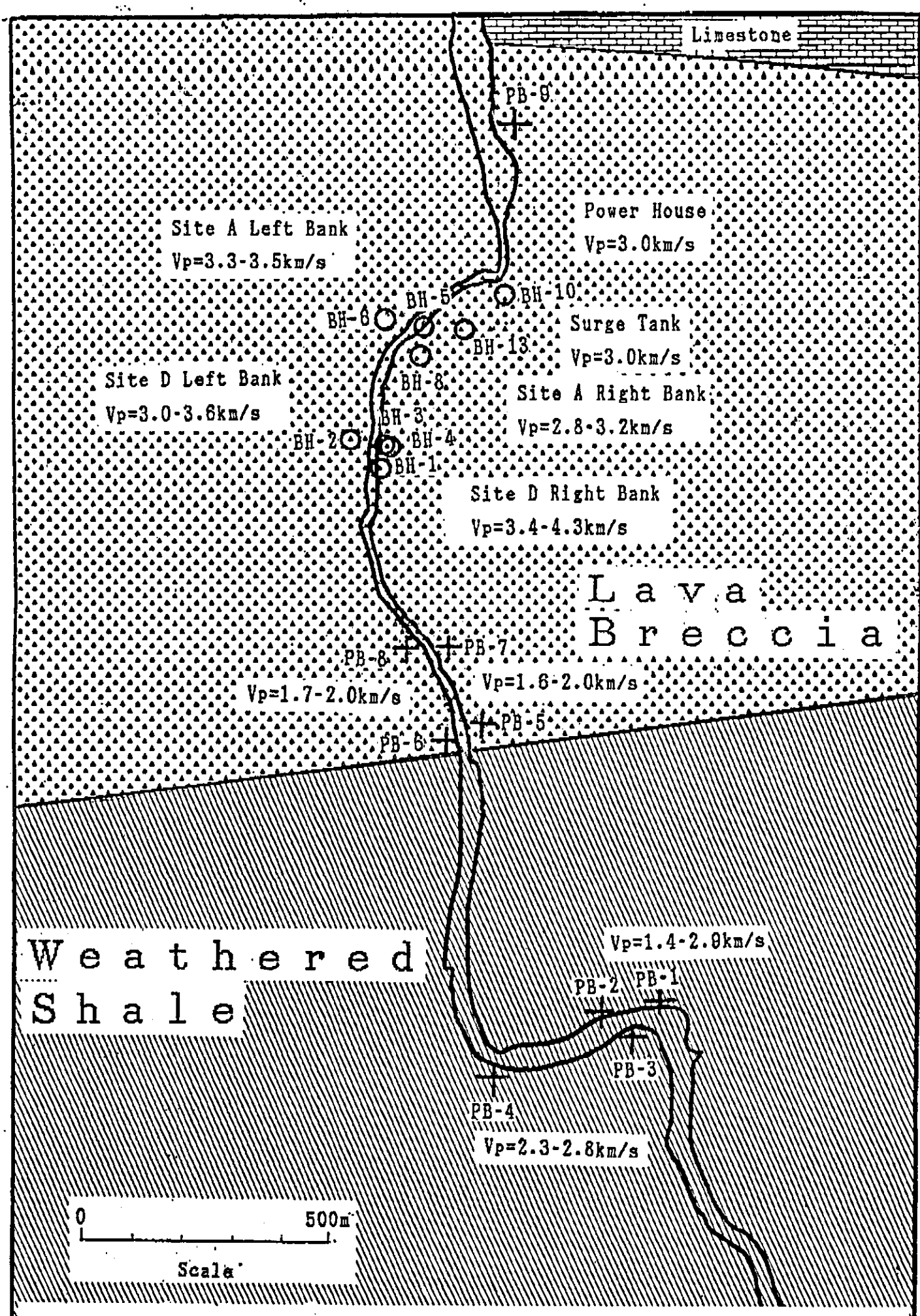
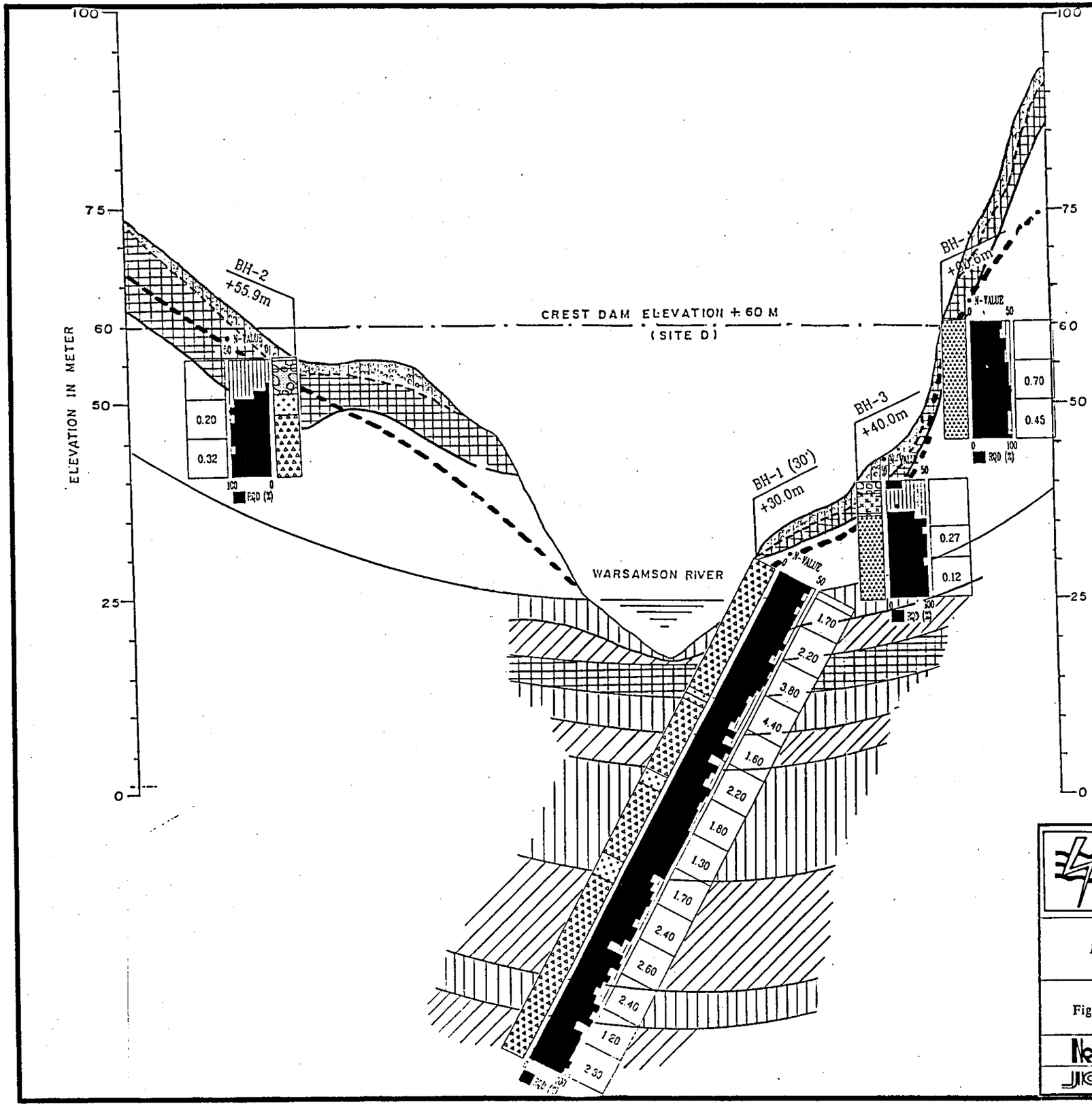


Figure 3-10 Geologycal Map Around Site with Seismic Wave Velocity of Base Rocks



LEGEND:

- 12.00 — Lugeon Value (Lugeon)
- Overburden
- Lugeon (L) < 1
- 1 ≤ L < 2
- 2 ≤ L < 4
- L ≥ 4
- Groundwater Level

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Figure 3-11 Lugeon Profile along Dam Site Alternative D

SCALE: V= 1:500 H= 1:500

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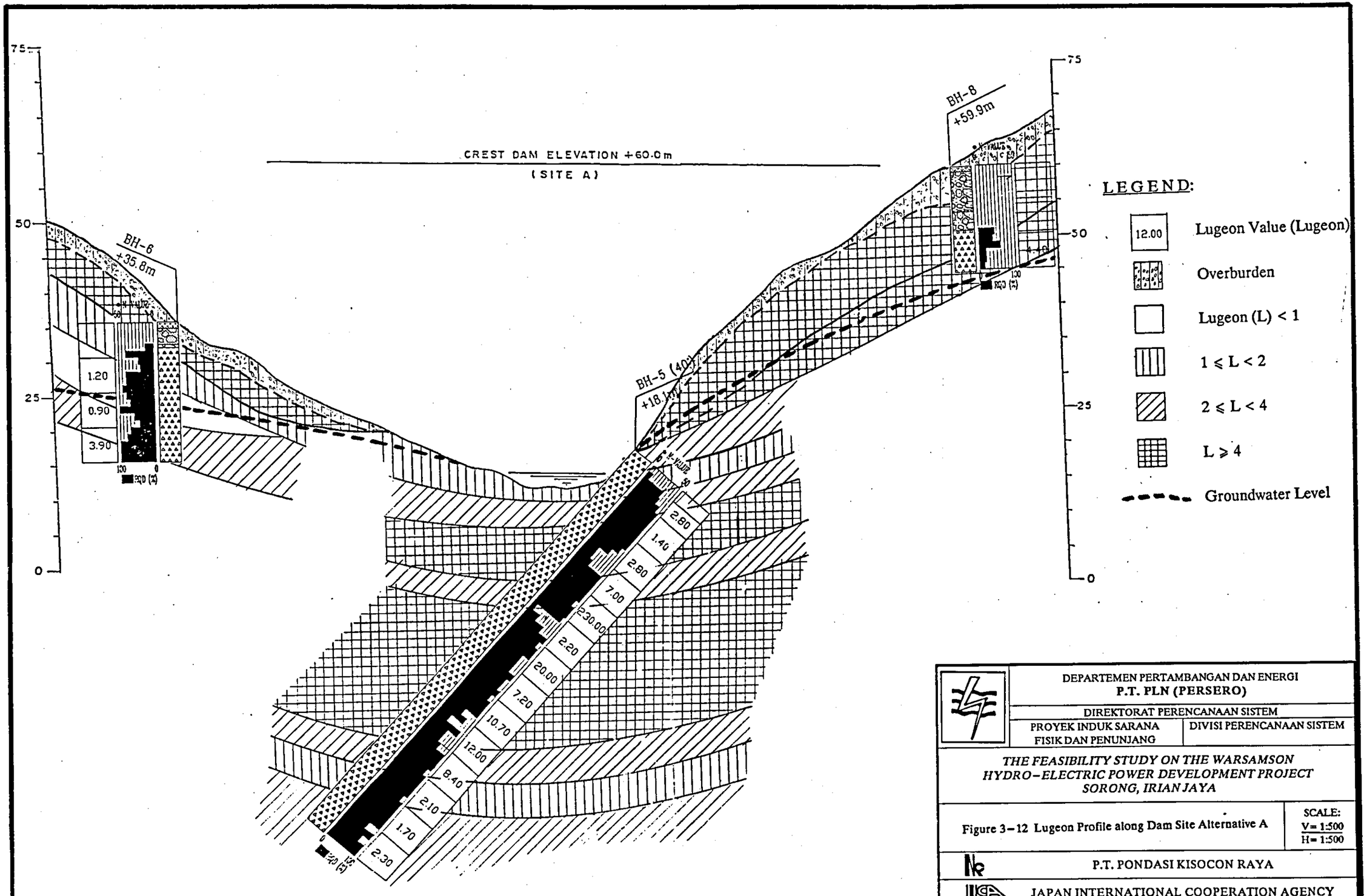

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Figure 3-12 Lugeon Profile along Dam Site Alternative A

SCALE:
V= 1:500
H= 1:500

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Coefficient of Permeability, cm/sec

Area	Residual Soils	Moderately Weathered Portion	Fresh to Slightly Weathered Portion
dam site alternative D	-	-	10^{-4} - 10^{-6}
dam site alternative A	10^{-3} - 10^{-5}	10^{-2} - 10^{-3}	10^{-3} - 10^{-5}
Power House	-	-	10^{-4} - 10^{-5}
Surge Tank	-	10^{-3} - 10^{-4}	-

The Lugeon values of 0.1 to 0.7 at BH-2, 3 and 4 on the slopes of the bank are equivalent to coefficient of permeability of 10^{-5} to 10^{-6} cm/sec, while on the river side, the Lugeon values at BH-1 are 1 to 5 or equivalent to 10^{-4} to 10^{-5} cm/sec.

From the above test results, the permeability of lava breccia at the dam site alternative D can be classified as low to very low. The permeability of the residual soils, although there was no permeability test performed, is expected to be high since the fines content such as silt and clay is very less in those soils at site D.

At the dam site alternative A, the permeability of the lava breccia is in the same order as that at the dam site alternative D according to the Lugeon values obtained. However, there are several numbers of high Lugeon values noted at BH-5 below the river bed. Among those high Lugeon values, a Lugeon value as high as 230, or equivalent to 10^{-2} to 10^{-3} cm/sec in term of coefficient of permeability, was recorded at the elevation of mean sea level.

Zone of Weathered Shale

The zone of weathered shale can be subdivided into two areas which are (1) saddle dam area and (2) river side area. The saddle dam area refers to the area in which BH-11, 12 and 14 were sunk while the river side area includes PB-1 to 4 along the Warsamson river.

At the saddle dam area, the shale does not contain many limestone boulders as that at the river side area. The coefficient of permeability obtained in the saddle dam area is 10^{-3} to

10^{-6} cm/sec which is classified as low to very low permeability. The permeability obtained within the limestone boulder encountered at BH-14 was 10^{-5} cm/sec, indicating very low permeability.

At the river side area, the coefficient of permeability of the shale with a lot of embedded limestone fragments ranges from 10^{-3} to 10^{-5} m/sec. Thus, the presence of limestone within shale does not affect the low permeability of the shale itself.

CHAPTER 4
ENGINEERING ANALYSIS

This chapter discusses the engineering analysis on the following issues:

(1) Bearing Capacity
(2) Leakage of Water Reservoir
(3) Construction Materials
(4) Seismicity

(1) Bearing Capacity

To obtain competent bearing layer with sufficient bearing capacity for the proposed concrete dam at the dam site alternatives A and D, it is necessary to remove the top residual soils. The moderately weathered lava breccia may need to be removed to certain extent also by stripping the weak portions from the fresh lava breccia. Figure 3-6 indicates the estimated removal depth to reach to the competent bearing layer as predetermined by the seismic survey.

Although there are several weak zones interpreted along the seismic lines, there is no critical or definite fault at the dam site alternatives, power house and surge tank area. The inclined boreholes sunk at both the alternative sites and crossing the river to the opposite bank also did not confirm the presence of fault. At the power house, there is a topographic lineament of steep gorge crossing BH-10 from south to north until it joins the river. The result of one borehole sunk at the power house and the seismic survey along two lines do not detect the presence of fault.

Some faults are suspected to be present around the area of PB-5, 6, 7 and 8 since the seismic velocity of the base rock is very low.

At the saddle dam area, there is a wide and very clear weak zone at the north of BH-14 running along the hill foot toward Makbon village. The weak zone may be the fault related to the movement of the Sorong Fault System. However, it does not much affect the installation of earth fill saddle dam there.

(2) Leakage of Water Reservoir

The fresh to slightly weathered portion of the lava breccia at the dam site alternative D is practically impermeable. The removal of the residual soils is considered sufficient to prevent the potential of leakage.

For the dam site alternative A, although the permeability of the fresh to slightly weathered portion of the lava breccia is low, care should be taken that medium permeable zones were detected at several depths below the river bed.

Leakage of reservoir water is considered not serious for the zone of weathered shale in spite of the fact that the boring results confirmed many limestone fragments frequently entrapped in the ground and some of them were seen as outcrops. It is believed that all the limestone fragments are isolated and surrounded by the impervious weathered shale.

For the zone of miscellaneous sedimentary rocks, we expect that the possibility of water leakage through limestones is low since the limestones encountered in the investigation are not the basic formation, instead they are present as boulders which are isolated and surrounded by other low permeable formation such as mudstone in similar condition as those in the zone of weathered shale. However, at least one limestone cliff was found during the reconnaissance survey at the zone of miscellaneous sedimentary rocks with a height of 5m and a width of 10m. There is a possibility that water may leak from this limestone cliff.

(3) Construction Materials

The construction materials under the present investigation are as below:

* general earth fill materials
* fine aggregates for concrete
* coarse aggregates for concrete

General Earth Fill Material

The samples for the general fill material were collected from the zones of weathered shale and miscellaneous sedimentary rocks, and also from the top of the hills at the zone of lava breccia. Table 2-3 summarizes the results of the laboratory tests performed on those fill samples. As shown in the table, the fines content for the samples is generally high and,

depending on the purpose, coarse material such as gravels or sand should be added.

Fine Aggregate

Table 2-4 shows the results of the laboratory tests performed on the sand samples collected near the site. As indicated in the table, all the sand samples from Makbon are considered not suitable for the fine concrete aggregates due to the high absorption that exceed the standard proposed by the Japanese Civil Engineering Society. The quality of other sample from the estuary of the Warsamson river is rather critical in respect to the soundness. Based on the field observation, the sand from Sorong city can not be directly used as concrete fine aggregates because the fines content is very high by visual observation.

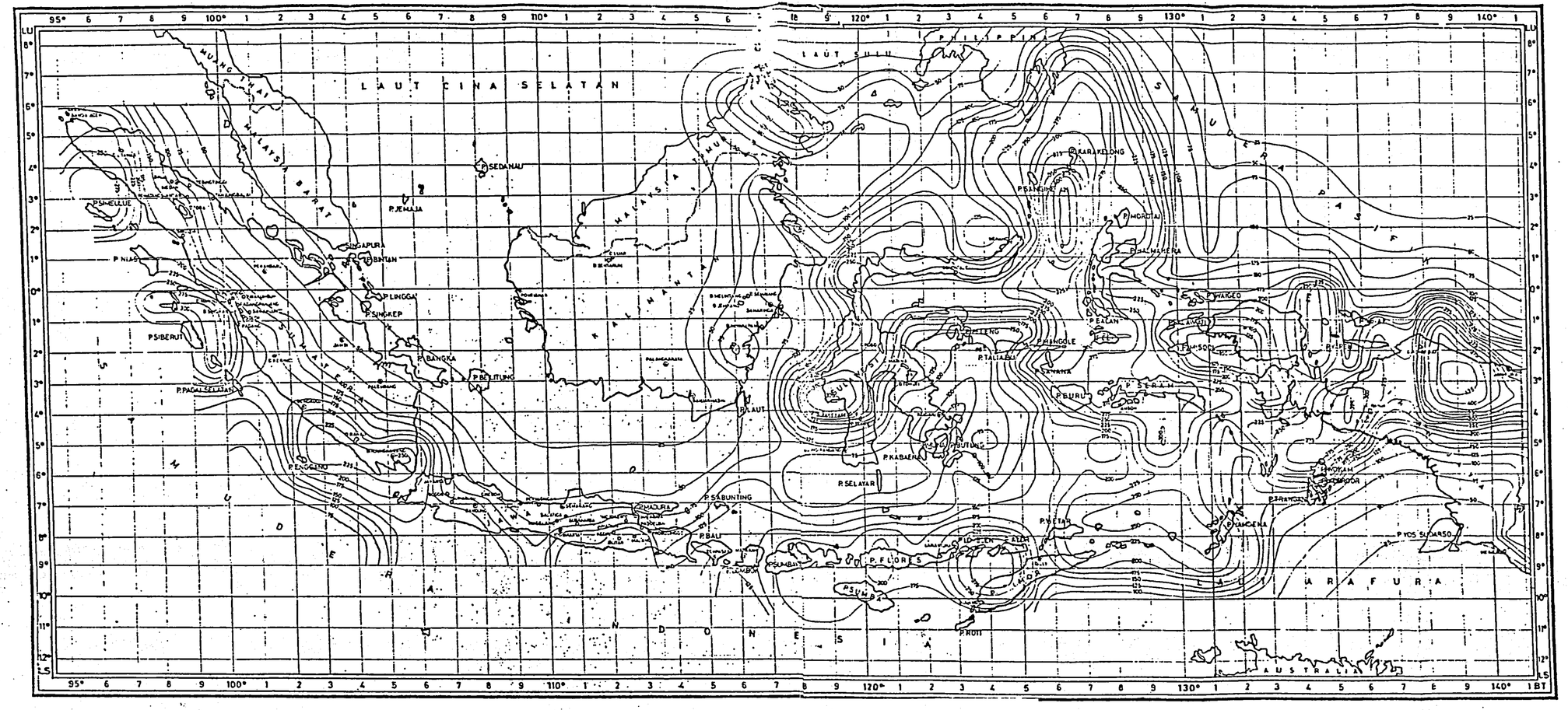
Coarse Aggregate

According to the results of laboratory tests for the coarse aggregate samples in Table 2-5, only the estuary conglomerate is considered not suitable for coarse aggregates because the abrasion loss is close to the maximum allowable limit. However, trial mix of concrete is recommended to further confirm the suitability of these materials as concrete aggregates.

(4) Seismicity

We studied the design seismic factors by: (1) employing recurrence analysis on data of earthquakes occurred around Sorong from the year of 1923 to 1994 and (2) using a seismic risk map issued by the Research Institute for the Development of Water Resources (DPMA).

The peak ground acceleration obtained in the recurrence analysis by Kawasumi and Plotting Position Methods for a return period of 100 years is 130-150 gals or equivalent to a seismic coefficient of 0.13-0.15 g. The seismic risk map indicates a ground acceleration of 200 gals or equivalent to 0.2 g seismic coefficient for the same return period. Therefore, for the safety side, we recommend to use 200 gals for the ground acceleration or 0.2 g for the seismic coefficient for 100 years return period. Figures 4-1 and 4-2 show the seismic risk map for a return period of 100 and 500 years respectively and Appendix H gives the earthquake data and calculations in the recurrence analysis.



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SKALA

0 45 90 180 450 Km

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Figure 4-1 PROBABLE ACCELERATION IN GAL FOR RETURN PERIOD OF 100 YEARS
SOURCE DPMA (DIREKTORAT PENYELIDIKAN MASALAH AIR)

SCALE:

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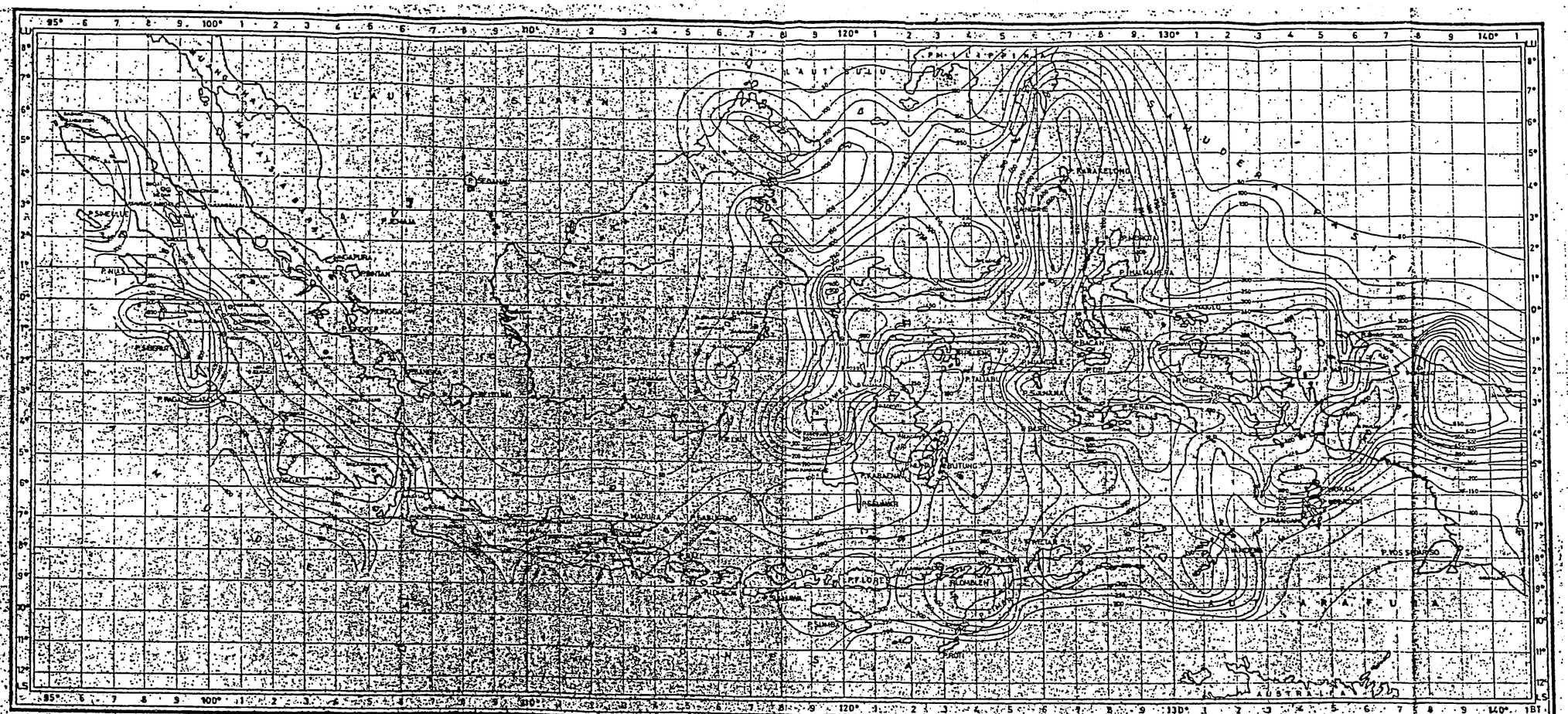
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Figure 4-2 PROBABLE ACCELERATION IN GAL FOR RETURN PERIOD OF 500 YEARS SOURCE DPMA (DIREKTORAT PENYELIDIKAN MASALAH AIR)
SCALE:
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APPENDICES

APPENDIX A

Description of Field Work Methods

A.1 Exploratory Drilling

A.2 Standard Penetration Test

A.3 Field Permeability Test

A.4 Field Density Test

A.5 Seismic Refraction Survey

APPENDIX A.1

EXPLORATORY DRILLING

The boreholes were drilled using rotary type drilling machine. Figure A.1.1 shows the general set up of a rotary drilling rig. The diameter of the boreholes in the present study was 76mm.

Core drilling method was employed in the present investigation. Two types of core barrels were used in the present investigation: (a) a triple tube core barrel with diamond bit for drilling in fresh rock formation and (b) a single core barrel with steel bit for advancing the borehole in completely weathered rock formation.

To maintain the stability of the borehole in rock layer having high potential of collapsing, casing pipes with diameter of 89mm were installed immediately following the advance of the borehole to about 0.5m above the bottom of the borehole. In stable rock formation, casing pipes were only installed at the top 1 to 2m of the borehole to stabilize the borehole mouth.

In the drilling operation the core barrel is lowered to the bottom of the borehole by drill rods. The borehole is advanced by rotating the core barrel with gentle thrust actions. Clean water is fed to the bottom of the borehole through the triple tube core barrel to flush out the cuttings and to cool the diamond bit. When the core barrel is full with rock or soil cores, the core barrel is withdrawn from the borehole. With the help of water pressure pumped to the upper end of the core barrel, the soil or rock core is pushed out from the core barrel. The retrieved core sample is then stored in the core boxes in depth order.

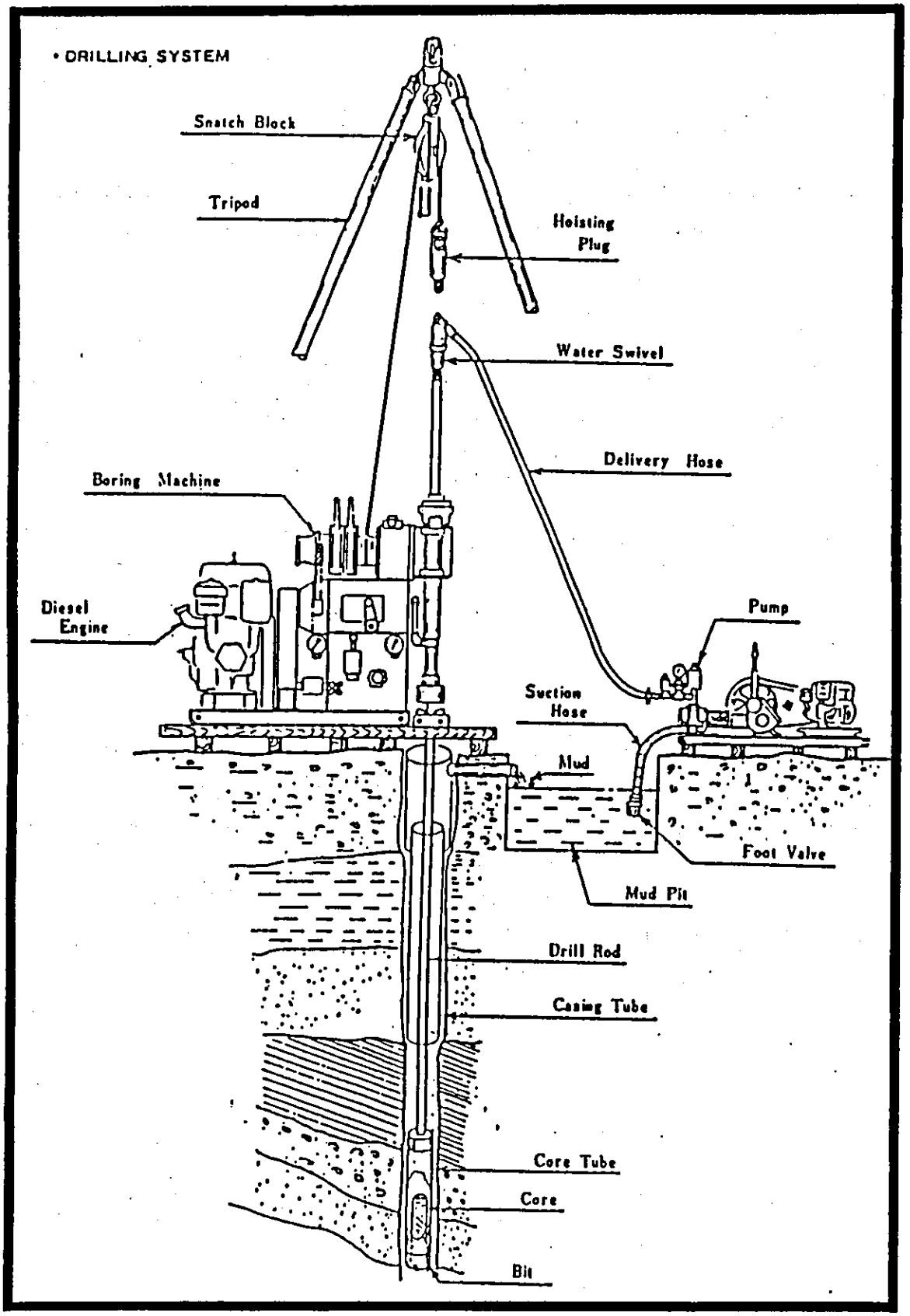


Figure A.1.1 Set up of Drilling Operation

APPENDIX A.2

STANDARD PENETRATION TEST (SPT)

The purpose of performing the test is to determine relative density or consistency of completely weathered rocks and to obtain rock samples for identification. A split barrel sampler of 50mm outer diameter as shown in Figure A.2.1 is lowered to the bottom of the borehole by drill rods. The sampler is then driven 450mm into the soil by a 63.5 kg free falling hammer over a height of 760mm. The 760mm free fall height is controlled by a hook shown in Figure A.2.2. The first 150mm penetration is regarded as the seating drive, hence the number of blows to achieve this penetration is not included in the SPT N-value. The total cumulative numbers of the blow counts required for each 100mm of the last 300mm penetration is recorded as the N-value. The recovered samples are kept in plastic jars and plastic bags for soil identification.

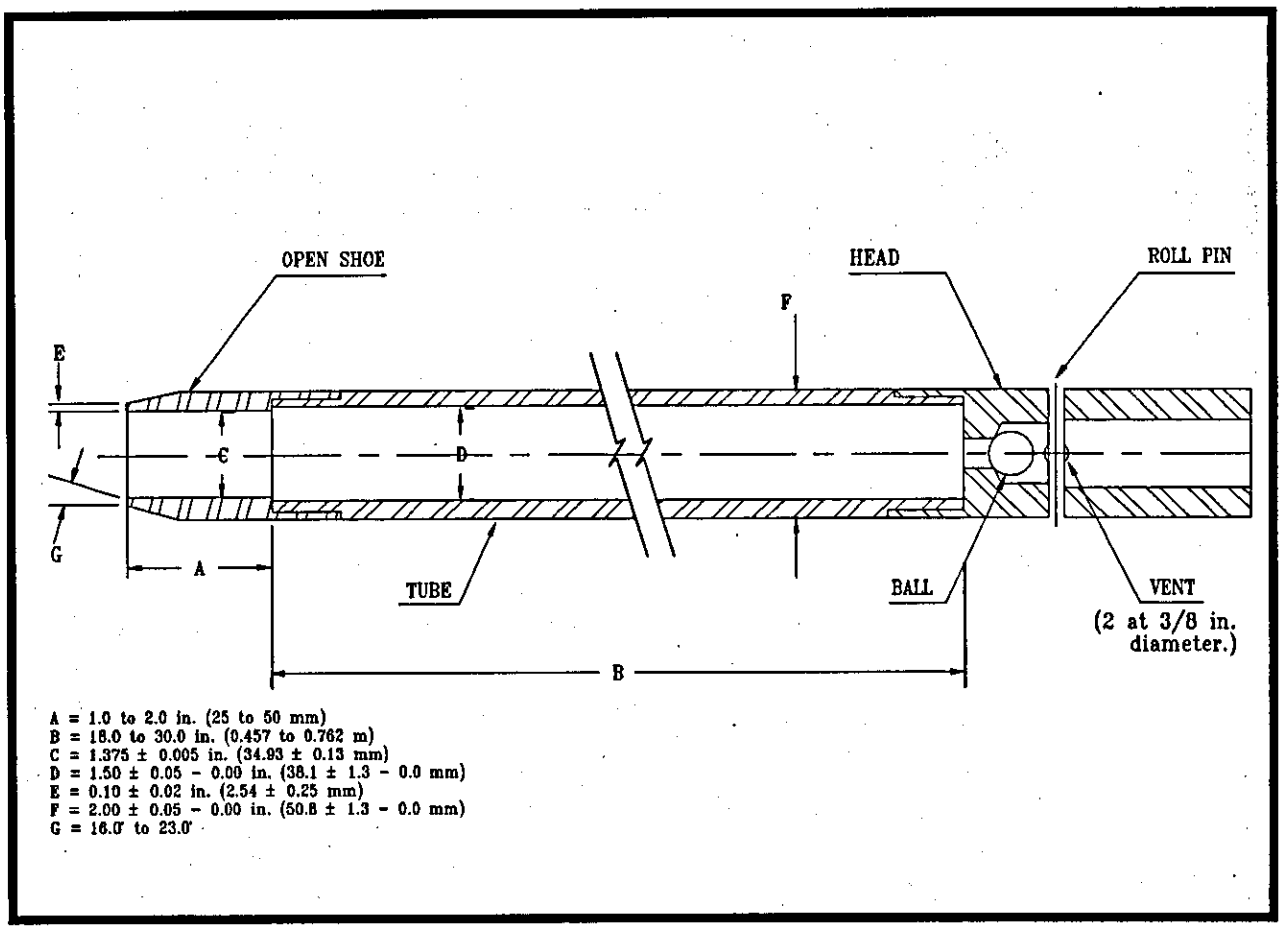
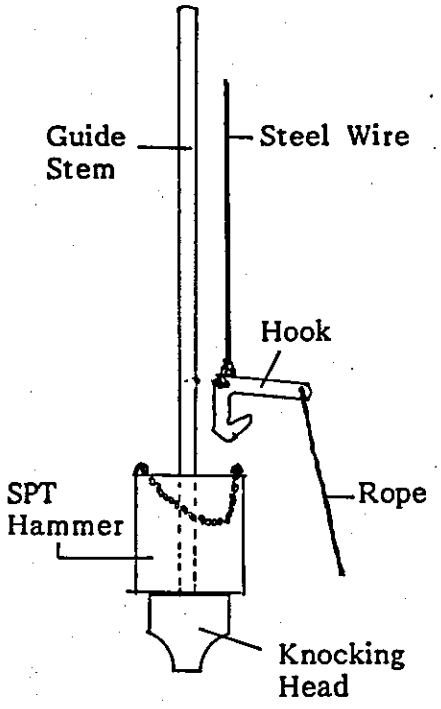
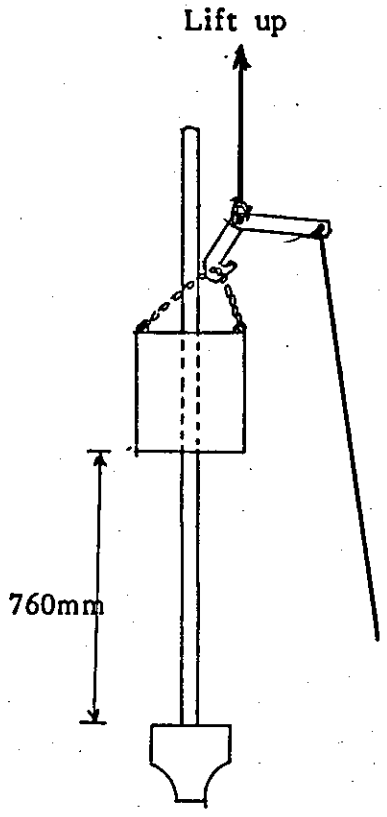


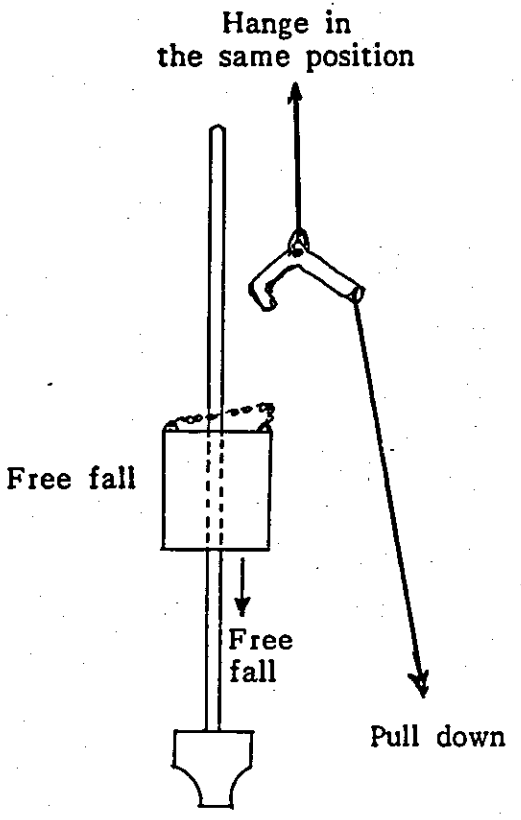
Figure A.2.1 Standard Penetration Split Barrel Sampler



1. Initial position



2. Hook the SPT hammer and lift up steel wire to a required falling height of 760 mm



3. Pull down the rope while maitain the position of the steel wire to let the hammer to free fall

Figure A.2.2 A Hook to Control Free Fall of the SPT Hammer

APPENDIX A.3

FIELD PERMEABILITY TEST

To determine in situ permeability of the ground, the following field tests can be applied in a borehole :

(a) variable head permeability test (falling head or rising head) for soils
(b) constant head permeability test for soils
(c) Lugeon test (packer test) for rocks

(a) Variable Head Permeability Test

The variable head permeability test involves the application of a hydraulic pressure in the borehole different from that in the ground and the flow due to the difference is measured to estimate the permeability of the ground.

There are two types of tests, i.e., "falling head" and "rising head" test. In the "falling head" or "in flow" test, the hydraulic pressure in the borehole is increased by introducing water into it and the rate of the water level to fall in the borehole is measured. In the "rising head" or "outflow" test, the hydraulic pressure is decreased by pumping water out from the borehole to lower the water level in the borehole and the rate of the water level to rise is measured.

To conduct the test, the borehole is sunk to the required testing depth and then is cleaned from the cutting debris. The borehole wall is protected by casing pipes and the test portion of the ground is uncased. The test portion can be right at the bottom of the casing pipes or protruded further down from the casing pipes. The uncased part may be supported by suitable filter material with a permeability much greater than that of the ground being tested.

The water level in the borehole is then raised by pouring water into the borehole or is lowered by pumping out water depending on the type of the test (falling head or rising head). The rate of the water level to sink or to rise is then measured by recording the water levels in the borehole at several time intervals.

The permeability of the ground is estimated by the following formulas :

$$k = \frac{A}{F(t_2 - t_1)} \log_e \frac{H_1}{H_2}$$

where:

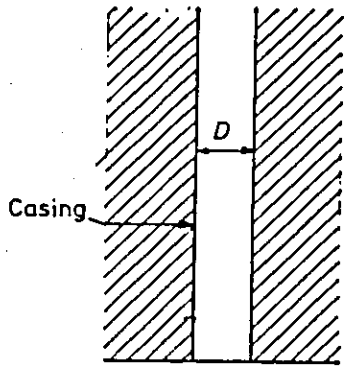
k is the permeability of soil
F is the intake factor
H_1 is the variable head measured at time t_1 after commencement of test
H_2 is the variable head measured at time t_2 after commencement of test
A is the cross-sectional area of borehole casing or standpipe as appropriate

Depending on the condition of the ground and the uncased part of the borehole, the intake factor (F) are given in Figure A.3.1 after British Standard BS5930:1981.

(b) Constant Head Permeability Test

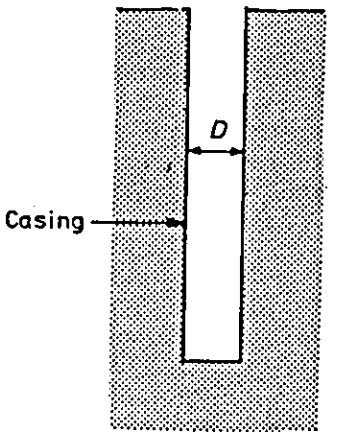
The constant head permeability test involves the application of a hydraulic pressure that is maintained constant in the borehole. To conduct the test, the borehole is sunk to the required testing depth and then is cleaned from the cutting debris. The borehole wall is protected by casing pipes and the test portion of the ground is uncased. The test portion can be right at the bottom of the casing pipes or protruded further down from the casing pipes. The uncased part may be supported by suitable filter material with a permeability much greater than that of the ground being tested.

Water is then poured into the borehole to create a difference of hydraulic pressure from the original water table in the ground. The water level is then maintained constant by adjusting the supply of water in balance condition with the water seeping through the uncased portion of the borehole. The simplest way is to raise the water level to the top of the casing pipe and the supply of water is adjusted in such a way so that the water level will be right at the top of casing pipe without pouring out from the casing. When the balance condition is achieved, the rate of steady flow is measured by recording volume of water in a specific time interval.



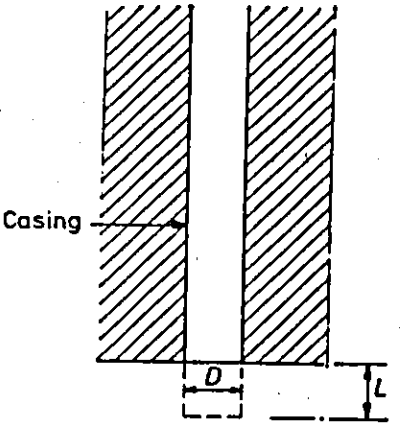
$F = 2D$

(a) Soil flush with bottom at impervious boundary



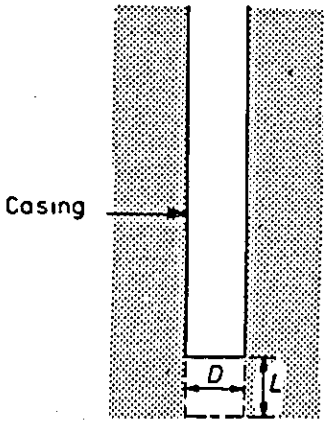
$F = 2.75D$

(b) Soil flush with bottom in uniform soil



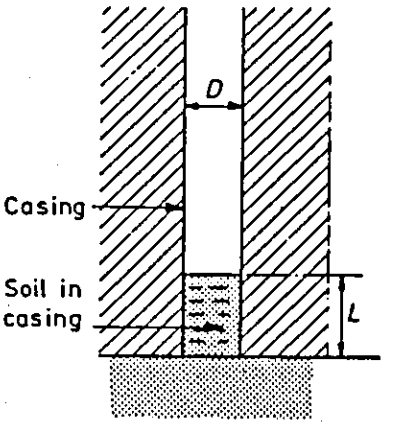
$$F = \frac{2\pi L}{\log_e [(2L/D) + \sqrt{(1 + (2L/D)^2}]}$$

(c) Well point or hole extended at impervious boundary



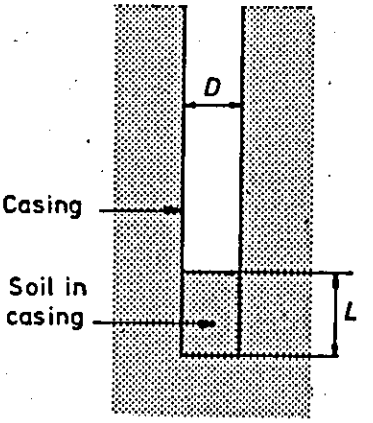
$$F = \frac{2\pi L}{\log_e [(L/D) + \sqrt{(1 + (L/D)^2}]}$$

(d) Well point or hole extended in uniform soil



$$F = \frac{2D}{1 + (8/\pi)\,(L/D)}$$

(e) Soil in casing with bottom at impervious boundary



$$F = \frac{2.75D}{1 + (11/\pi)\,(L/D)}$$

(f) Soil in casing with bottom in uniform soil

Figure A.3.1 Values of Intake Factor, F, in Borehole Permeability Tests (After British Standard, BS5930 : 1981)

The permeability of the ground is estimated using the following formula :

$$k = \frac{q}{F H_c}$$

where :

q is the rate of flow
F is the intake factor
H_c is the constant head above the original groundwater table

Depending on the condition of the ground and the uncased part of the borehole, the intake factor (F) are given in Figure A.3.1 after British Standard BS5930:1981.

(c) Lugeon Test (Packer Test)

The packer test is usually conducted to measure the permeability in rocks. The test was originally introduced by Lugeon (1933) to provide an acceptable standard for the permeability of dam foundations. The principle of the test is to measure the volume of water that can escape from an uncased section of the borehole in a given time under a given pressure. The flow is confined between two packers in the double packer test, or between one packer and the bottom of the borehole in the single packer test. Figure A.3.2 illustrates the arrangement of a packer test.

The function of the packer is to confine the outflowing water to the specified testing section in the borehole. There are several types of packers, such as the mechanical tail type, the manual mechanical expanding packer and the hydraulic self-expanding packer. In loose condition, the packers can freely move in the borehole. After expanding to the borehole wall, the packer serves as a seal to prevent the pressurized water to flow beyond the tested section. Therefore, it is important that the expanded diameter of the packer should be sufficient to provide an efficient seal. The expanding pressure should be sufficient to expand the packer against the head of water in the borehole, but not causing heaving of the ground surface or fracturing of the rock.

To conduct the single packer test, the borehole is sunk to the required test depth and the packer is lowered down to a certain distance (usually 5m) above the bottom of the borehole. After the packer is expanded against the borehole wall, a flow of water is introduced to the section in between the packer and the bottom of the borehole through the drill rods.

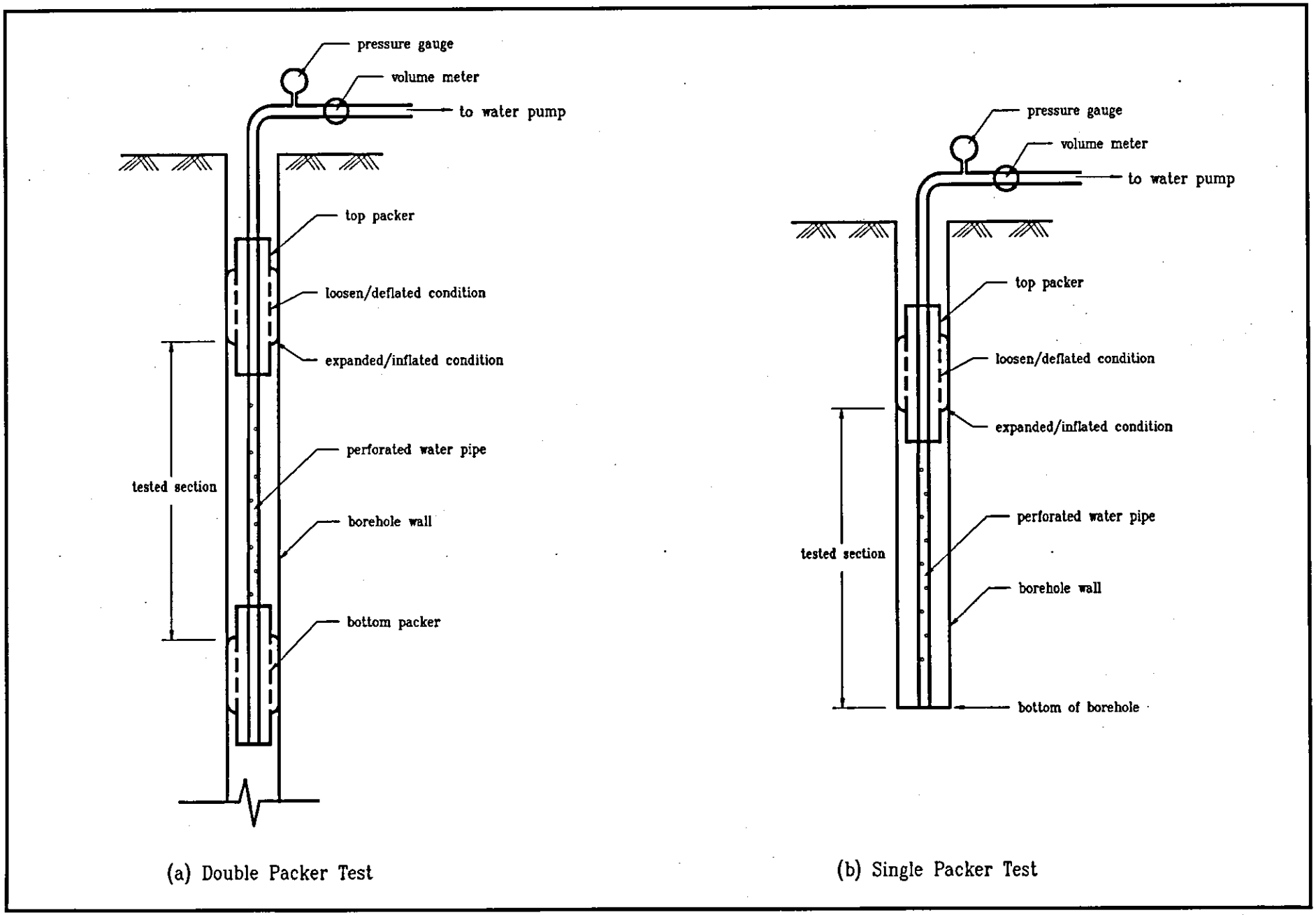


Figure A.3.2 General Set up for Lugeon Test (Packer Test)

The discharged rates corresponding to the various given pressures are then recorded. To conduct the test at the following depths, the packer has to be withdrawn and the borehole is drilled further to the next testing depth. The testing procedure as discussed above is repeated in the next test.

In the double packer test, the test is conducted in a completed borehole. Two packers arranged in a certain spacing (usually 5m) are lowered down to the required testing depth. After the packers are expanded against the borehole wall, a flow of water is introduced to the section in between the two packers through the drill rods. The discharged rates corresponding to the various given pressures are then recorded. To conduct the test at the next depth, the packers are loosen from the borehole wall and then lowered down or raised up to the next testing depth. The same testing procedure is then repeated.

APPENDIX A.4

FIELD DENSITY TEST

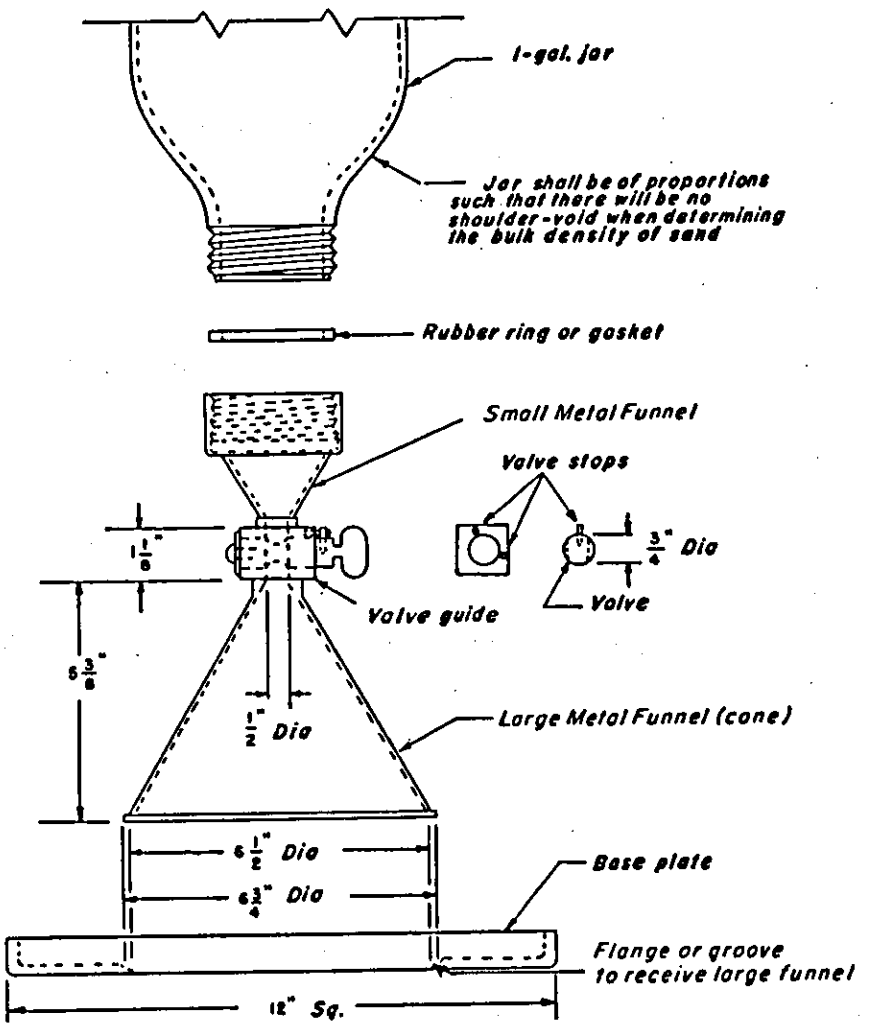
The purpose of the test is to determine the in-place density of natural soil deposit. The sand cone test method was carried out for this purpose. Figure A.4.1 shows the sand cone test apparatus.

After removing the plantation and levelling the ground surface, the base plate with a round hole in the middle as shown in Figure A.4.1 is placed on the ground surface. A cylindrical hole is dug at the centre of the plate until the volume is approximately 1000 cm3 for soils finer than 4.75mm and 1500 to 3000cm3 for coarser materials. The weight of the excavated soil is measured and the moisture content is determined. Sand with known density from the apparatus is poured into the hole. The weight of the sand required to fill up the hole is determined and the volume of the hole is calculated.

The density of the natural soil is computed using the following formulas:

$$\text{wet density} = \frac{\text{weight of excavated soil}}{\text{volume of replacement sand}}$$

$$\text{dry density} = \frac{\text{wet density}}{1 + \text{moisture content}}$$



Metric Equivalents

in.	mm	in.	mm
1/2	12.7	5 3/8	136.5
3/4	19.1	6 1/2	165.1
1 1/8	28.6	6 3/4	171.5
		12	304.8

Figure A.4.1 Sand Cone Test Apparatus

APPENDIX A.5

SEISMIC REFRACTION SURVEY

The purpose of performing the survey is to determine the thicknesses of different rock layers below the ground surface. The results of the survey were correlated with borehole logs to obtain the physical property of each layer. The instruments used are TR-7 type seismic instrument from OYO which consists of one field graph, 24 channel amplifier, 28 geophones and one blaster.

The seismic refraction survey is carried out in spreads of 24 geophones. The geophones are stuck into the ground surface in one line at 5m interval forming one spread of 115m long. Shock waves are generated with firecrackers at four shot points within the spread and at two shot points outside the spread. The inner shot points are positioned between two geophones and distributed equally along the spread. The outside shots are located 55m from each end of the spread. The times required by the shock wave to travel from each shot point to each geophone location are recorded by the instrument through the geophones.

The presence of different rock layers below the spread and the thickness of each layer are interpreted from the recorded travel times and the corresponding distances between the shot points and the geophones. The different wave velocity of each layer determines the different rock layers.

APPENDIX B

Drilling Logs

SUBSURFACE EXPLORATION LOG

BORING No. : BH-1
SHEET : 1 OF 3
TOTAL DEPTH : 70.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 19, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: December 29, 1994
FEATURE	: DAM SITE (ALTERNATIVE D)	ANGLE	: 30 deg.
AREA DESIGNATION	: RIGHT ABUTMENT	DRILLER	: Uus · Koswara
GROUND ELEVATION	: 30.020m	SUPERVISOR	: Teddy
COORDINATES	: X=766,927.250m Y=9,911,590.615m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: GL - 5.5m	DRILLING MACHINE	: YBM-3E

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Details of Core							Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Permeability Test		Remarks
						Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.								Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 19, '94	1					1	3	100	90					LAVA BRECCIA, dark greenish grey and slightly weathered. With red and green strong subangular fragments consisting of andesite, basalt and diabase dia. 0.5-4cm. With widely spaced, less than 1mm thick, white silica veins. At 3.8-3.9m, open crack infilled with yellowish brown clay and gravels of lava breccia, max. dia. 3cm. At 7.5m, a 1cm thick crack with rough plane infilled with white silica. At 18.3-19.15m and 19.8-20m andesite blocks, dark grey, strong, fresh, massive and fine grained.		TRIPLE TUBE CORE BARREL NMLC DIAMOND BIT	89mm					
	2		0.8			2	2	100	100								1.0					
Dec 20, '94	3		1.2			3	1	100	90												1.7	
	4					4	2	100	80													
	5		1.3			5	0	100	90													
			2.9			6	1	100	90													
Dec 21, '94	6					7	2	100	90													
	7					8	3	100	90												2.2	
	8					9	0	100	90													
	9		2.7			10	1	100	90													
	10		4.3			11	0	100	90													
Dec 22, '94	11					12	1	100	95				CH									
	12					13	2	100	95												3.8	
	13					14	0	100	100													
	14					15	2	100	95													
	15		4.9			16	3	100	85													
	16		4.7			17	3	100	75													
Dec 23, '94	17					18	2	100	80												4.4	
	18					19	3	100	80													
	19					20	2	100	90													
	20					21	5	100	90													
	21					22	1	100	85													
	22					23	3	100	70												1.6	
	23		6.9			24	0	100	100													
	24		4.9			25	1	100	90													

SUBSURFACE EXPLORATION LOG

BORING No. : BH-1
SHEET : 2 OF 3
TOTAL DEPTH : 70.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 19, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: December 29, 1994
FEATURE	: DAM SITE (ALTERNATIVE D)	ANGLE	: 30 deg.
AREA DESIGNATION	: RIGHT ABUTMENT	DRILLER	: Uus Koswara
GROUND ELEVATION	: 30.020m	SUPERVISOR	: Teddy
COORDINATES	: X=766,927.250m Y=9,911,590.615m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: GL - 5.5m	DRILLING MACHINE	: YBM-3E

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 24, '94	26					21	4	100	60					LAVA BRECCIA, dark greenish grey and slightly weathered. With red and green strong subangular fragments consisting of andesite basalt and diabase, dia.1-6cm. With widely spaced white silica veins. Occasionally with fissures along silica veins. At, 25-26m with many irregular silica veins. Moderately weathered At 30-32m, Andesite block, greyish black, massive, fine to medium grained, strong and fresh. At, 42-45m, Andesite block greyish black, strong and moderately to slightly fractured. With very fine sand of weathered olivine and sericite on the surface of cracks. Max. thickness of crack is 4mm.		TRIPLE TUBE CORE BARREL NMLC DIAMOND BIT					
	27						1		90													
						22		100														
	28						2		80													
						23		100														
	29						4		75													
			5.3			24	0	100	100												2.2	
	30		5.4																			
							0		95													
	31																					
							0		90													
	32																					
						25	0	100	95												1.8	
	33																					
							0		95													
	34																					
						26	0	100	95													
	35																					
							0		100													
	36																					
						27	0	100	100													
	37																					
							0		100												1.3	
	38		7.8			28		100														
			6.2				0		100													
	39					29	0	100	100													
	40																					
							0		100													
	41																					
Dec 26, '94							0		100													
	42					30		100													1.7	
							3		70													
	43					31		100														
							3		80													
	44																					
			7.2			32	1	100	90													
	45		5.7																			
							2		95													
	46																					
						33	3	100	90													
	47																				2.4	
							3		90													
	48																					
						34	4	100	80													
	49																					
Dec 27, '94						35	3	100	95													
	50																					

SUBSURFACE EXPLORATION LOG

BORING No.	: BH-1
SHEET	: 3 OF 3
TOTAL DEPTH	: 70.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 19, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: December 29, 1994
FEATURE	: DAM SITE (ALTERNATIVE D)	ANGLE	: 30 deg.
AREA DESIGNATION	: RIGHT ABUTMENT	DRILLER	: Uus Koswara
GROUND ELEVATION	: 30.020m	SUPERVISOR	: Teddy
COORDINATES	: X=766,927.250m Y=9,911,590.615m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: GL - 5.5m	DRILLING MACHINE	: YBM-3E

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 27, '94	51					36	1	100	95				CH	LAVA BRECCIA, dark greenish grey and predominantly slightly weathered. With red and green strong subangular fragments consisting of andesite basalt and diabase, dia. 1-6cm. With widely spaced white silica veins Occasionally with fissures along silica veins.		TRIPLE TUBE CORE BARREL NMLC DIAMOND BIT					2.6	
	52						2		80													
	53					37	8	100	50													
	54					38	0	100	95													
	55		4.2			39	0	100	100													
Dec 28, '94	56		6.3				2		80					At 52.6-53m, highly fractured to grain size of 2-50mm. Friable with finger pressure.								
	57						1		90													
	58					40	2	100	80												2.4	
	59					41	3	100	70													
	60					42	2	100	80													
	61						0		100													
	62					43	1	100	90													
	63					44	0	100	100												1.2	
	64						2		65													
	65		1.6			45	1	100	90													
Dec 29, '94	66		5.5				0		90													
	67						1		90													
	68					46	1	100	90												2.3	
	69						1		100													
	70		4.2			47	2	100	90													
	71													End of Drilling								
	72																					
	73																					
	74																					
	75																					

SUBSURFACE EXPLORATION LOG

BORING No.	: BH-2
SHEET	: 1 OF 1
TOTAL DEPTH	: 15.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: January 2, 1995
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: January 4, 1995
FEATURE	: DAM SITE (ALTERNATIVE D)	ANGLE	: VERTICAL
AREA DESIGNATION	: LEFT ABUTMENT	DRILLER	: Uli Sadeli
GROUND ELEVATION	: 55.920m	SUPERVISOR	: Teddy
COORDINATES	: X=766,876.343m Y=9,911,654.722m	LOGGED	: Sultan
GROUND WATER LEVEL	: GL −3.5m	DRILLING MACHINE	: KOKEN OE-2L

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Jan 2, '95	0					1		80						SANDY SILT, dark brown, firm non plastic.								
	1					2		90						GRAVEL of andesite, dark grey dense, max. dia. 5cm, angular.								
	2					3		90														
						4		95														
	3					5		95														
						6		85														
						7		85						SANDY GRAVEL, dark grey to brown, dense, angular, max. dia. 10cm, consist of andesite, poorly graded. Highly weathered.								
						8		85														
	4		2.3			9	28	100	10			D				ST - NK	Dia. 89mm					
						10		100									4.0					
	5						6		40													
						11		100						ANDESITE, slightly weathered, greenish dark grey, med. strong With vertical silica veins. Inter-locking basalt from 6.25-7m.	Dip of joint 60°							
	6						1		90													
	7					12	0	100	100			CM										
							4		90					LAVA BRECCIA, slightly weathered, greenish dark grey. With widely spaced, strong, joints infilled by silica. Width of joint is predominantly 0.5-1mm.								
	8					13		100													0.2	
							0		100													
	9														At 9.6m, dip of joint 60°							
						14	0	100	100													
	10						1		100													
			2.0			15																
			3.5				0	100	90							TRIPLE TUBE CORE BARREL - NMLC - DIAMOND BIT						
Jan 3, '95	11																					
							0		100												0.3	
	12					16		100														
							0		100													
	13																					
						17	0	100	100													
Jan 4, '95	14		3.5																			
	15													End of Drilling								
	16																					
	17																					
	18																					
	19																					
	20																					
	21																					
	22																					
	23																					
	24																					
	25																					

Coring ■ SPT ▨

SUBSURFACE EXPLORATION LOG

BORING No. : BH-3
SHEET : 1 OF 1
TOTAL DEPTH : 15.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 25, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: December 27, 1994
FEATURE	: DAM SITE (ALTERNATIVE D)	ANGLE	: VERTICAL
AREA DESIGNATION	: RIGHT ABUTMENT	DRILLER	: Uli Sadeli
GROUND ELEVATION	: 40.000m	SUPERVISOR	: Teddy
COORDINATES	: X=766,937.500m Y=9,911,648.150m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: GL - 5.0m	DRILLING MACHINE	: KOKEN OE-2L

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Details of Core							Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Permeability Test		Remarks
						Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.								Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 25, '94	0					1		90	40			D		Gravel to cobble of moderately weathered lava breccia, brown and grey colour, dense, angular, dia. 1-4cm. max. dia. 20cm.								
	1					2		40														
	2					3		100														
	3					4		100						Clayey silt, reddish brown to yellowish, stiff to very stiff high palstic. With angular gravels of max. dia. 2cm.					13			6/15, 6/15, 7/15
	4					5		100														
	5					6		100														
Dec 26, '94	6					7			70													
	7						1	100														
	8					8	3	100	90					Lava breccia, greenish grey, slightly weathered, strong. With subangular fragments of red basalt (dia. 1-3cm) and grey diorite (dia. 2-15cm, many olivine). With white silica veins, no fissures along the veins at 4-4.3m, gravels of lava breccia, dia. 2-7cm.	Dip 30-60°	TRIPLE TUBE CORE BARREL NMLC - DIAMOND BIT	Dia. 89mm	5.6			0.3	
	9		5.0			9	0	100	100													
	10		5.0			10	0	100	100			CH										
Dec 27, '94	11					11	1	100	90													
	12					12	0	100	100													
	13					13	0	100	100												0.1	
	14		5.0			14	0	100	100													
	15													End of Drilling								
	16																					
	17																					
	18																					
	19																					
	20																					
	21																					
	22																					
	23																					
	24																					
	25																					

SUBSURFACE EXPLORATION LOG

BORING No. : BH-4
SHEET : 1 of 1
TOTAL DEPTH : 15.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 18, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: December 21, 1994
FEATURE	: DAM SITE (ALTERNATIVE D)	ANGLE	: VERTICAL
AREA DESIGNATION	: RIGHT ABUTMENT	DRILLER	: Uli Sadeli
GROUND ELEVATION	: 60.610m	SUPERVISOR	: Teddy
COORDINATES	: X=766,953.076m Y=9,911,642.219m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: GL -4.4m	DRILLING MACHINE	: KOKEN OE-2L

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Details of Core							Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Permeability Test		Remarks
						Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.								Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 18	0					1		90														
						2	5	80	80													
Dec 19, '94	1					3	4	80	75													
	2																					
	3					4	3	100	90													
	4																					
	5		1.0			5	1	100	85					LAVA BRECCIA, slightly weathered, grey, strong, joint, filled with silica. Fragment consist of basalt, diabase and large fragment of andesite (50cm), mean dia. 0.5-10cm.	At 2.5-2.7m, joint dip 30°	TRIPLE TUBE CORE BARREL NMLC DIAMOND BIT / STEP						
	6		1.5			6	2	100	95													
Dec 20, '94	7					7	1	100	95				CH								0.7	
	8		1.0			8	1	100	100													
	9		4.4																			
	10					9	2	100	100													
Dec 21, '94	11																					
	12					10	3	100	90												0.5	
	13																					
	14					11	1	100	90													
	15		6.0			12	0	100	100					End of Drilling								
	16																					
	17																					
	18																					
	19																					
	20																					
	21																					
	22																					
	23																					
	24																					
	25																					

SUBSURFACE EXPLORATION LOG

BORING No. : BH-5
SHEET : 1 OF 3
TOTAL DEPTH : 70.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: January 6, 1995
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: January 15, 1995
FEATURE	: DAM SITE (ALTERNATIVE A)	ANGLE	: 40 deg.
AREA DESIGNATION	: RIGHT ABUTMENT	DRILLER	: Uus Koswara
GROUND ELEVATION	: 18.060m	SUPERVISOR	: Teddy
COORDINATES	: X=767,016.541m Y=9,911,881.019m	LOGGED	: Sultan
GROUND WATER LEVEL	: GL -2.0m	DRILLING MACHINE	: YBM-3E

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Jan 6, '95	1					1		60	0			CM		LAVA BRECCIA, highly weathered, dark grey, medium weak, completely fractured. Maximum size size of fragments is 5cm.		TRIPLE TUBE CORE BARREL - NMLC DIAMOND BIT	Dia. 89mm					
	2					2		80	15								2.0					
	3					3	7	100	70			CH		LAVA BRECCIA, slightly weathered, dark grey, strong to very strong, with subangular fragments of red basalt, diabase and andesite. With medium spaced white silica veins of maximum thickness of 3mm. Occasionally fisured along the veins.							2.8	
	4		1.8			4	10	100	75													
	5		2.1				3		90													
	6					5	1	100	100												1.4	
	7					6	1	100	100													
Jan 7, '95	8					7	1	100	100													
	9					8	1	100	100												2.8	
	10		1.6				2		90													
	11		2.2			9	8	100	70													
	12					10	15	100	40			CM		LAVA BRECCIA, highly fractured along silica veins to sizes of mostly 2 to 10cm. Grey to dark grey, medium weak to medium strong.								
	13					11	11	100	40													
	14					12		100														
	15					13	13	100	50													
	16					14	0	100	100			CH		LAVA BRECCIA, slightly weathered to fresh, dark grey, strong to very strong. Moderately weathered at 19.7m. Water loss at 20m.							7.0	
	17					15	1	100	100													
	18					16	1	100	100													
	19					17	2	100	90												230	
	20		1.3				1		100													
	21		1.8			18	3	100	100													
	22																					
	23																					
	24																					
	25																					

SUBSURFACE EXPLORATION LOG

BORING No.	: BH-5
SHEET	: 2 OF 3
TOTAL DEPTH	: 70.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: January 6, 1995
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: January 15, 1995
FEATURE	: DAM SITE (ALTERNATIVE A)	ANGLE	: 40 deg.
AREA DESIGNATION	: RIGHT ABUTMENT	DRILLER	: Uus Koswara
GROUND ELEVATION	: 18.060m	SUPERVISOR	: Teddy
COORDINATES	: X=767,016.541m Y=9,911,881.019m	LOGGED	: Sultan
GROUND WATER LEVEL	: GL -2.0m	DRILLING MACHINE	: YBM-3E

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Jan 9, '95	26					19	1	100	95					LAVA BRECCIA, slightly weathered to fresh.		TRIPLE TUBE CORE BARREL -NMLC- DIAMOND BIT						
	27					20	20	100	15			CM		LAVA BRECCIA, highly fractured to 3 - 10cm, grey to dark grey, medium weak to medium strong. Fissured surfaces are often stained with iron oxide.							2.2	
	28					21	12	100	40													
	29						7		70					LAVA BRECCIA, slightly weathered, grey to dark grey, strong to medium strong. With some silica veins and occasionally fissured along the veins.								
	30		0.7			22	0	100	100													
Jan 10, '95	31		1.4				4		90													
	32					23	2	100	100												20.0	
	33					24	2	100	100													
	34					25	5	100	80													
	35		1.2			26	3	100	80													
Jan 11, '95			1.7			27		100														
	36					28	3	100	80													
	37					29	1	100	100												7.2	
	38						3		90													
	39						1		90			CH										
	40		0.9			30	2	100	100													
			1.2																			
Jan 12, '95	41						3		90													
	42					31	1	100	100												10.7	
	43						2		100													
	44					32	1	100	100													
	45					33	4	100	60					LAVA BRECCIA, moderately fractured especially along silica veins. Grey to dark green, medium weak to medium strong. Sometimes with fine sericite on fissured surface.								
	46						5		80													
	47					34	8	100	40												12	
	48					35	3	100	90			CH										
	49						6		60													
	50		0.0			36	8	100	60													
						37																

SUBSURFACE EXPLORATION LOG

BORING No. : BH-5
SHEET : 3 OF 3
TOTAL DEPTH : 70.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: January 6, 1995
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: January 15, 1995
FEATURE	: DAM SITE (ALTERNATIVE A)	ANGLE	: 40 deg.
AREA DESIGNATION	: RIGHT ABUTMENT	DRILLER	: Uus Koswara
GROUND ELEVATION	: 18.060m	SUPERVISOR	: Teddy
COORDINATES	: X=767,016.541m Y=9,911,881.019m	LOGGED	: Sultan
GROUND WATER LEVEL	: GL -2.0m	DRILLING MACHINE	: YBM-3E

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Jan 13, '95	51		0.6			38	8	100	70					LAVA BRECCIA, moderately fractured.		TRIPLE TUBE CORE BARREL - NMLC- DIAMOND BIT						
	52					39	1	100	100					LAVA BRECCIA, predominantly fresh, grey to dark grey, strong to very strong. With white silica veins and occasionally fissured along the veins.								
	53					40	0	100	100												8.4	
	54						1		100													
	55		0.0			41	3	100	90													
Jan 14, '95	56		1.4				0		100													
	57						0		100													
	58					42	1	100	100												2.1	
	59						1		100													
	60					43	2	100	90			CH										
	61						1		100													
	62						1		100													
	63					44	0	100	100												1.7	
	64						0		100													
	65					45	1	100	100													
	66						3		70													
	67						0		100													
	68					46	2	100	80												2.3	
	69						1		100													
	70		0.8			47	1	100	100													
	71		1.1											End of Drilling								
	72																					
	73																					
	74																					
	75																					

SUBSURFACE EXPLORATION LOG

BORING No. : BH-6
SHEET : 1 OF 1
TOTAL DEPTH : 20.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: January 8, 1995
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: January 11, 1995
FEATURE	: DAM SITE (ALTERNATIVE A)	ANGLE	: VERTICAL
AREA DESIGNATION	: LEFT ABUTMENT	DRILLER	: Uli Sadeli
GROUND ELEVATION	: 35.780m	SUPERVISOR	: Teddy
COORDINATES	: X=766,948.819m Y=9,911,894.507m	LOGGED	: Sultan
GROUND WATER LEVEL	: GL -12.2m	DRILLING MACHINE	: KOKEN OE-2L

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Jan 8, '95	0					1		95						TOP SOIL with organic matter		ST - NK	Dia. 89mm					
	1					2		95						SANDY GRAVEL with silt, light brown, derived from completely weathered lava breccia. Maximum size of gravels is 5cm.								
	2		1.0			3		95				D										
	3					4		95														
	4					5		95														
	5					6		95														
	6					7		95	25					GRAVEL, grey, highly weathered Lava Breccia stained with iron oxide.								
Jan 9, '95	7					8	4	100	80								4.3					
	8					9	16	95	45					LAVA BRECCIA, grey, moderately to slightly weathered. With subangular fragments of red basalt, diabase and andesite. Sometimes with silica veins of 3mm in thickness. Occasionally with fissures along the veins.							1.2	
	9					10	9	100	40													
	10					11	5	100	80													
	11		1.5			12	6	100	80					Highly fractured to gravel size at 5.0 to 5.3m.								
	12		5.0			13	3	100	90			CM										
Jan 10, '95	13					14	5	100	80					Moderately fractured and stained with iron oxide on the fissure surface from 13.8 to 15.3m.								
	14					15	5	100	70												0.9	
	15		5.5			16	0	100	100													
	16		12.2			17	10	100	60													
	17					18	15	95	45													
Jan 11, '95	18					19	6	100	70							TRIPLE TUBE CORE BARREL NMLC - DIAMOND BIT						
	19					20	4	100	80												3.9	
	20		13.5			21	0	100	100			CH										
	21						1	100	100													
	22						3	100	100													
	23													End of Drilling								
	24																					
	25																					

SUBSURFACE EXPLORATION LOG

BORING No. : BH-8
SHEET : 1 OF 1
TOTAL DEPTH : 15.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 30, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: January 1, 1995
FEATURE	: DAM SITE (ALTERNATIVE A)	ANGLE	: VERTICAL
AREA DESIGNATION	: RIGHT ABUTMENT	DRILLER	: Asep D.
GROUND ELEVATION	: 59.910m	SUPERVISOR	: Teddy
COORDINATES	: X=767,025.184m Y=9,911,824.059m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: Lower than GL -15.0m	DRILLING MACHINE	: YSO-01

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Details of Core							Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Permeability Test		Remarks
						Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.								Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 30, '94	1					1		100						TOP SOIL, sandy clay, medium stiff. With roots and plant remains at the top most 0.4m.								
						2		100														
						3		100														
						4		100														
						5		100														
	2					6		100						CLAYEY GRAVEL, dense to very dense, yellowish brown to grey.					50/10			30/10, 50/10
						7		100														
						8		100						The gravels consist of breccia, sandstone with maximum diameter of 7cm, angular.								
	3					9		100														
						10		100														
	4					11		100														
						12		100														
			4.0			13		100												5.2E-5		
	5		1			14		100												FALLING HEAD (4.5-5m)		
						15		100														
	6					16		100														
						17		100														
						18		100														
Dec 31, '94	7					19		100						GRAVELLY SAND with clay, grey, derived from highly weathered Lava Breccia. Maximum diameter is 6cm.								
						20		100														
						21		100														
	8					22		100														
						23		100														
						24		100														
	9					25		100										9.0		9.3E-4		
			8.0			26	8	100	45			D		LAVA BRECCIA, moderately to slightly weathered. Greenish grey with red spots, medium strong to strong.						CONSTANT HEAD (9-10m)		
	10		1				12		40													
						27		100						Fair to highly jointed, close spacing, rough joint plane, dip 30 to 45 degrees.	Joint dip 30-45°							
	11						7		60													
						28	8	100	20			CH		Fragments are subangular and consist of andesite and basalt.							4.4	
	12						11		20													
						29		100						With andesit block at 10.1 to 11.5m and 12.7 to 13.0m.								
Jan 1, '95	13					30	15	100	15													
	14																					
	15													End of Drilling								
	16																					
	17																					
	18																					
	19																					
	20																					
	21																					
	22																					
	23																					
	24																					
	25																					

SINGLE CORE BARREL STEEL BIT
Dia. 89mm
TTCB NMLC DIAMOND BIT

SUBSURFACE EXPLORATION LOG

BORING No.	: BH-10
SHEET	: 1 OF 1
TOTAL DEPTH	: 20.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 9, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: December 15, 1994
FEATURE	: POWER HOUSE	ANGLE	: VERTICAL
AREA DESIGNATION	:	DRILLER	: Asep D
GROUND ELEVATION	: 4.220m	SUPERVISOR	: Teddy
COORDINATES	: X=767,185.090m Y=9,911,943.730m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: GL +0.5m	DRILLING MACHINE	: YSO-01

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 9, '84	1					1		60				D		GRAVEL derived from highly fractured Andesite with sizes of 5 to 10cm. Subangular, strong, slightly weathered. With silica veins.		TRIPLE TUBE CORE BARREL NMLC – DIAMOND BIT	Dia. 89mm					
						2		60														
						3		70														
						4		70														
						5		75														
	2					6		100														
			0.6			7		100									2.5					
			0.5																			
Dec 10, '84	3					8	13	100	18			CM		SILTSTONE, highly to moderately fractured sith silica veins and FeS particles, moderately weathered. Grey and brownish colours.								
	4					9	12	100	20													
	5						8		65													
	6		0.5			10		100														
			0.5				11		45					LAVA BRECCIA, greyish brown. Moderately strong. Moderately weathered. Consists of diabase and andesite. Highly jointed. Joints are filled with silica and FeS.	Joint dip 26-85° rough surface							
Dec 11, '84	7					11	13	100													2.6	
	8					12	9	100	42													
	9																					
	10		0.5			13	11	100	12													
			0.5			14	8	100														
Dec 12	11		0.5			15		100														
			0.5				10		30													
	12					16	30	100													5.2	
Dec 13, '84	13																					
	14					17	7	100	35													
	15		0.5			18	9	100														
			0.5																			
Dec 14, '84	16					19	10	100	35													
						20		100														
	17						10		20													
			0.5			21		100														
			0.5				11		17													
Dec 15, '84	18					22		100													2.6	
						23	30	100														
	19					24		100														
			0.5			25	12	100														
	20													End of Drilling								
	21																					
	22																					
	23																					
	24																					
	25																					

SUBSURFACE EXPLORATION LOG

BORING No.	: BH-11
SHEET	: 1 OF 2
TOTAL DEPTH	: 40.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 8, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: December 29, 1994
FEATURE	: SADDLE DAM	ANGLE	: VERTICAL
AREA DESIGNATION	: RESERVOIR / POND AREA	DRILLER	: Kosasih
GROUND ELEVATION	: 44.600m	SUPERVISOR	: Teddy
COORDINATES	: X=768,320.084m Y=9,910,725.011m	LOGGED	: Sultan
GROUND WATER LEVEL	: GL - 5.4m	DRILLING MACHINE	: YSO-01

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Details of Core							Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Permeability Test		Remarks
						Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.								Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 8, '94	1					1		100						SILTY CLAY, light brown, soft to medium stiff, high plasticity. Residual soil from weathered Shale.					15			6/15, 8/15, 9/15
						2		100														
	2					3		100														
						4		100						CLAYEY SILT with sand and gravel. Brown to dark brown. Stiff. High plasticity. Maximum gravel size is 1cm. Completely weathered Shale.					25			7/15, 11/15, 14/15
Dec 9	3		3.2			5		100											64			16/15, 24/15, 40/15
						6		100												1.5E-4		
Dec 10, '94	4		1.4																	FALLING HEAD (3.5-4m)		
						7		70						SILTY GRAVEL highly to completely weathered Shale). Dark grey to blackish. Very dense. Very calcareous. With calcite and silica minerals. Maximum gravel size is 5cm. Stained with iron oxide from 5.8 to 7.5m.								
	5																					
	6		1.9			8		65														
Dec 12, '94			1.5																			
	7					9		70														
	8					10		60														
			1.8																			
	9		2.2			11		30														
Dec 13, '94																				2.2E-3		
	10					12		50												CONSTANT HEAD (9.5-10m)		
			4.6			13		20														
	11		4.8																			
Dec 14, '94						14		25														
	12																					
						15		30														
	13		6.9			16		100														
Dec 16			5.3			17		100											50/20			26/15, 25/5
	14					18		100												7.9E-4		
			5.2			19		100												CONSTANT HEAD (14.5-15m)		
Dec 17, '94	15		6.5			20		100														
						21		100														
						22		100														
						23		100														
	16					24		100														
			5.9			25		100														
Dec 18			5.4																			
	17		5.3			26		80														
Dec 19			5.4			27		90														
			5.4			28		100														
Dec 20	18		5.4																			
			2.5			29		60												5.3E-4		
	19		5.4																50/10	CONSTANT HEAD (19.5-20m)		50/10
						30		80														
	20					31		100														
Dec 21, '94																						
	21																					
						32		40												1.3E-4		
	22																			CONSTANT HEAD (20-25m)		
						33		100														
	23																					
						34		40														
	24																					
			3.6																			
	25																					

Soil Description or Rock Lithology

SILTY CLAY, light brown, soft to medium stiff, high plasticity. Residual soil from weathered Shale.

CLAYEY SILT with sand and gravel. Brown to dark brown. Stiff. High plasticity. Maximum gravel size is 1cm. Completely weathered Shale.

SILTY GRAVEL highly to completely weathered Shale). Dark grey to blackish. Very dense. Very calcareous. With calcite and silica minerals. Maximum gravel size is 5cm. Stained with iron oxide from 5.8 to 7.5m.

SHALE. Highly to completely weathered and changed into fine to medium grained gravels. Dark grey to blackish. Gravels are crushable by finger pressure. With veins of calcite and limestone.

SHALE, highly weathered. Dark grey to blackish. With many fissures, slicken side and cleavage dipping 45 degrees.

Type of Core Barrel and Bit: TRIPLE TUBE CORE BARREL - STEEL BIT

Diameter of Casing: Dia. 89mm

Permeability Test: 1.5E-4 FALLING HEAD (3.5-4m); 2.2E-3 CONSTANT HEAD (9.5-10m); 7.9E-4 CONSTANT HEAD (14.5-15m); 5.3E-4 CONSTANT HEAD (19.5-20m); 1.3E-4 CONSTANT HEAD (20-25m)

SUBSURFACE EXPLORATION LOG

BORING No. : BH-11
SHEET : 2 OF 2
TOTAL DEPTH : 40.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 8, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: December 29, 1994
FEATURE	: SADDLE DAM	ANGLE	: VERTICAL
AREA DESIGNATION	: RESERVOIR / POND AREA	DRILLER	: Kosasih
GROUND ELEVATION	: 44.600m	SUPERVISOR	: Teddy
COORDINATES	: X=768,320.084m Y=9,910,725.011m	LOGGED	: Sultan
GROUND WATER LEVEL	: GL - 5.4m	DRILLING MACHINE	: YSO-01

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 26, '94	26		5.4			35		60						SHALE. Highly weathered. Dark grey to blackish. With many fissures, slicken side and cleavage dipping 45 degrees.		TRIPLE TUBE CORE BARREL STEEL BIT	Dia. 89mm					
	27					36		100														
			5.3			37		60														
Dec 27, '94	28		5.4			38		90														
	29					39		90														
			5.3			40		90												2.4E-4 FALLING HEAD (30m)		
	30		5.4			41		90									30.7					
	31					42		95												2.6E-6 CONSTANT HEAD (30-35m)		
Dec 28, '94	32					43		100														
	33					44		100														
	34					45		100												1.4E-6 CONSTANT HEAD (30-40m)		
	35					46		100														
	36		5.3			47		100														
	37		5.4			48		100														
Dec 29, '94	38					49		100														
	39		5.3			50		100					CL									
	40													End of Drilling								
	41																					
	42																					
	43																					
	44																					
	45																					
	46																					
	47																					
	48																					
	49																					
	50																					

Coring
SPT

SUBSURFACE EXPLORATION LOG

BORING No. : BH-12
SHEET : 1 OF 2
TOTAL DEPTH : 30.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: January 2, 1995
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: January 6, 1995
FEATURE	: SADDLE DAM	ANGLE	: VERTICAL
AREA DESIGNATION	:	DRILLER	: Kosasih
GROUND ELEVATION	: 48.780m	SUPERVISOR	: Teddy
COORDINATES	: X=769,700.133m Y=9,911,208.343m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: GL - 2.4m	DRILLING MACHINE	: YSO-01

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Details of Core							Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Permeability Test		Remarks
						Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.								Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Jan 2, '95	1					1		100					D	TOP SOIL, clay, dark brown. Stiff. Medium plasticity.		SINGLE						
						2		100						CLAYEY SAND, yellowish brown. Stiff.					32			6/15, 20/15, 12/15
	2					3		100						CLAY with gravel from weathered Limestone. Brownish white. Hard. Gravels are coarse grained with diameter of 2 to 5cm, moderately strong.					50/15			28/15, 50/15
						4		100							Fractures dipping 30 degrees at 3 to 4m depth.							
	3					5		100	45													
						6	5	100	70													
	4																					
			2.5			7	2	100	90													
	5																					
			2.5			8	3	100	95					LIMESTONE. Slightly weathered to fresh. Strong. Greyish white. With many calcite vein and joints. With very close to close spaced silica veins. At 9.4-9.5m with open cracks of 10mm filled by blackish shale.								
	6																					
						9	3	100	95													
Jan 3, '95	7																					
						10	2	100	100												0.2	
	8																					
						11	2	100	95													
	9																					
			2.5			12	1	100	100				CM									
	10		1.3																			
						13	1	100	100													
	11																					
						14	1	100	100													
	12																					
						15	2	100	100												0.4	
	13																					
							1		100													
	14					16		100														
						17	1	100	100													
	15																	15.0				
						18	0	100	95													
	16																					
			6.7			19		100	50													
Jan 4, '95	17		2.4																50/25	7.8E-6		25/15, 22/15, 28/10
						20		100						SHALE, black, completely to highly weathered. With some limestone gravels.		SINGLE CORE BARREL STEEL BIT				CONSTANT HEAD (15-20m)		
	18					21		100														
						22		100														
	19					23		100														
						24		100														
						25		100											50/25	2.2E-6		30/15, 20/10
	20					26		100												CONSTANT HEAD (15-25m)		
						27		100														
						28		100														
Jan 5, '95	21					29		100														
						30		100														
						31		100														
	22					32		100														
						33		100												1.6E-6		
						34		100												CONSTANT HEAD (15-30m)		
	23					35		100														
						36		100														
	24					37		100														
						38		100														
						39		100														
	25		2.4			40		100														

SUBSURFACE EXPLORATION LOG

BORING No. : BH-12
SHEET : 2 OF 2
TOTAL DEPTH : 30.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: January 2, 1995
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: January 6, 1995
FEATURE	: SADDLE DAM	ANGLE	: VERTICAL
AREA DESIGNATION	:	DRILLER	: Kosasih
GROUND ELEVATION	: 48.780m	SUPERVISOR	: Teddy
COORDINATES	: X=769,700.133m Y=9,911,208.343m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: GL – 2.4m	DRILLING MACHINE	: YSO-01

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Details of Core							Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Permeability Test		Remarks
						Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.								Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Jan 6, '95	26		2.4			41		100						Shale, black, completely to highly wethered. With some limestone gravels.		SINGLE STEEL BIT						
	27					42		100														
						43		100														
						44		100														
						45		100														
	28					46		100														
						47		100														
						48		100														
						49		100														
	29					50		100														
						51		100														
						52		100														
						53		100														
	30					54		100				CL		End of Drilling								
	31																					
	32																					
	33																					
	34																					
	35																					
	36																					
	37																					
	38																					
	39																					
	40																					
	41																					
	42																					
	43																					
	44																					
	45																					
	46																					
	47																					
	48																					
	49																					
	50																					

SUBSURFACE EXPLORATION LOG

BORING No. : BH-13
SHEET : 1 OF 1
TOTAL DEPTH : 20.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: December 24, 1994
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: December 26, 1994
FEATURE	: SURGE TANK / PENSTOCK	ANGLE	: VERTICAL
AREA DESIGNATION	: TUNNEL	DRILLER	: Asep D
GROUND ELEVATION	: 70.000m	SUPERVISOR	: Teddy
COORDINATES	: X=767,108.844m Y=9,911,875.200m	LOGGED	: A. Irianto
GROUND WATER LEVEL	: GL -3.2m	DRILLING MACHINE	: YSO-01

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Dec 24, '94	0					1		100						SANDY CLAY, brown, very stiff contains fine gravel.								
	1					2		100														
						3		100														
	2					4		100											27			10/15, 12/15, 15/15
	3					5		100											50/10			18/15, 50/10
						6		100														
	4					7		100						SANDY GRAVEL, with clay, brown very dense. Gravel consist of fracture andesite, max dia. 5cm. derived from completely weathered lava breccia.								
	5					8		100														
						9		100												6.9E-5 Falling Head (4.5-5m)		
	6					10		100														
						11		100														
	7					12		100														
						13		100														
	8					14		100														
						15		100														
	9					16		100														
						17		100														
	10		2.2			18		100					D									
			3.0			19		100												4.2E-4 Constant Head (9.5-10m)		
						20		100														
Dec 25, '94	11					21		100														
						22		100														
	12					23		100														
						24		100														
	13					25		100														
						26		100														
	14					27		100														
						28		100														
	15		2.0			29		100												8.9E-4 Constant Head (14.5-15m)		
			3.2			30		100														
						31		100														
	16					32		100	15								16.0					
Dec 26, '94	17																					
						33	10	100	60				CM	LAVA BRECCIA, moderate to slightly weathered, medium weak - medium strong, highly jointed, rough surface and stained with iron oxide. With red basalt fragments of dia. 2-5cm.	Joint dip 30° - 60°						4.0	
	18						6		40													
						34		100														
	19		2.0			35	5	100	60													
	20													END OF DRILLING								
	21																					
	22																					
	23																					
	24																					
	25																					

SUBSURFACE EXPLORATION LOG

BORING No.	: BH-14
SHEET	: 1 OF 1
TOTAL DEPTH	: 25.00m

PROJECT	: WARSAMSON HEPP FEASIBILITY STUDY	DATE COMMENCED	: January 8, 1995
LOCATION	: SORONG, IRIAN JAYA	DATE COMPLETED	: January 12, 1995
FEATURE	: SADDLE DAM	ANGLE	: Vertical
AREA DESIGNATION	: CACAO FARM	DRILLER	: Asep D
GROUND ELEVATION	: 48.580m	SUPERVISOR	: Teddy
COORDINATES	: X=770,975.500m Y=9,911,650.411m	LOGGED	: Sultan
GROUND WATER LEVEL	: GL -0.1m	DRILLING MACHINE	: YSO-01

1	2	3	4	5	6	7							8	9	10	11	12	13	14	15		16
						Details of Core														Permeability Test		Remarks
Date	Depth (m)	Elevation (m-MSL)	Ground Water Level (m)	Drilling Rate / 10cm	Depth of Water Loss (m)	Run No.	Fractures / m	% Recovery	R.Q.D (%)	Graph of R.Q.D.	Legend	C.R.Q.	Method of Sampling	Soil Description or Rock Lithology	Rock Structure	Type of Core Barrel and Bit	Diameter of Casing	Blow / 30cm Casing	SPT N-Value (Blows/30cm)	Coefficient of Permeability (cm/sec)	Lugeon Value	Coring / SPT
Jan 8, '95	1					1	2	100						SILTY SAND, dark grey to blackish, loose								
	2					2		100											5			2/15, 2/15, 3/15
	3					3		100						SILTY CLAY, dark brown to greyish brown, medium stiff to hard, low plasticity, stained with iron oxide. (Completely weathered Shale)					35			6/15, 15/15, 20/15
	4					4		100											37			13/15, 17/15, 20/15
	5					5		100											36			11/15, 15/15, 21/15
			4.0			6		100												2.0E-4		
			0.1																33	Falling Head (5m)		9/15, 14/15, 19/15
	6					7		100											50			13/15, 23/15, 27/15
Jan 9, '95	7					8		100											90			23/15, 40/15, 60/15
	8					9		100											61			13/15, 21/15, 40/15
	9					10		100											63			9/15, 13/15, 50/15
																				9.9E-7		
	10		2.7			11		100											51/28	Falling Head (10m)		8/15, 21/15, 30/13
			0.1																50/20			29/15, 21/5
	11					12		100											50/20			30/15, 20/5
	12					13		100											58/20			28/15, 30/5
	13					14		100											50/10			50/10
	14					15		100														
			10.0																50/10	2.1E-5		50/10
			0.1																	Falling Head (15m)		
	15					16		100											50/10			50/10
Jan 11, '95	16					17		100											55/20			35/15, 20/5
	17					18		100											60/20			40/15, 20/5
	18					19		100											50/10			50/10
	19					20		100														
			10.0																50/10	2.7E-5		50/10
			0.1																	Falling Head (20m)		
	20					21		100											60/20			35/15, 25/5
	21					22		100											50/15			50/15
	22					23		100											50/15			50/15
	23					24		100														
Jan 12, '95	24					25		100											50/5	(25m) Falling Head 6.8E-4		50/5
	25		1.2			26		100					CL	End of Drilling		SINGLE CORE BARREL / ST - NK	Dia. 89mm	25.0				

APPENDIX C

Results of Field Tests

C.1 Field Permeability Test

C.2 Field Density Test

C.3 Seismic Refraction Survey

APPENDIX C.1

Field Permeability Test

- Lugeon Test

- Constant Head Test

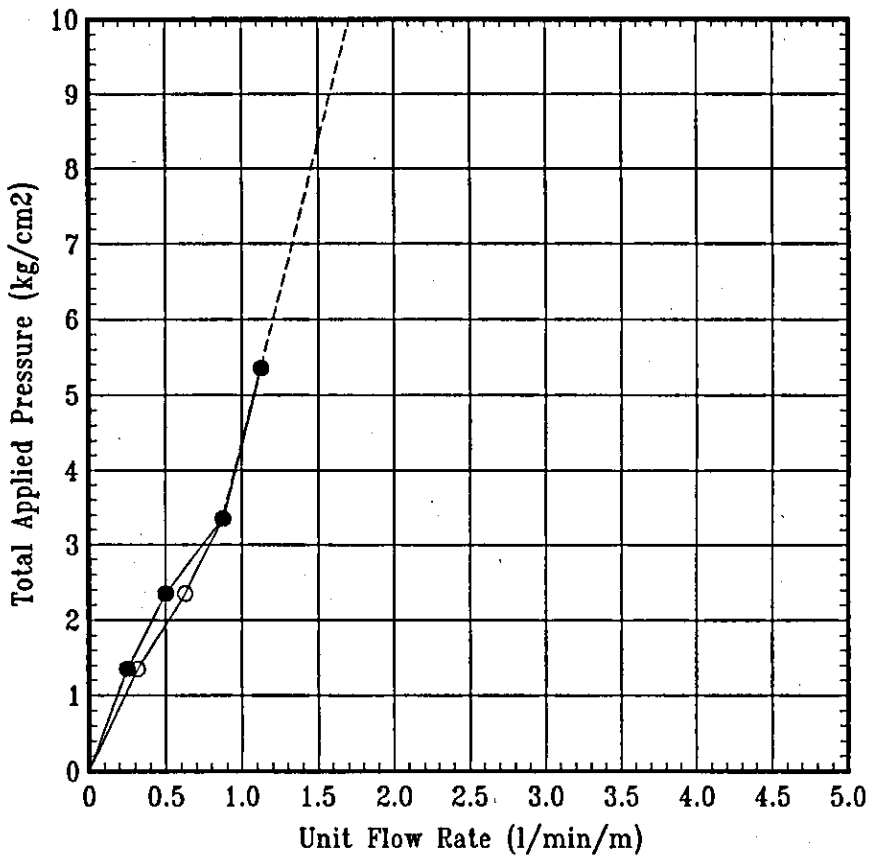
- Falling Head Test

Lugeon Test

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical : 30 °	
Location : Dam Site (Alternative D)			
Borehole No. : 1		Borehole Diameter : 7.6 cm	
Testing Depth : From 1 m to 5 m		Distance of Pressure Gauge to the Ground : 1.25 m	
Ground Elevation : 30.02 m			
Ground Water Table : GL - 2.60 m		Tested by : Uus Kuswara	
Date : Dec 20, '94		Supervisor : Teddy	

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	1.00	0.0002	1.35	0.25	2.3E-05
2	2	2.00	0.0004	2.35	0.50	2.6E-05
3	3	3.50	0.0007	3.35	0.88	3.2E-05
4	5	4.50	0.0009	5.35	1.13	2.6E-05
5	3	3.50	0.0007	3.35	0.88	3.2E-05
6	2	2.50	0.0005	2.35	0.63	3.3E-05
7	1	1.25	0.0003	1.35	0.31	2.9E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

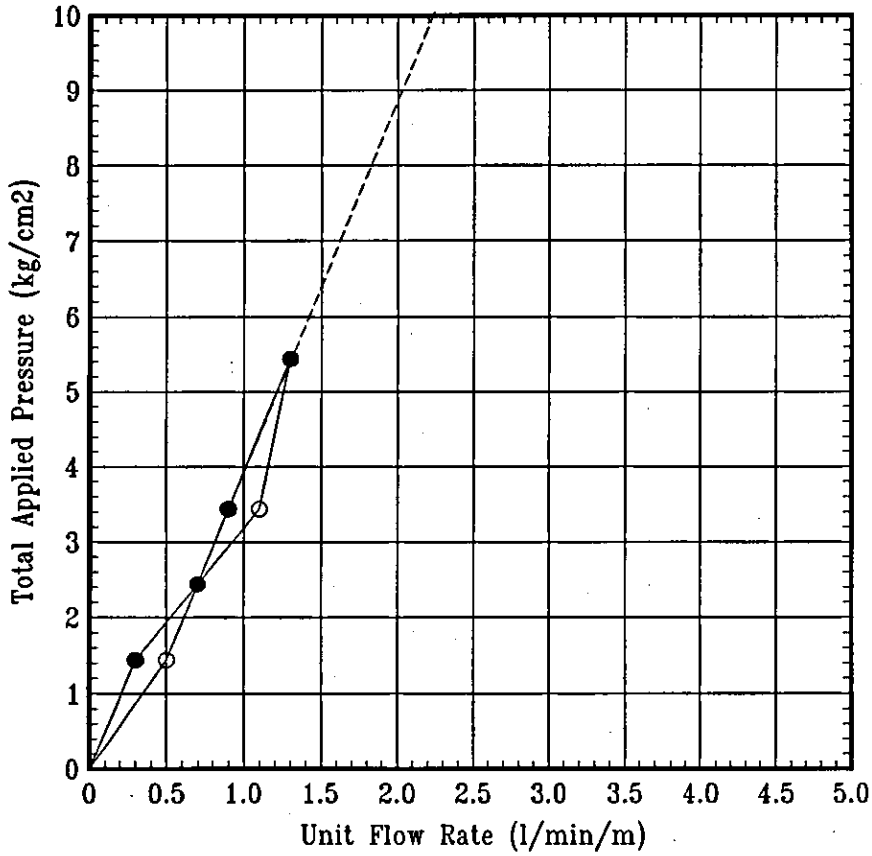
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 1.7

LUGEON TEST

Project : Warsamson HEPP Feasibility Study	Borehole Axis to Vertical : 30 °
Location : Dam Site (Alternative D)	Borehole Diameter : 7.6 cm
Borehole No. : 1	Distance of Pressure Gauge to the Ground : 1.25 m
Testing Depth : From 5 m to 10 m	Tested by : Uus Kuswara
Ground Elevation : 30.02 m	Supervisor : Teddy
Ground Water Table : GL - 3.65 m	
Date : Dec 21, '94	

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	1.50	0.0008	1.44	0.30	2.7E-05
2	2	3.50	0.0020	2.44	0.70	3.7E-05
3	3	4.50	0.0025	3.44	0.90	3.4E-05
4	5	6.50	0.0036	5.44	1.30	3.1E-05
5	3	5.50	0.0031	3.44	1.10	4.1E-05
6	2	3.50	0.0020	2.44	0.70	3.7E-05
7	1	2.50	0.0014	1.44	0.50	4.5E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

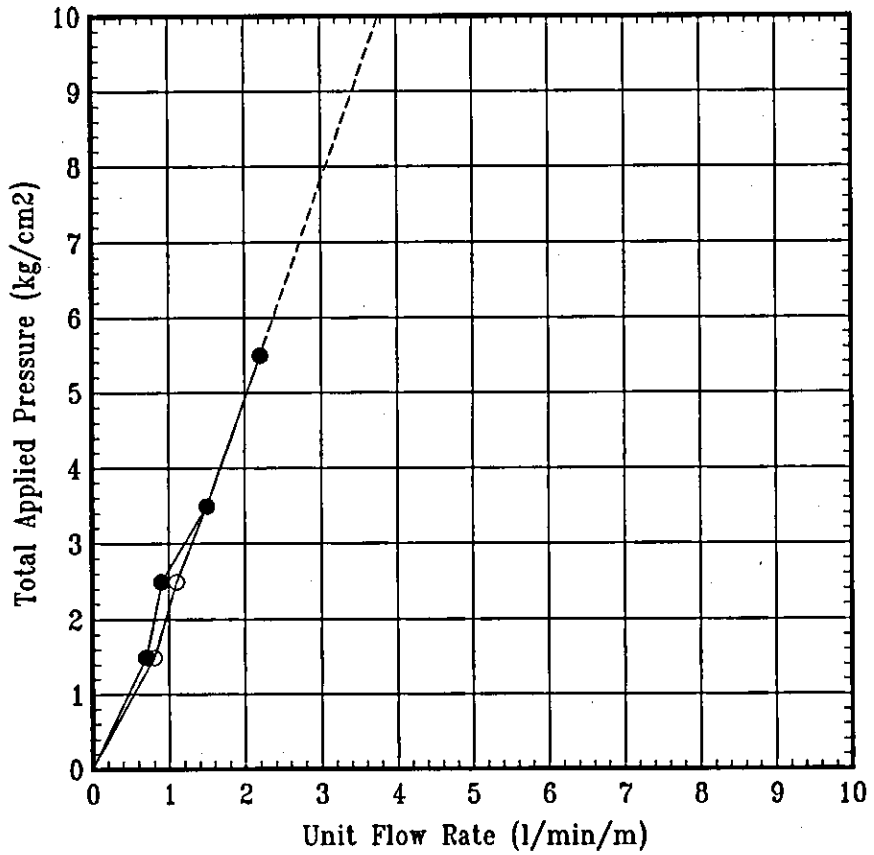
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.2

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 30 ^{o}
Location	: Dam Site (Alternative D)	Borehole Diameter	: 7.6 cm
Borehole No.	: 1	Distance of Pressure Gauge to the Ground	: 1.25 m
Testing Depth	: From 10 m to 15 m	Tested by	: Uus Kuswara
Ground Elevation	: 30.02 m	Supervisor	: Teddy
Ground Water Table	: GL - 4.25 m		
Date	: Dec 22, '94		

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	3.50	0.0029	1.49	0.70	6.1E-05
2	2	4.50	0.0038	2.49	0.90	4.7E-05
3	3	7.50	0.0063	3.49	1.50	5.6E-05
4	5	11.00	0.0092	5.49	2.20	5.2E-05
5	3	7.50	0.0063	3.49	1.50	5.6E-05
6	2	5.50	0.0046	2.49	1.10	5.7E-05
7	1	4.00	0.0034	1.49	0.80	6.9E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

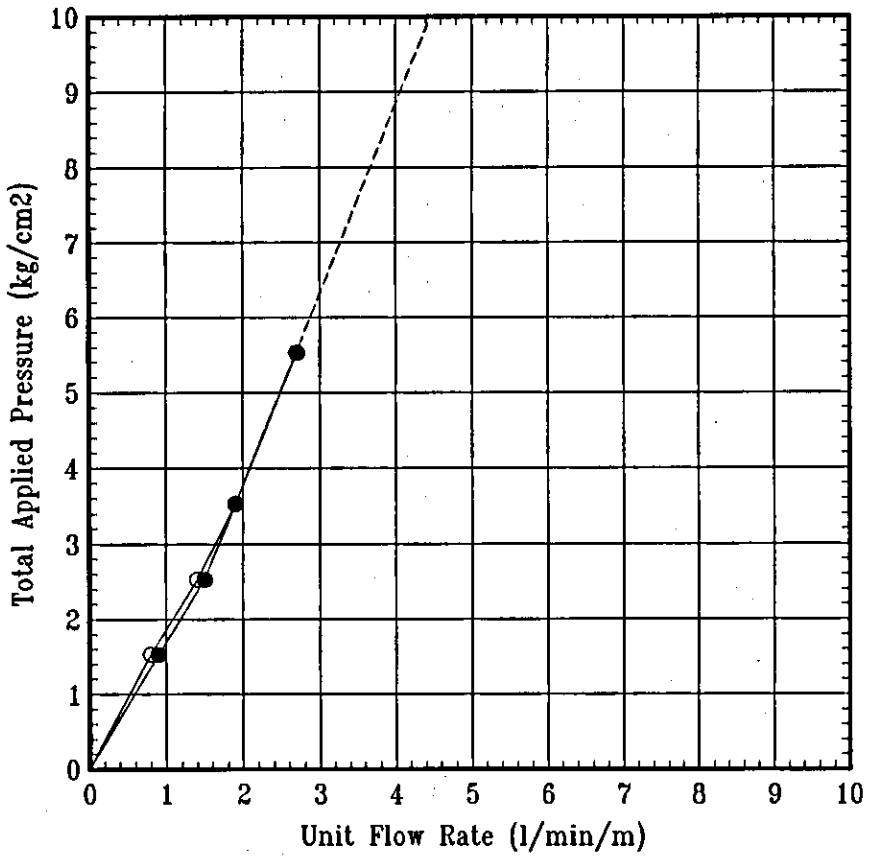
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 3.8

LUGEON TEST

Project : Warsamson HEPP Feasibility Study	Borehole Axis to Vertical : 30 °
Location : Dam Site (Alternative D)	
Borehole No. : 1	Borehole Diameter : 7.6 cm
Testing Depth : From 15 m to 20 m	Distance of Pressure Gauge to the Ground : 1.25 m
Ground Elevation : 30.02 m	
Ground Water Table : GL - 4.65 m	Tested by : Uus Kuswara
Date : Dec 23, '94	Supervisor : Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	4.50	0.0052	1.53	0.90	7.6E-05
2	2	7.50	0.0087	2.53	1.50	7.7E-05
3	3	9.50	0.0110	3.53	1.90	7.0E-05
4	5	13.50	0.0156	5.53	2.70	6.3E-05
5	3	9.50	0.0110	3.53	1.90	7.0E-05
6	2	7.00	0.0081	2.53	1.40	7.2E-05
7	1	4.00	0.0046	1.53	0.80	6.8E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

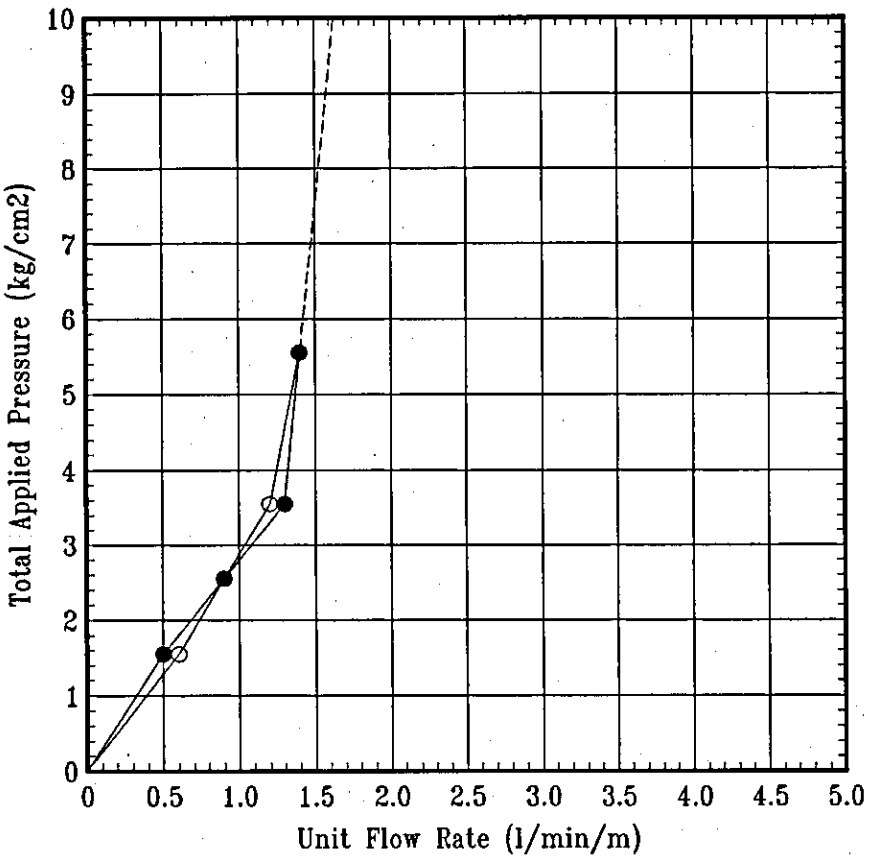
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 4.4

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 30 °
Location : Dam Site (Alternative D)			
Borehole No. : 1		Borehole Diameter	: 7.6 cm
Testing Depth : From 20 m to 25 m		Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation : 30.02 m			
Ground Water Table : GL - 4.90 m		Tested by	: Uus Kuswara
Date : Dec 24, '94		Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.50	0.0040	1.55	0.50	4.2E-05
2	2	4.50	0.0072	2.55	0.90	4.6E-05
3	3	6.50	0.0105	3.55	1.30	4.7E-05
4	5	7.00	0.0113	5.55	1.40	3.3E-05
5	3	6.00	0.0097	3.55	1.20	4.4E-05
6	2	4.50	0.0072	2.55	0.90	4.6E-05
7	1	3.00	0.0048	1.55	0.60	5.0E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

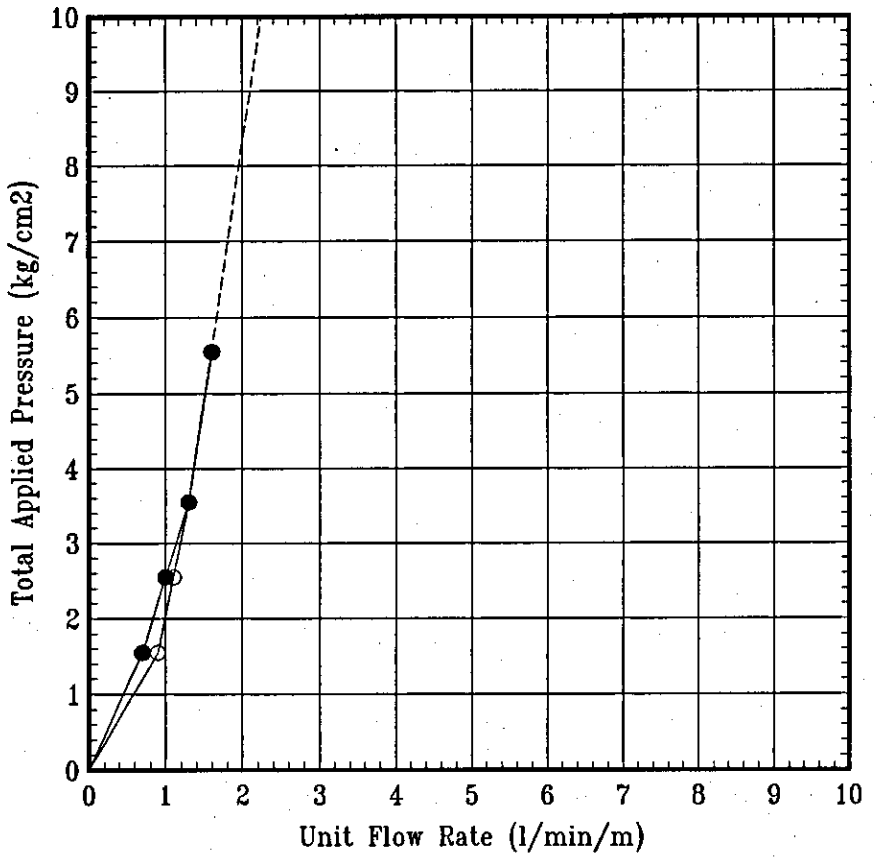
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 1.6

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 30 ^{o}
Location	: Dam Site (Alternative D)		
Borehole No.	: 1	Borehole Diameter	: 7.6 cm
Testing Depth	: From 25 m to 30 m	Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation	: 30.02 m		
Ground Water Table	: GL - 4.90 m	Tested by	: Uus Kuswara
Date	: Dec 24, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	3.50	0.0071	1.55	0.70	5.9E-05
2	2	5.00	0.0102	2.55	1.00	5.1E-05
3	3	6.50	0.0132	3.55	1.30	4.7E-05
4	5	8.00	0.0162	5.55	1.60	3.7E-05
5	3	6.50	0.0132	3.55	1.30	4.7E-05
6	2	5.50	0.0112	2.55	1.10	5.6E-05
7	1	4.50	0.0091	1.55	0.90	7.5E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

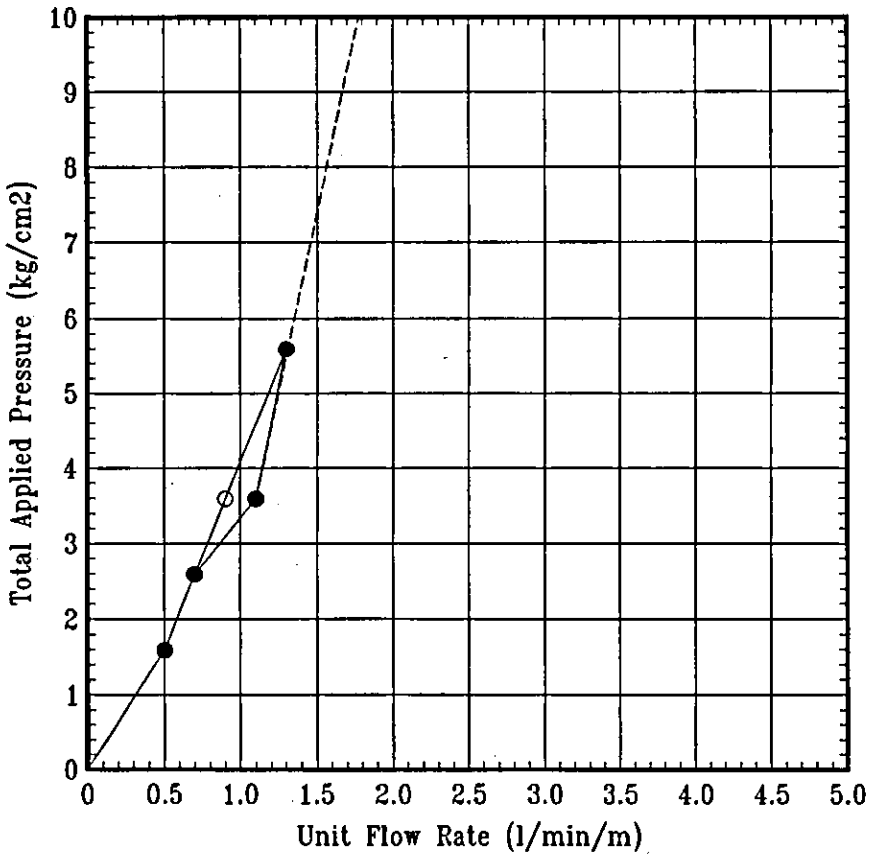
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.2

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 30 °
Location	: Dam Site (Alternative D)		
Borehole No.	: 1	Borehole Diameter	: 7.6 cm
Testing Depth	: From 30 m to 35 m	Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation	: 30.02 m		
Ground Water Table	: GL - 5.40 m	Tested by	: Uus Kuswara
Date	: Dec 25, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.50	0.0059	1.59	0.50	4.1E-05
2	2	3.50	0.0082	2.59	0.70	3.5E-05
3	3	5.50	0.0129	3.59	1.10	4.0E-05
4	5	6.50	0.0152	5.59	1.30	3.0E-05
5	3	4.50	0.0106	3.59	0.90	3.2E-05
6	2	3.50	0.0082	2.59	0.70	3.5E-05
7	1	2.50	0.0059	1.59	0.50	4.1E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

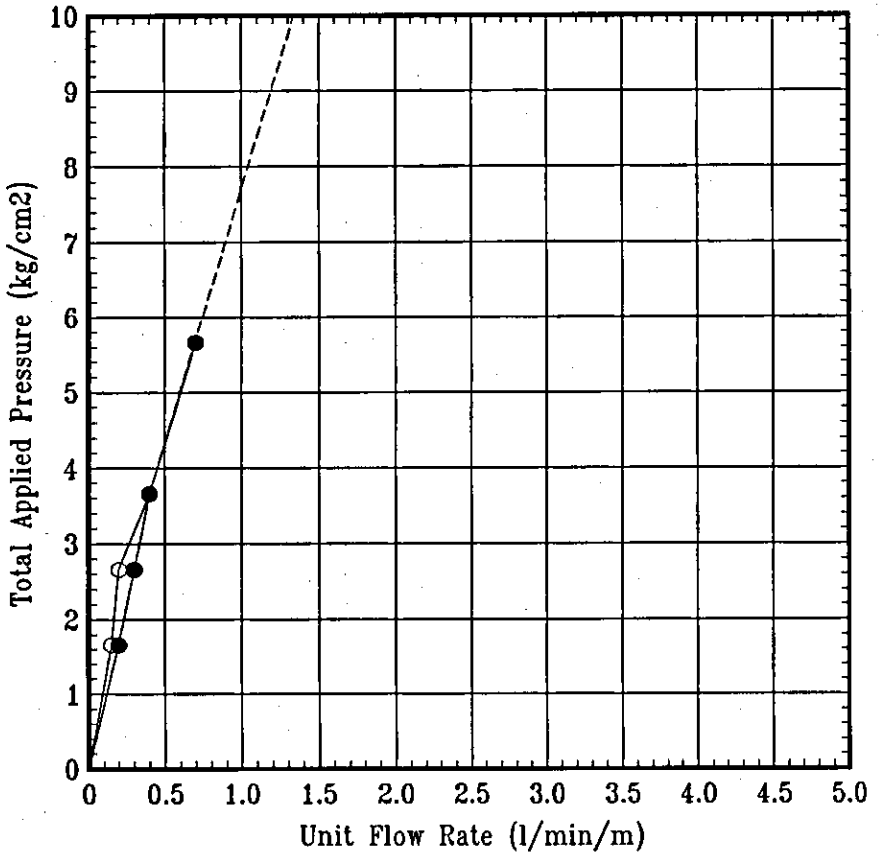
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 1.8

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 30 °
Location	: Dam Site (Alternative D)		
Borehole No.	: 1	Borehole Diameter	: 7.6 cm
Testing Depth	: From 35 m to 40 m	Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation	: 30.02 m		
Ground Water Table	: GL - 6.20 m	Tested by	: Uus Kuswara
Date	: Dec 26, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	1.00	0.0027	1.66	0.20	1.6E-05
2	2	1.50	0.0040	2.66	0.30	1.5E-05
3	3	2.00	0.0053	3.66	0.40	1.4E-05
4	5	3.50	0.0093	5.66	0.70	1.6E-05
5	3	2.00	0.0053	3.66	0.40	1.4E-05
6	2	1.00	0.0027	2.66	0.20	9.7E-06
7	1	0.75	0.0020	1.66	0.15	1.2E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

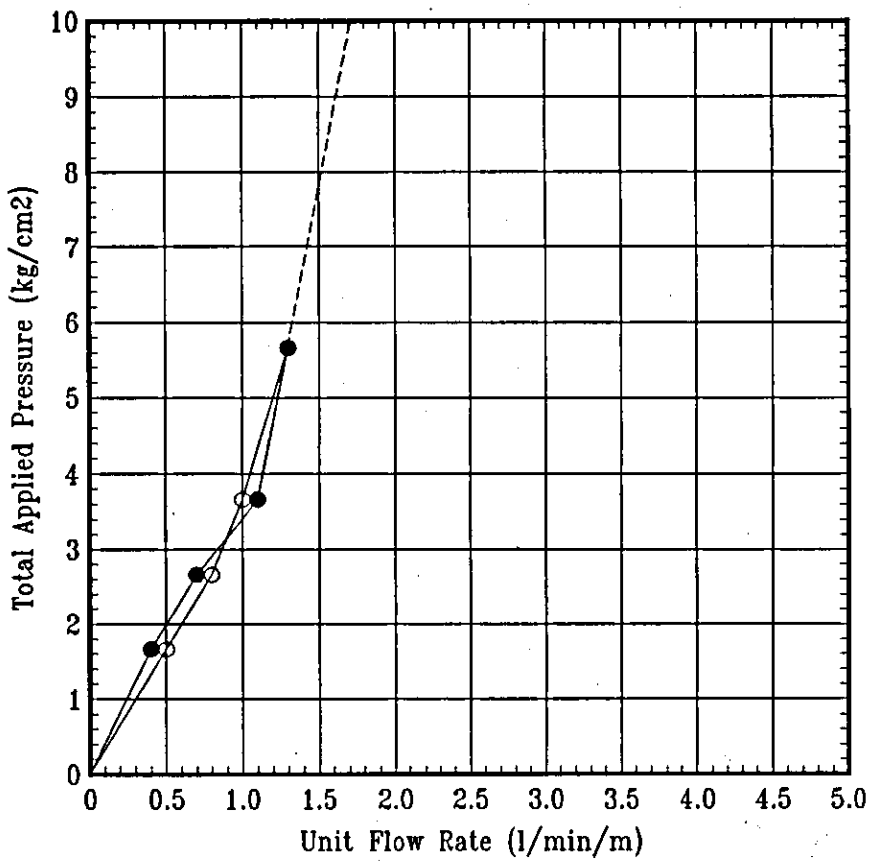
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 1.3

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 30 °
Location : Dam Site (Alternative D)			
Borehole No. : 1		Borehole Diameter	: 7.6 cm
Testing Depth : From 40 m to 45 m		Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation : 30.02 m			
Ground Water Table : GL - 6.20 m		Tested by	: Uus Kuswara
Date : Dec 26, '94		Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.00	0.0062	1.66	0.40	3.1E-05
2	2	3.50	0.0108	2.66	0.70	3.4E-05
3	3	5.50	0.0169	3.66	1.10	3.9E-05
4	5	6.50	0.0200	5.66	1.30	3.0E-05
5	3	5.00	0.0154	3.66	1.00	3.5E-05
6	2	4.00	0.0123	2.66	0.80	3.9E-05
7	1	2.50	0.0077	1.66	0.50	3.9E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

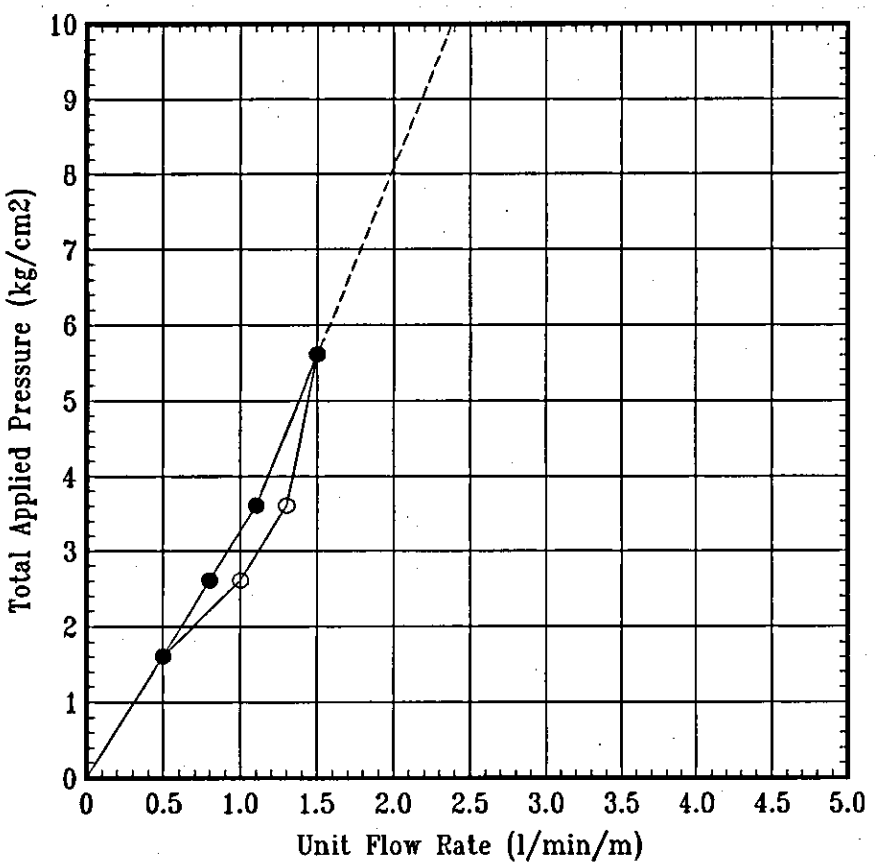
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 1.7

LUGEON TEST

Project : Warsamson HEPP Feasibility Study	Borehole Axis to Vertical : 30 ^{o}
Location : Dam Site (Alternative D)	
Borehole No. : 1	Borehole Diameter : 7.6 cm
Testing Depth : From 45 m to 50 m	Distance of Pressure Gauge to the Ground : 1.25 m
Ground Elevation : 30.02 m	
Ground Water Table : GL - 5.65 m	Tested by : Uus Kuswara
Date : Dec 27, '94	Supervisor : Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.50	0.0085	1.61	0.50	4.0E-05
2	2	4.00	0.0136	2.61	0.80	4.0E-05
3	3	5.50	0.0187	3.61	1.10	3.9E-05
4	5	7.50	0.0255	5.61	1.50	3.5E-05
5	3	6.50	0.0221	3.61	1.30	4.7E-05
6	2	5.00	0.0170	2.61	1.00	5.0E-05
7	1	2.50	0.0085	1.61	0.50	4.0E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

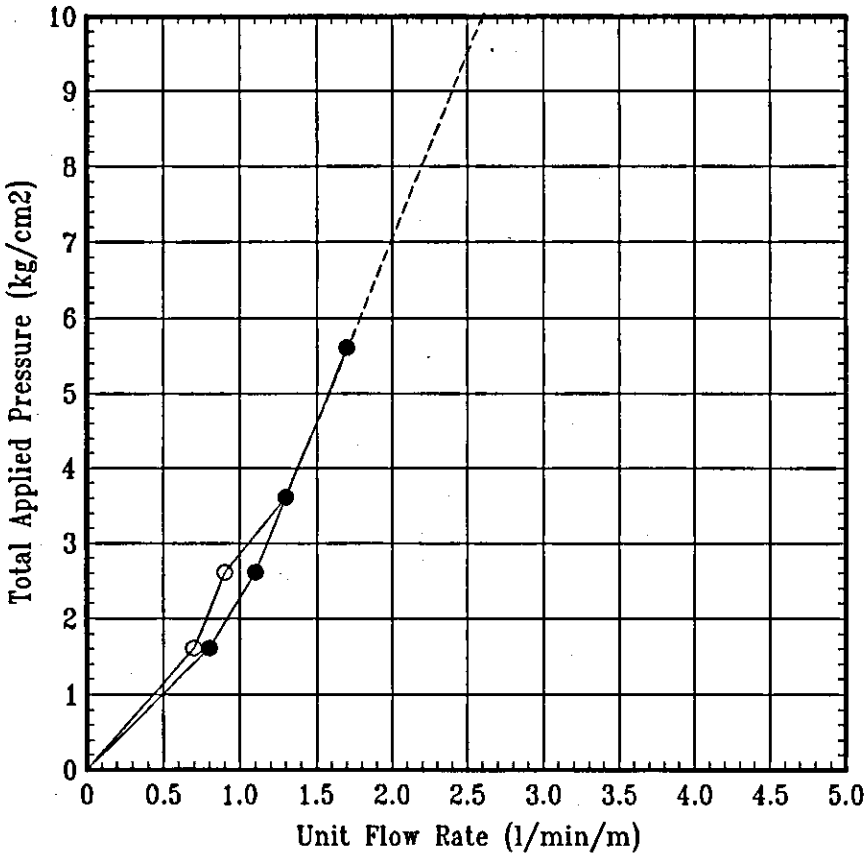
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.4

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 30 °
Location : Dam Site (Alternative D)			
Borehole No. : 1		Borehole Diameter	: 7.6 cm
Testing Depth : From 50 m to 55 m		Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation : 30.02 m			
Ground Water Table : GL - 5.65 m		Tested by	: Uus Kuswara
Date : Dec 27, '94		Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	4.00	0.0148	1.61	0.80	6.4E-05
2	2	5.50	0.0204	2.61	1.10	5.4E-05
3	3	6.50	0.0241	3.61	1.30	4.7E-05
4	5	8.50	0.0315	5.61	1.70	3.9E-05
5	3	6.50	0.0241	3.61	1.30	4.7E-05
6	2	4.50	0.0167	2.61	0.90	4.5E-05
7	1	3.50	0.0130	1.61	0.70	5.6E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

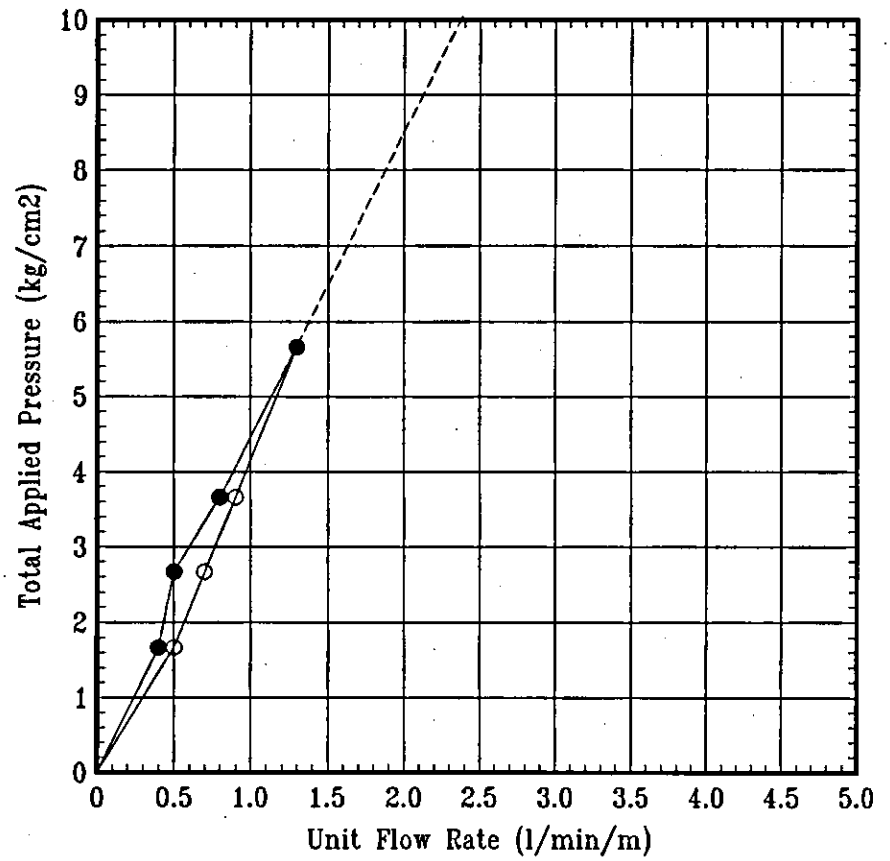
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.6

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 30 °
Location	: Dam Site (Alternative D)		
Borehole No.	: 1	Borehole Diameter	: 7.6 cm
Testing Depth	: From 55 m to 60 m	Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation	: 30.02 m		
Ground Water Table	: GL - 6.25 m	Tested by	: Uus Kuswara
Date	: Dec 28, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.00	0.0081	1.67	0.40	3.1E-05
2	2	2.50	0.0102	2.67	0.50	2.4E-05
3	3	4.00	0.0162	3.66	0.80	2.8E-05
4	5	6.50	0.0264	5.66	1.30	3.0E-05
5	3	4.50	0.0183	3.66	0.90	3.2E-05
6	2	3.50	0.0142	2.67	0.70	3.4E-05
7	1	2.50	0.0102	1.67	0.50	3.9E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

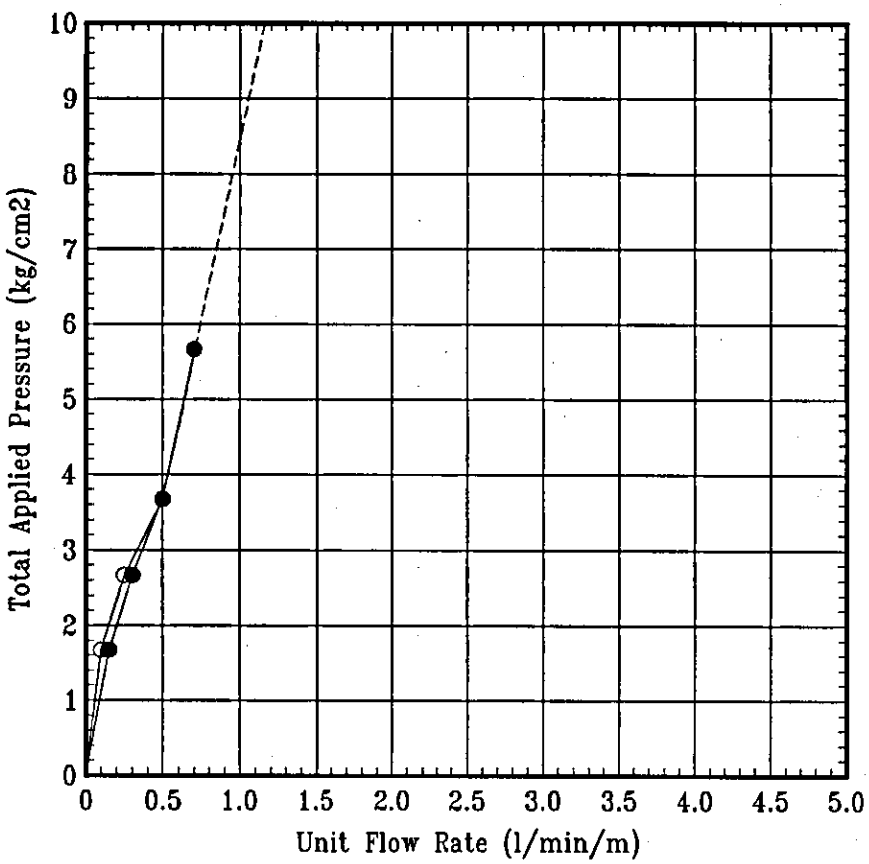
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.4

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 30 °
Location : Dam Site (Alternative D)			
Borehole No. : 1		Borehole Diameter	: 7.6 cm
Testing Depth : From 60 m to 65 m		Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation : 30.02 m			
Ground Water Table : GL - 6.25 m		Tested by	: Uus Kuswara
Date : Dec 28, '94		Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	0.75	0.0033	1.67	0.15	1.2E-05
2	2	1.50	0.0067	2.67	0.30	1.5E-05
3	3	2.50	0.0111	3.67	0.50	1.8E-05
4	5	3.50	0.0156	5.66	0.70	1.6E-05
5	3	2.50	0.0111	3.67	0.50	1.8E-05
6	2	1.25	0.0056	2.67	0.25	1.2E-05
7	1	0.50	0.0022	1.67	0.10	7.8E-06
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

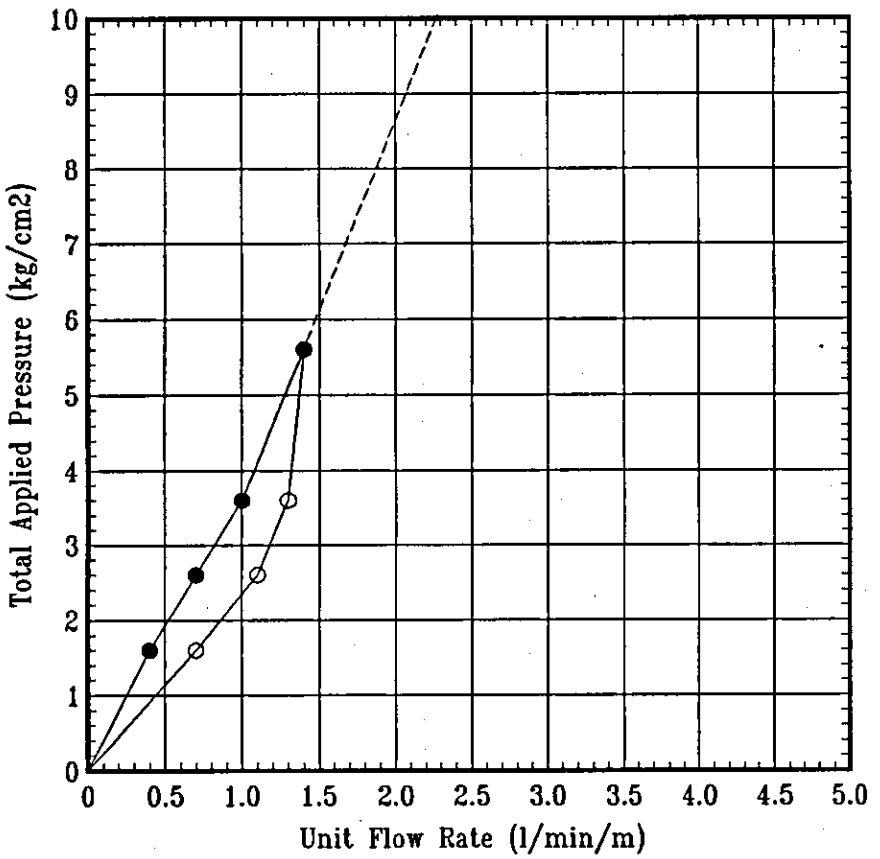
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 1.2

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 30 °
Location	: Dam Site (Alternative D)		
Borehole No.	: 1	Borehole Diameter	: 7.6 cm
Testing Depth	: From 65 m to 70 m	Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation	: 30.02 m		
Ground Water Table	: GL - 5.50 m	Tested by	: Uus Kuswara
Date	: Dec 29, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.00	0.0097	1.60	0.40	3.2E-05
2	2	3.50	0.0170	2.60	0.70	3.5E-05
3	3	5.00	0.0243	3.60	1.00	3.6E-05
4	5	7.00	0.0341	5.60	1.40	3.2E-05
5	3	6.50	0.0316	3.60	1.30	4.7E-05
6	2	5.50	0.0268	2.60	1.10	5.5E-05
7	1	3.50	0.0170	1.60	0.70	5.7E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

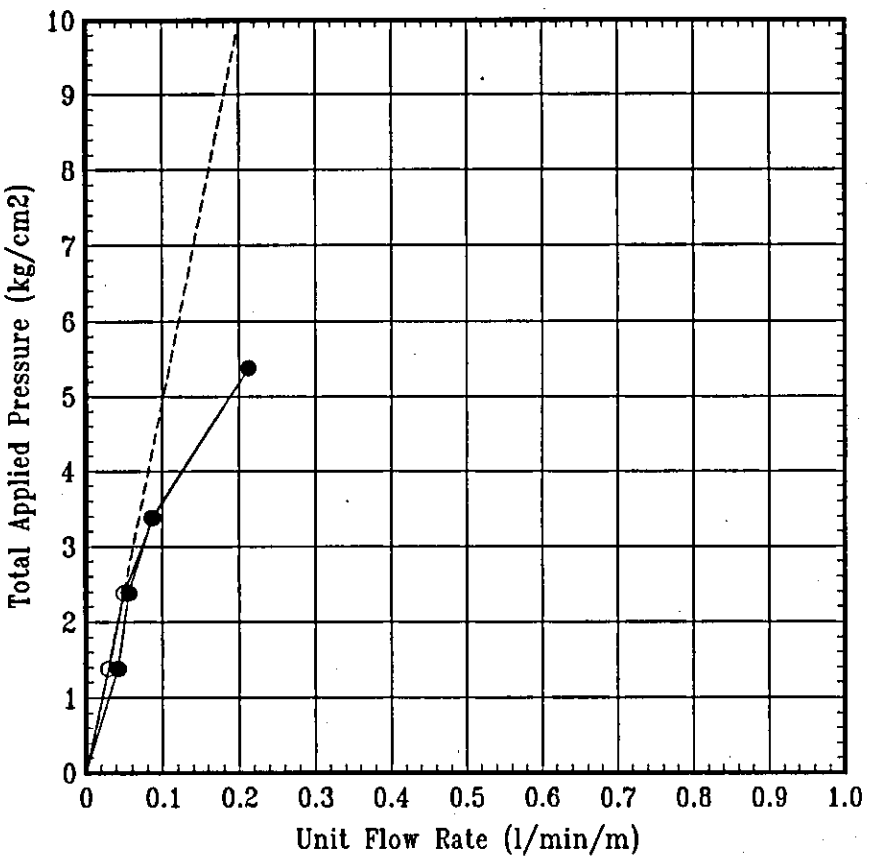
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.3

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 0 °
Location	: Dam Site (Alternative D)		
Borehole No.	: 2	Borehole Diameter	: 7.6 cm
Testing Depth	: From 5 m to 10 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 55.92 m		
Ground Water Table	: GL - 2.30 m	Tested by	: Uli Sadeli
Date	: Jan 3, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	0.21	0.0001	1.38	0.04	3.9E-06
2	2	0.28	0.0002	2.38	0.06	3.0E-06
3	3	0.43	0.0003	3.38	0.09	3.3E-06
4	5	1.06	0.0007	5.38	0.21	5.1E-06
5	3	0.44	0.0003	3.38	0.09	3.4E-06
6	2	0.25	0.0002	2.38	0.05	2.7E-06
7	1	0.15	0.0001	1.38	0.03	2.8E-06
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

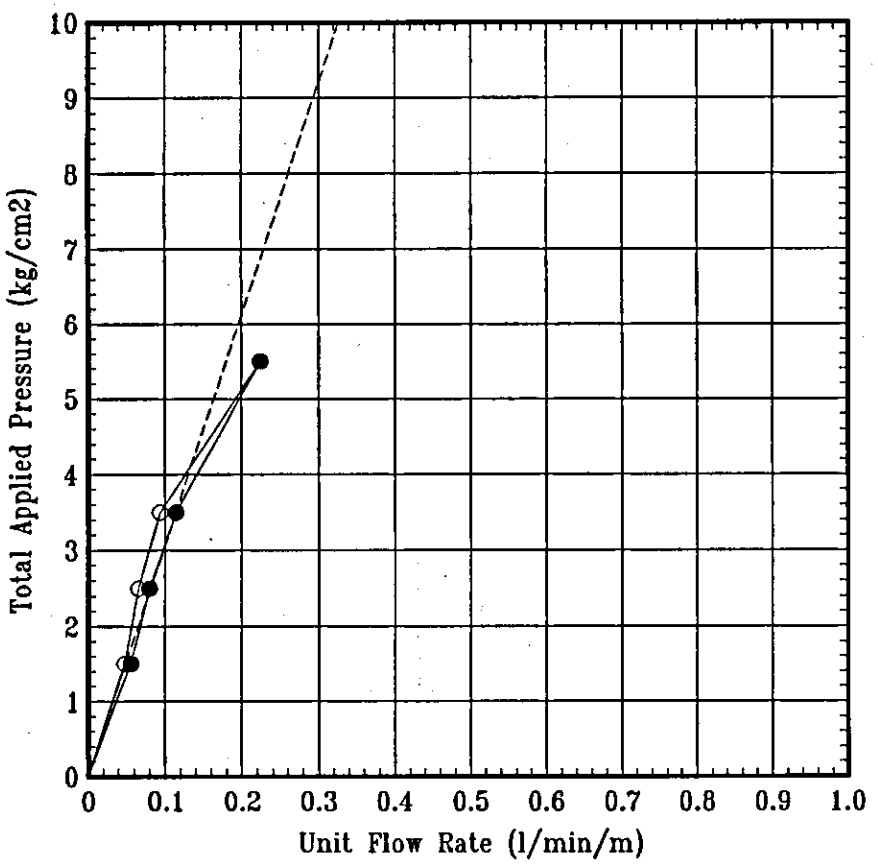
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 0.2

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 0 °
Location	: Dam Site (Alternative D)		
Borehole No.	: 2	Borehole Diameter	: 7.6 cm
Testing Depth	: From 10 m to 15 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 55.92 m		
Ground Water Table	: GL - 3.50 m	Tested by	: Uli Sadeli
Date	: Jan 4, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	0.28	0.0003	1.50	0.06	4.8E-06
2	2	0.40	0.0004	2.50	0.08	4.1E-06
3	3	0.57	0.0005	3.50	0.11	4.2E-06
4	5	1.12	0.0001	5.50	0.22	5.3E-06
5	3	0.47	0.0004	3.50	0.09	3.5E-06
6	2	0.33	0.0003	2.50	0.07	3.4E-06
7	1	0.24	0.0002	1.50	0.05	4.1E-06
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

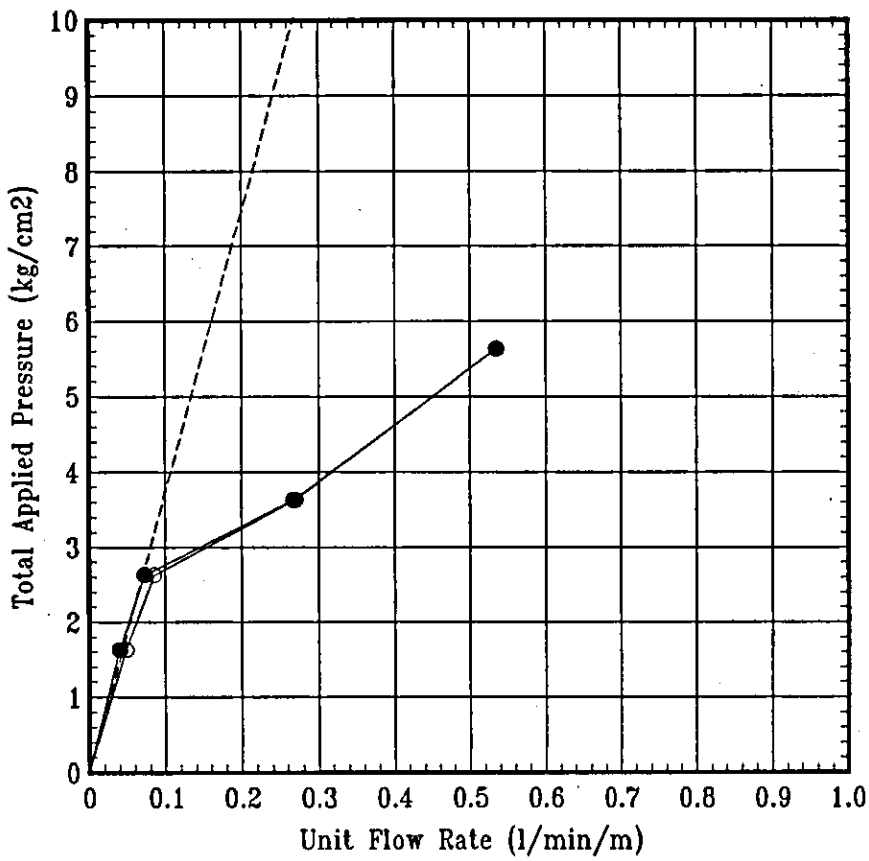
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 0.32

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 0 °
Location	: Dam Site (Alternative D)		
Borehole No.	: 3	Borehole Diameter	: 7.6 cm
Testing Depth	: From 6 m to 10 m	Distance of Pressure Gauge to the Ground	: 1.3 m
Ground Elevation	: 40.00 m		
Ground Water Table	: GL - 5.00 m	Tested by	: Uli Sadeli
Date	: Dec 27, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	0.16	0.0001	1.63	0.04	3.0E-06
2	2	0.29	0.0002	2.63	0.07	3.4E-06
3	3	1.07	0.0006	3.63	0.27	9.1E-06
4	5	2.14	0.0011	5.63	0.54	1.2E-05
5	3	1.08	0.0006	3.63	0.27	9.2E-06
6	2	0.34	0.0002	2.63	0.09	4.0E-06
7	1	0.19	0.0001	1.63	0.05	3.6E-06
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

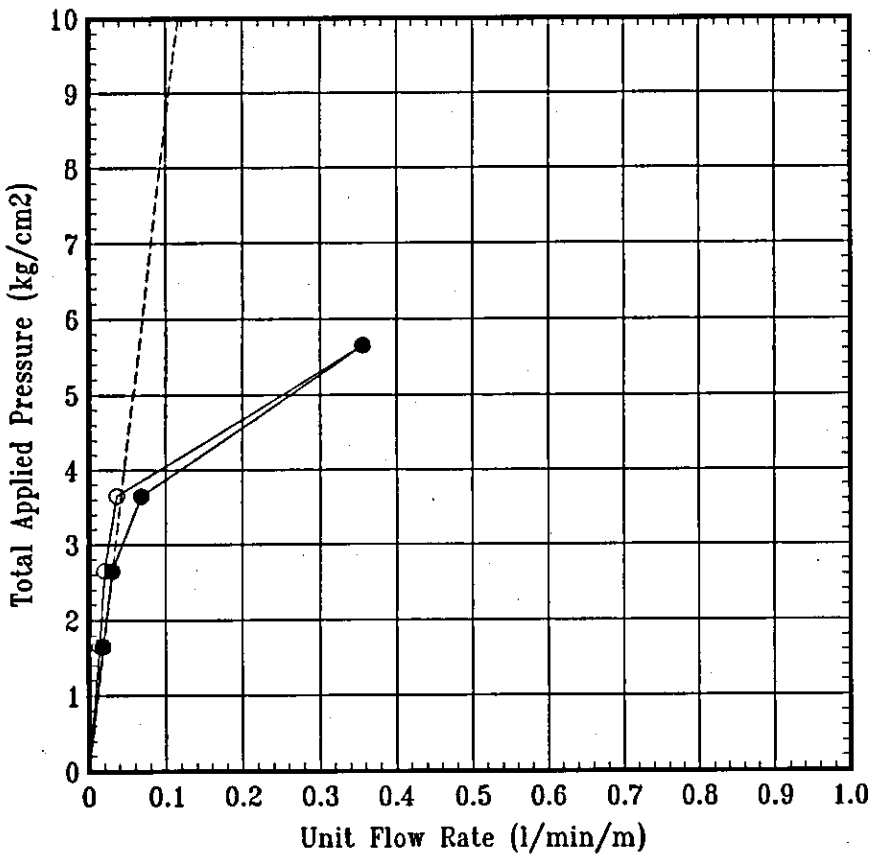
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 0.27

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 0 °
Location : Dam Site (Alternative D)			
Borehole No.	: 3	Borehole Diameter	: 7.6 cm
Testing Depth	: From 10 m to 15 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 40.00 m		
Ground Water Table	: GL - 5.00 m	Tested by	: Uli Sadeli
Date	: Dec 28, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	0.09	0.0001	1.65	0.02	1.4E-06
2	2	0.15	0.0001	2.65	0.03	1.5E-06
3	3	0.34	0.0003	3.65	0.07	2.4E-06
4	5	1.78	0.0015	5.65	0.36	8.2E-06
5	3	0.18	0.0002	3.65	0.04	1.3E-06
6	2	0.10	0.0001	2.65	0.02	9.8E-07
7	1	0.07	0.0001	1.65	0.01	1.1E-06
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

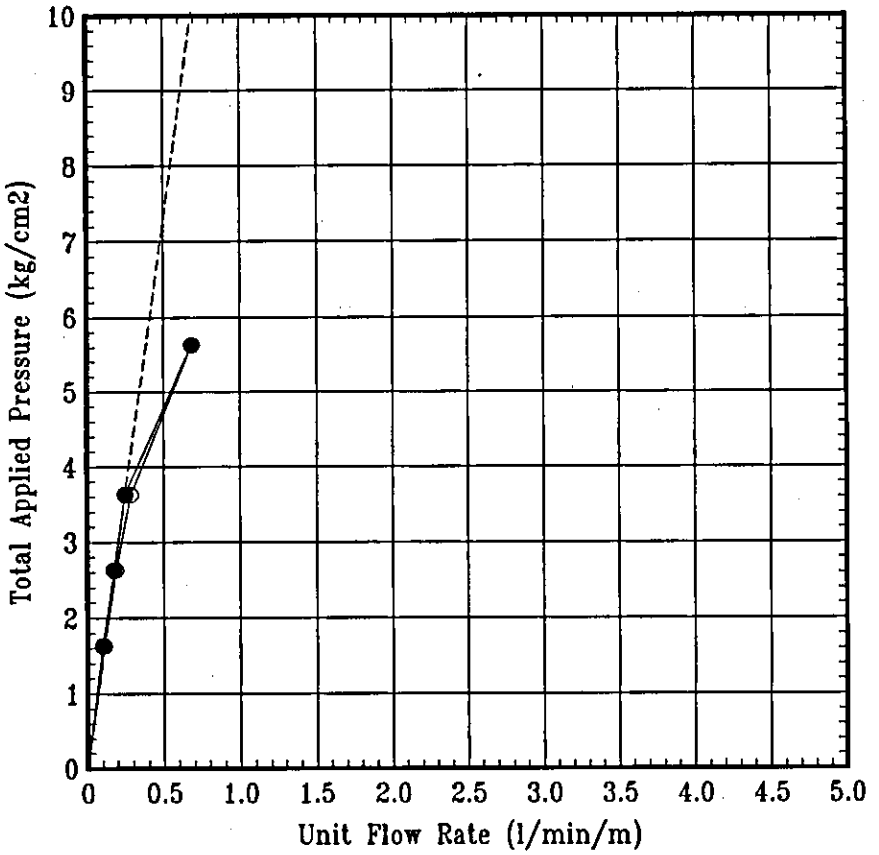
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 0.12

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 0 °
Location	: Dam Site (Alternative D)		
Borehole No.	: 4	Borehole Diameter	: 7.6 cm
Testing Depth	: From 5 m to 10 m	Distance of Pressure Gauge to the Ground	: 2 m
Ground Elevation	: 60.61 m		
Ground Water Table	: GL - 4.35 m	Tested by	: Uli Sadeli
Date	: Dec 21, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	0.51	0.0003	1.63	0.10	8.1E-06
2	2	0.87	0.0005	2.63	0.17	8.5E-06
3	3	1.26	0.0008	3.63	0.25	9.0E-06
4	5	3.43	0.0022	5.63	0.69	1.6E-05
5	3	1.43	0.0009	3.63	0.29	1.0E-05
6	2	0.94	0.0006	2.63	0.19	9.2E-06
7	1	0.56	0.0004	1.63	0.11	8.9E-06
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

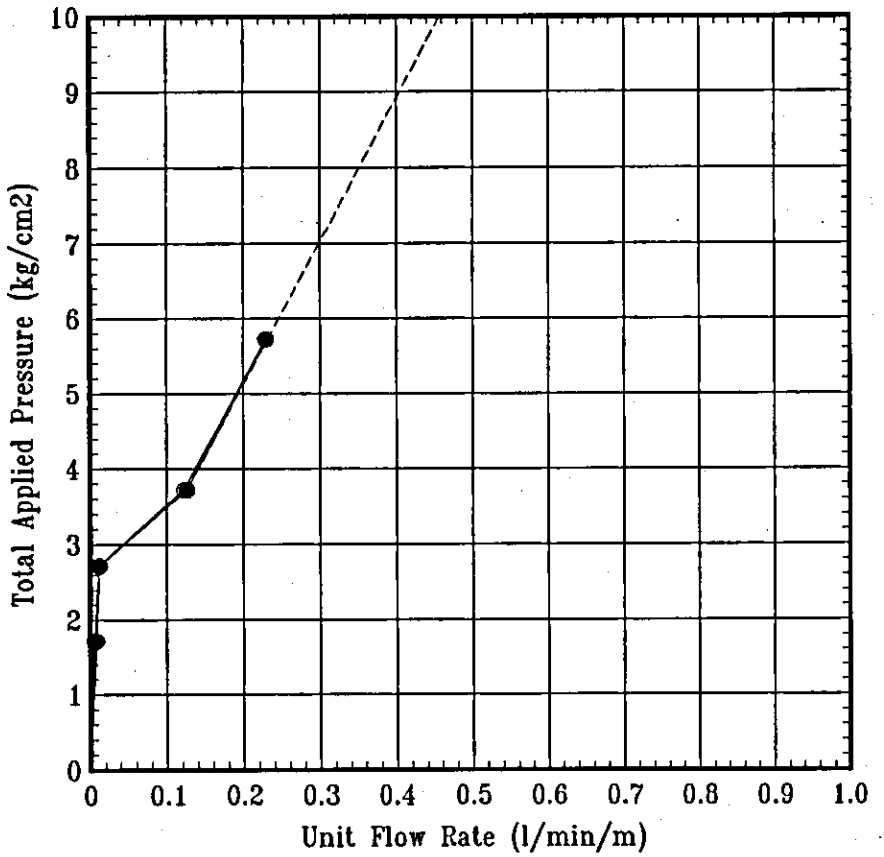
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 0.7

LUGEON TEST

Project : Warsamson HEPP Feasibility Study	Borehole Axis to Vertical : 0 o
Location : Dam Site (Alternative D)	
Borehole No. : 4	Borehole Diameter : 7.6 cm
Testing Depth : From 10 m to 15 m	Distance of Pressure Gauge to the Ground : 1.25 m
Ground Elevation : 60.61 m	
Ground Water Table : GL - 6.00 m	Tested by : Uli Sadeli
Date : Dec 22, '94	Supervisor : Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	0.03	0.0000	1.72	0.01	4.5E-07
2	2	0.06	0.0001	2.72	0.01	5.7E-07
3	3	0.63	0.0006	3.72	0.13	4.4E-06
4	5	1.14	0.0011	5.72	0.23	5.2E-06
5	3	0.61	0.0006	3.72	0.12	4.2E-06
6	2	0.06	0.0001	2.72	0.01	5.5E-07
7	1	0.04	0.0000	1.72	0.01	6.0E-07
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

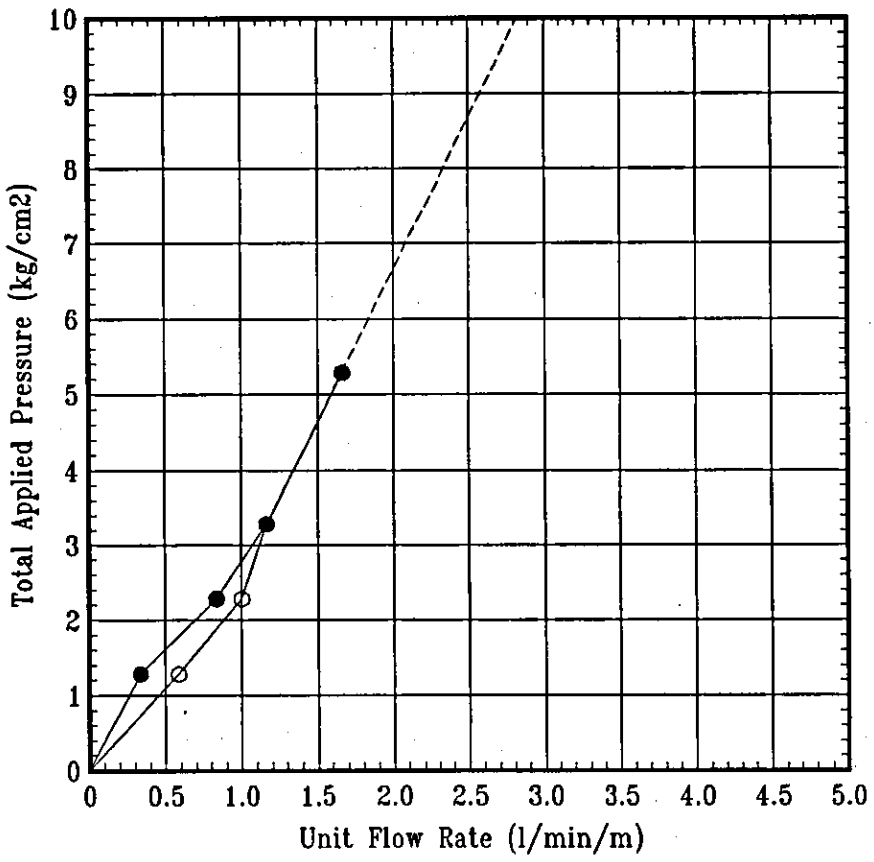
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 0.45

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 40 °
Location	: Dam Site (Alternative A)		
Borehole No.	: 5	Borehole Diameter	: 7.6 cm
Testing Depth	: From 2 m to 5 m	Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation	: 18.06 m		
Ground Water Table	: GL - 1.75 m	Tested by	: Uus Kuswara
Date	: Jan 6, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	1.00	0.0004	1.28	0.33	3.0E-05
2	2	2.50	0.0011	2.28	0.83	4.2E-05
3	3	3.50	0.0015	3.28	1.17	4.1E-05
4	5	5.00	0.0021	5.28	1.67	3.7E-05
5	3	3.50	0.0015	3.28	1.17	4.1E-05
6	2	3.00	0.0013	2.28	1.00	5.1E-05
7	1	1.75	0.0007	1.28	0.58	5.3E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

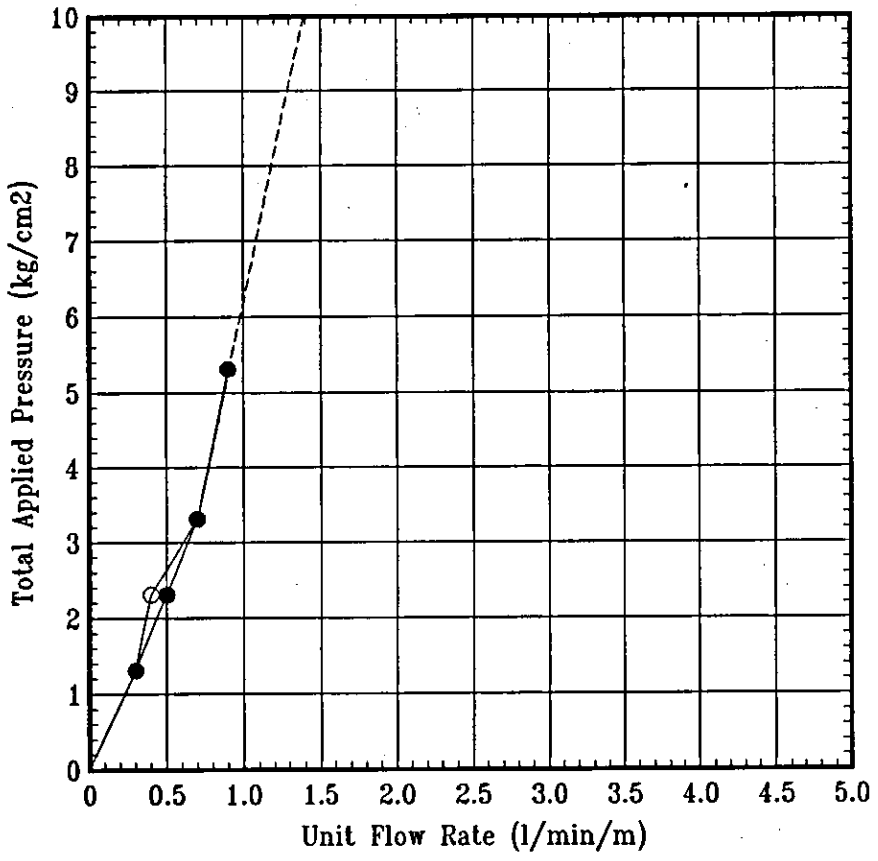
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.8

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 40 °
Location	: Dam Site (Alternative A)		
Borehole No.	: 5	Borehole Diameter	: 7.6 cm
Testing Depth	: From 5 m to 10 m	Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation	: 18.06 m		
Ground Water Table	: GL - 2.10 m	Tested by	: Uus Kuswara
Date	: Jan 7, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	1.50	0.0009	1.31	0.30	3.0E-05
2	2	2.50	0.0015	2.31	0.50	2.8E-05
3	3	3.50	0.0021	3.31	0.70	2.7E-05
4	5	4.50	0.0027	5.31	0.90	2.2E-05
5	3	3.50	0.0021	3.31	0.70	2.7E-05
6	2	2.00	0.0012	2.31	0.40	2.2E-05
7	1	1.50	0.0009	1.31	0.30	3.0E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

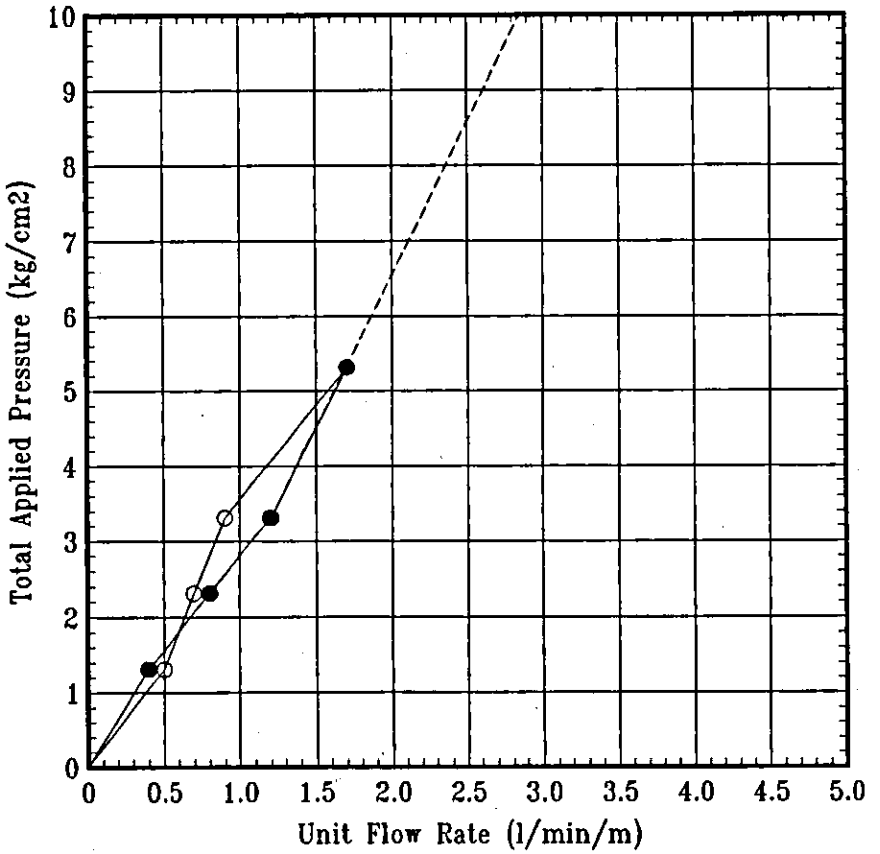
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 1.4

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 40 ^{o}
Location	: Dam Site (Alternative A)		
Borehole No.	: 5	Borehole Diameter	: 7.6 cm
Testing Depth	: From 10 m to 15 m	Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation	: 18.06 m		
Ground Water Table	: GL - 2.20 m	Tested by	: Uus Kuswara
Date	: Jan 8, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.00	0.0019	1.31	0.40	3.9E-05
2	2	4.00	0.0038	2.31	0.80	4.5E-05
3	3	6.00	0.0057	3.31	1.20	4.7E-05
4	5	8.50	0.0080	5.31	1.70	4.1E-05
5	3	4.50	0.0043	3.31	0.90	3.5E-05
6	2	3.50	0.0033	2.31	0.70	3.9E-05
7	1	2.50	0.0024	1.31	0.50	4.9E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

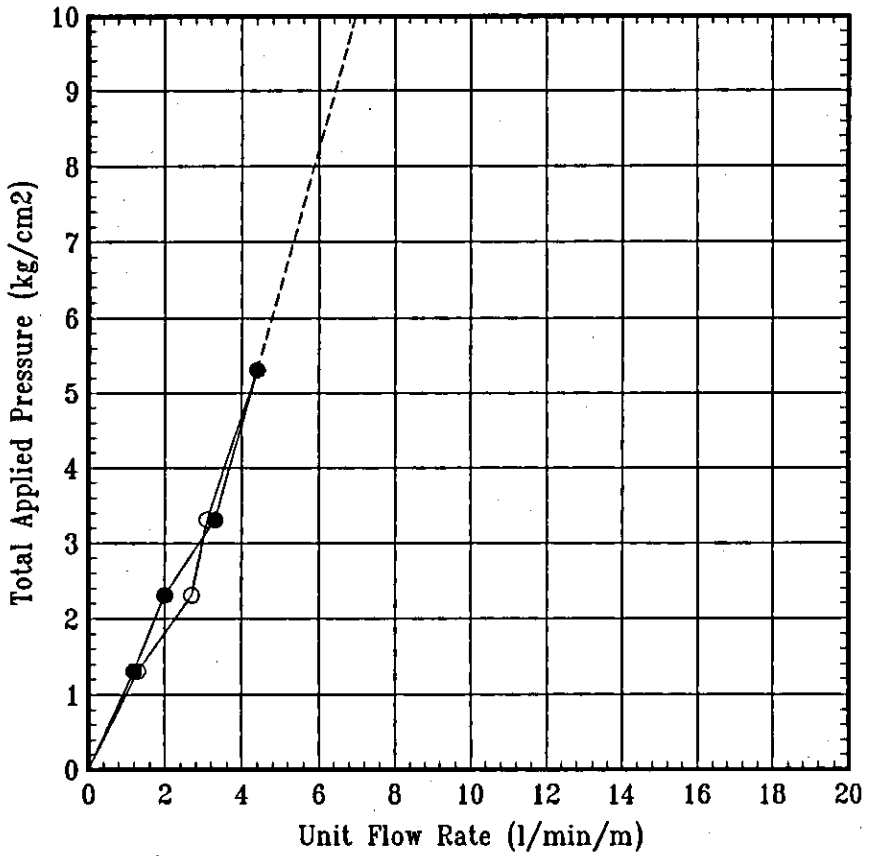
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.8

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 40 °
Location	: Dam Site (Alternative A)		
Borehole No.	: 5	Borehole Diameter	: 7.6 cm
Testing Depth	: From 15 m to 20 m	Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation	: 18.06 m		
Ground Water Table	: GL - 2.20 m	Tested by	: Uus Kuswara
Date	: Jan 8, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	6.00	0.0076	1.31	1.20	1.2E-04
2	2	10.00	0.0126	2.31	2.00	1.1E-04
3	3	16.50	0.0208	3.31	3.30	1.3E-04
4	5	22.00	0.0277	5.31	4.40	1.1E-04
5	3	15.50	0.0195	3.31	3.10	1.2E-04
6	2	13.50	0.0170	2.31	2.70	1.5E-04
7	1	6.50	0.0082	1.31	1.30	1.3E-04
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

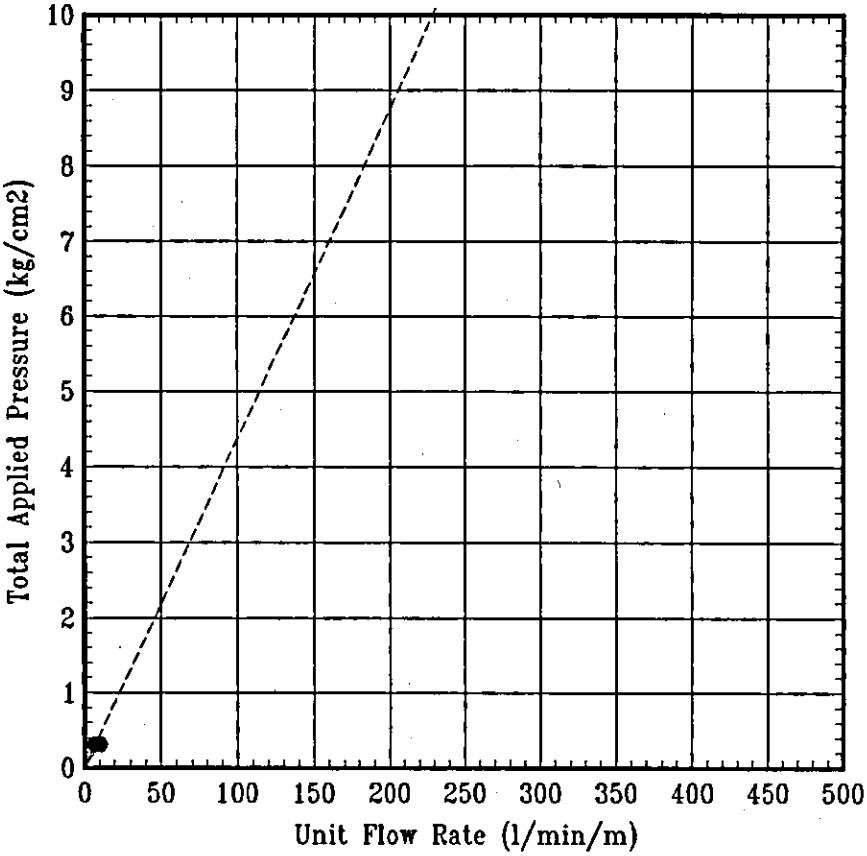
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 7.0

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 40 °
Location	: Dam Site (Alternative A)		
Borehole No.	: 5	Borehole Diameter	: 7.6 cm
Testing Depth	: From 20 m to 25 m	Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation	: 18.06 m		
Ground Water Table	: GL - 2.20 m	Tested by	: Uus Kuswara
Date	: Jan 9, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	0.0	36.00	0.0605	0.31	7.20	3.0E-03
2	0.0	48.00	0.0806	0.31	9.60	4.0E-03
3	0.0	47.00	0.0790	0.31	9.40	4.0E-03
4	0.0	48.00	0.0806	0.31	9.60	4.0E-03
5	0.0	49.00	0.0823	0.31	9.80	4.1E-03
6						
7						
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

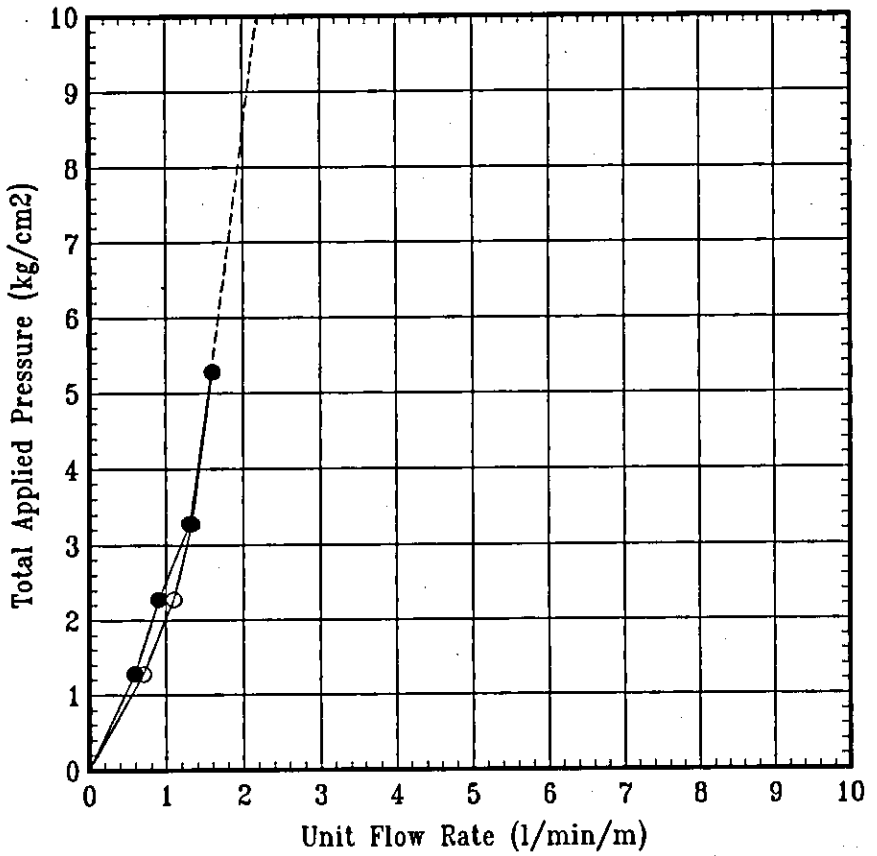
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 230

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 40 °
Location : Dam Site (Alternative A)			
Borehole No. : 5		Borehole Diameter	: 7.6 cm
Testing Depth : From 25 m to 30 m		Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation : 18.06 m			
Ground Water Table : GL - 1.78 m		Tested by	: Uus Kuswara
Date : Jan 10, '95		Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.95	0.0059	1.28	0.59	6.0E-05
2	2	4.50	0.0090	2.28	0.90	5.1E-05
3	3	6.50	0.0130	3.28	1.30	5.1E-05
4	5	8.00	0.0160	5.28	1.60	3.9E-05
5	3	6.65	0.0133	3.28	1.33	5.2E-05
6	2	5.50	0.0110	2.28	1.10	6.2E-05
7	1	3.50	0.0070	1.28	0.70	7.1E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

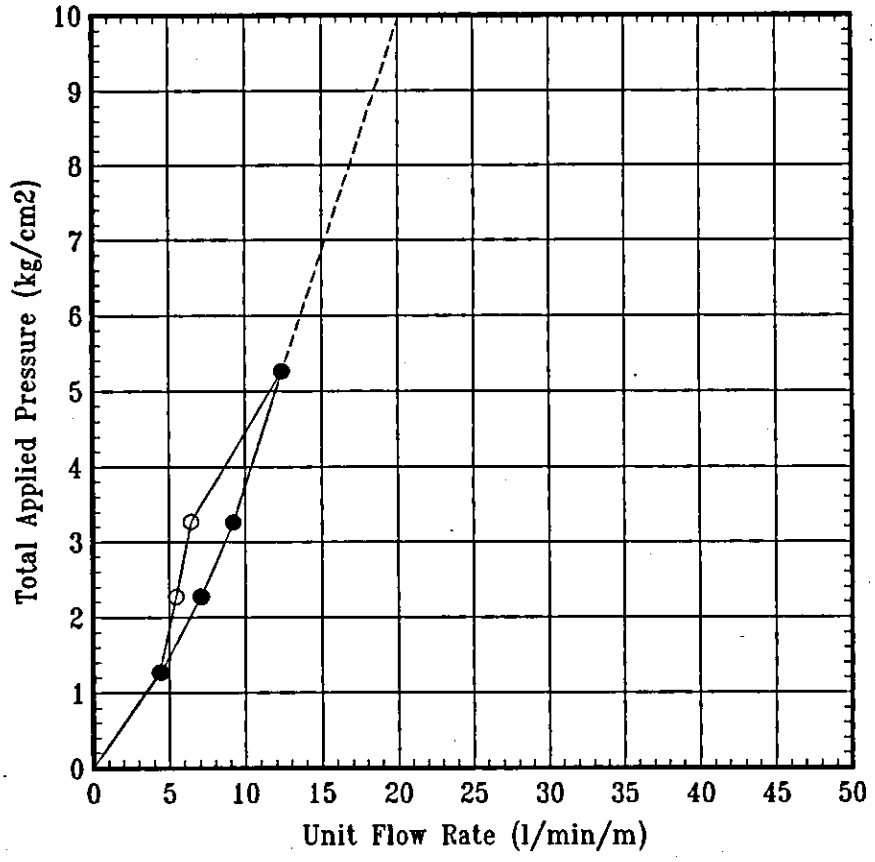
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.2

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical : 40 °	
Location : Dam Site (Alternative A)			
Borehole No. : 5		Borehole Diameter : 7.6 cm	
Testing Depth : From 30 m to 35 m		Distance of Pressure Gauge to the Ground : 1.45 m	
Ground Elevation : 18.06 m			
Ground Water Table : GL - 1.65 m		Tested by : Uus Kuswara	
Date : Jan 11, '95		Supervisor : Teddy	

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	22.30	0.0515	1.27	4.46	4.6E-04
2	2	35.50	0.0820	2.27	7.10	4.1E-04
3	3	46.10	0.1065	3.26	9.22	3.7E-04
4	5	62.10	0.1435	5.26	12.42	3.1E-04
5	3	32.30	0.0746	3.27	6.46	2.6E-04
6	2	27.20	0.0628	2.27	5.44	3.1E-04
7	1	21.75	0.0502	1.27	4.35	4.4E-04
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

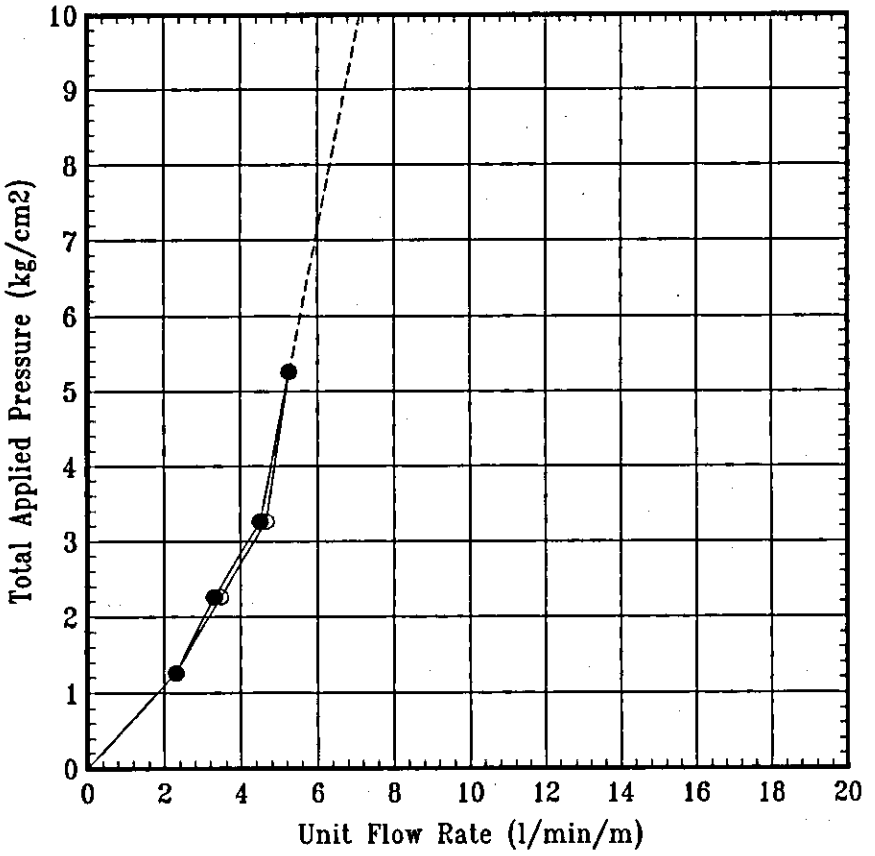
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 20

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 40 °
Location	: Dam Site (Alternative A)		
Borehole No.	: 5	Borehole Diameter	: 7.6 cm
Testing Depth	: From 35 m to 40 m	Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation	: 18.06 m		
Ground Water Table	: GL - 1.55 m	Tested by	: Uus Kuswara
Date	: Jan 12, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	11.45	0.0313	1.26	2.29	2.3E-04
2	2	16.45	0.0449	2.26	3.29	1.9E-04
3	3	22.50	0.0614	3.26	4.50	1.8E-04
4	5	26.30	0.0718	5.26	5.26	1.3E-04
5	3	23.25	0.0635	3.26	4.65	1.8E-04
6	2	17.30	0.0472	2.26	3.46	2.0E-04
7	1	11.45	0.0313	1.26	2.29	2.3E-04
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

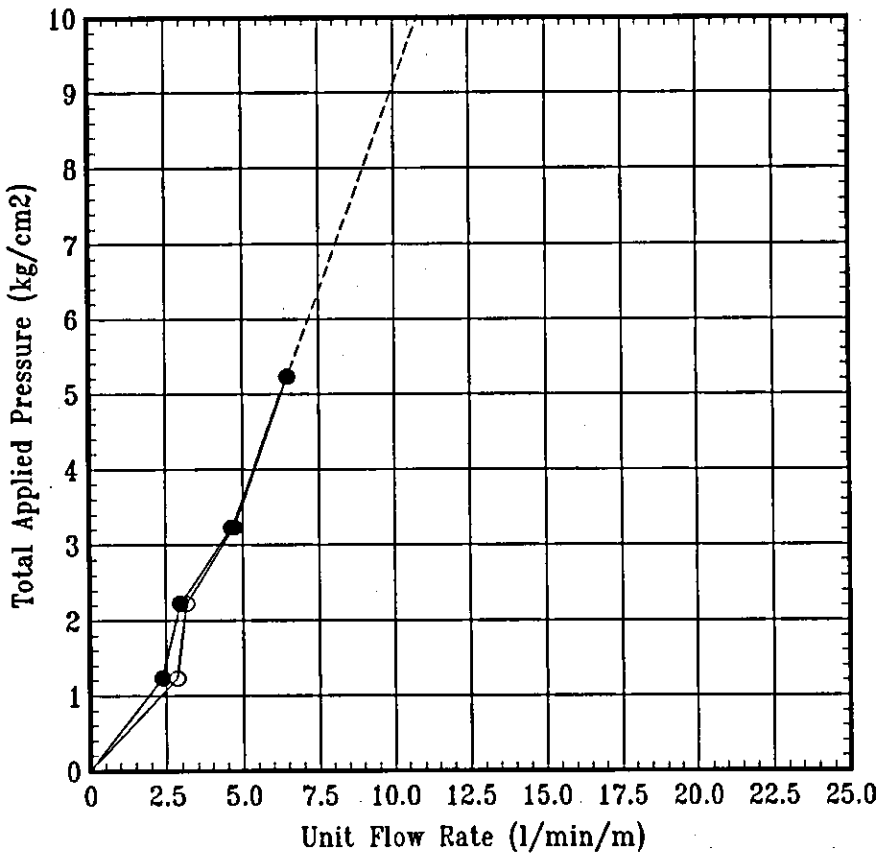
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 7.2

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 40 °
Location	: Dam Site (Alternative A)		
Borehole No.	: 5	Borehole Diameter	: 7.6 cm
Testing Depth	: From 40 m to 45 m	Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation	: 18.06 m	Tested by	: Uus Kuswara
Ground Water Table	: GL - 1.20 m	Supervisor	: Teddy
Date	: Jan 12, '95		

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	11.85	0.0361	1.23	2.37	2.5E-04
2	2	14.75	0.0449	2.23	2.95	1.7E-04
3	3	23.30	0.0709	3.23	4.66	1.9E-04
4	5	32.35	0.0985	5.23	6.47	1.6E-04
5	3	23.65	0.0720	3.23	4.73	1.9E-04
6	2	15.70	0.0478	2.23	3.14	1.8E-04
7	1	14.20	0.0432	1.23	2.84	3.0E-04
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

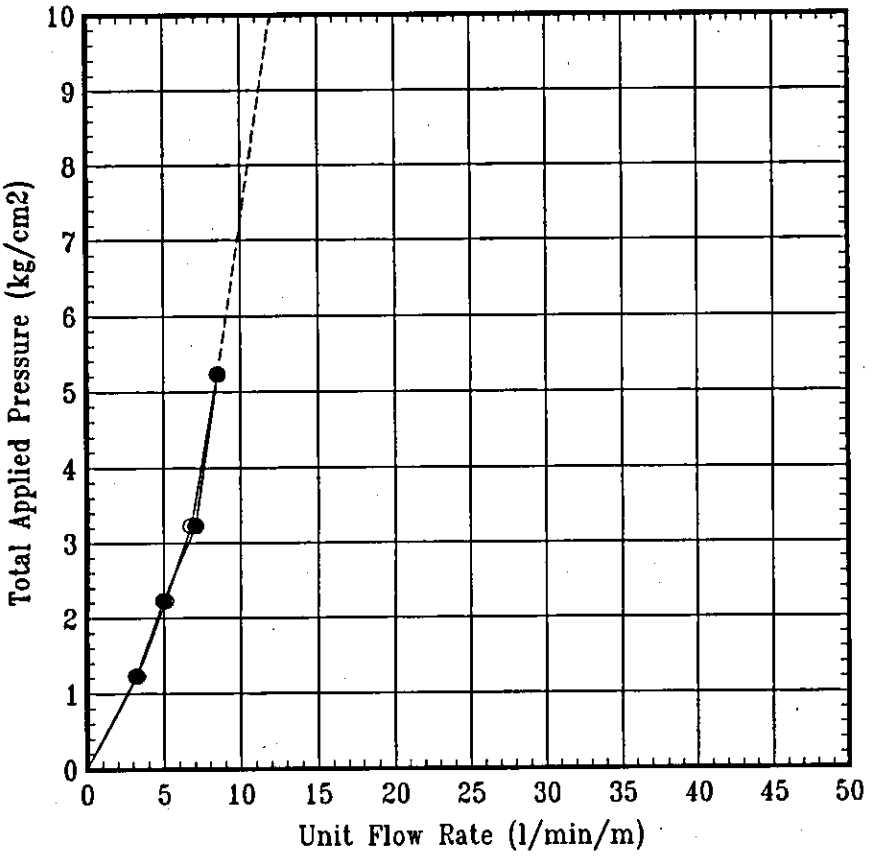
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 10.7

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 40 ^{o}
Location : Dam Site (Alternative A)		Borehole Diameter	: 7.6 cm
Borehole No. : 5		Distance of Pressure Gauge to the Ground	: 1.45 m
Testing Depth : From 45 m to 50 m		Tested by	: Uus Kuswara
Ground Elevation : 18.06 m		Supervisor	: Teddy
Ground Water Table : GL - 1.20 m			
Date : Jan 12, '95			

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	15.95	0.0536	1.23	3.19	3.3E-04
2	2	24.80	0.0833	2.23	4.96	2.9E-04
3	3	35.15	0.1181	3.23	7.03	2.8E-04
4	5	42.45	0.1426	5.23	8.49	2.1E-04
5	3	33.80	0.1136	3.23	6.76	2.7E-04
6	2	25.40	0.0853	2.23	5.08	2.9E-04
7	1	16.15	0.0543	1.23	3.23	3.4E-04
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

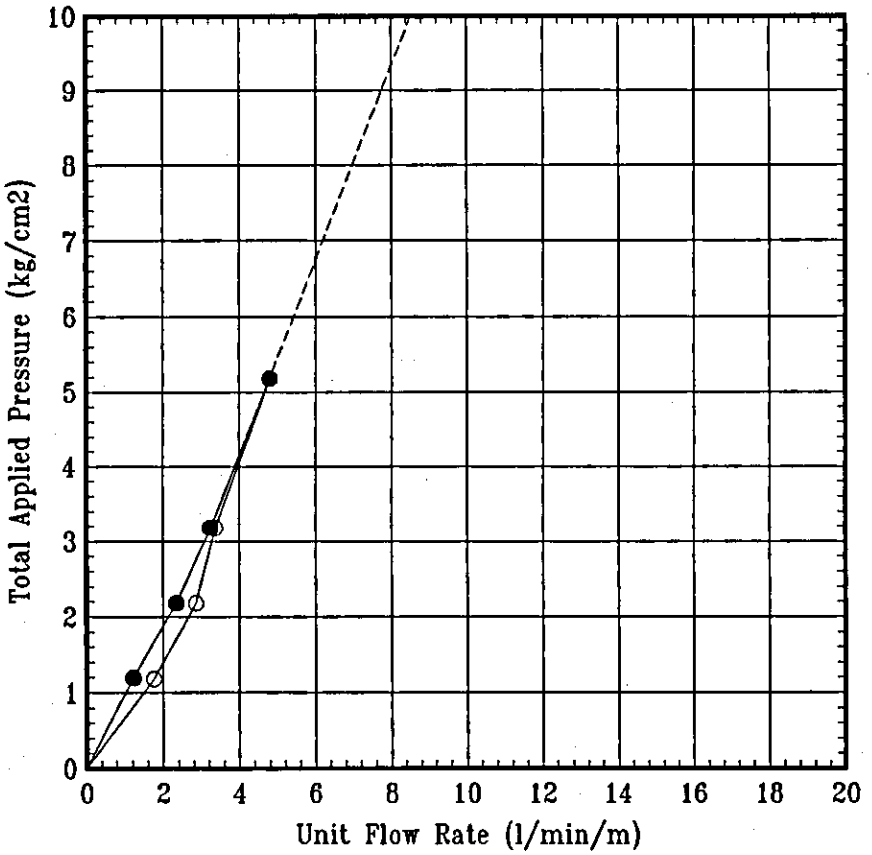
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 12

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 40 ^{o}
Location	: Dam Site (Alternative A)		
Borehole No.	: 5	Borehole Diameter	: 7.6 cm
Testing Depth	: From 50 m to 55 m	Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation	: 18.06 m		
Ground Water Table	: GL - 0.55 m	Tested by	: Uus Kuswara
Date	: Jan 13, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	6.10	0.0231	1.19	1.22	1.3E-04
2	2	11.65	0.0440	2.18	2.33	1.4E-04
3	3	16.15	0.0610	3.18	3.23	1.3E-04
4	5	24.00	0.0907	5.18	4.80	1.2E-04
5	3	16.80	0.0635	3.18	3.36	1.4E-04
6	2	14.30	0.0541	2.18	2.86	1.7E-04
7	1	8.75	0.0331	1.18	1.75	1.9E-04
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

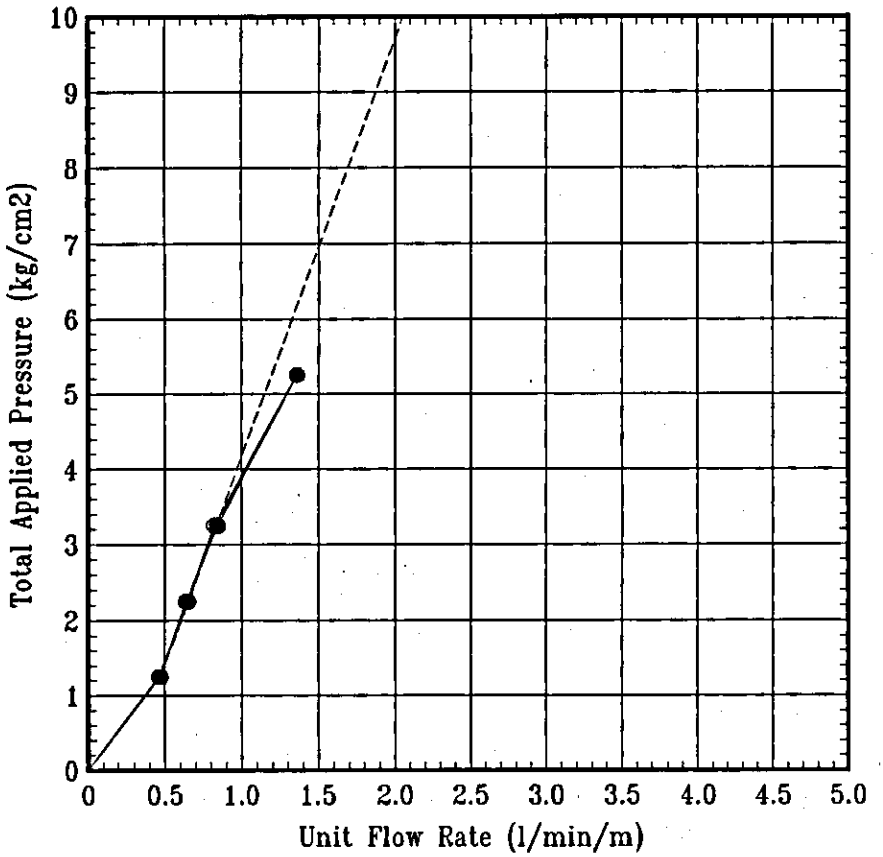
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 8.4

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical : 40 ^{o}	
Location : Dam Site (Alternative A)			
Borehole No. : 5		Borehole Diameter : 7.6 cm	
Testing Depth : From 55 m to 60 m		Distance of Pressure Gauge to the Ground : 1.45 m	
Ground Elevation : 18.06 m			
Ground Water Table : GL - 1.40 m		Tested by : Uus Kuswara	
Date : Jan 14, '95		Supervisor : Teddy	

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.35	0.0096	1.25	0.47	4.9E-05
2	2	3.20	0.0131	2.25	0.64	3.7E-05
3	3	4.20	0.0172	3.25	0.84	3.3E-05
4	5	6.80	0.0278	5.25	1.36	3.4E-05
5	3	4.10	0.0168	3.25	0.82	3.3E-05
6	2	3.25	0.0133	2.25	0.65	3.7E-05
7	1	2.30	0.0094	1.25	0.46	4.8E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

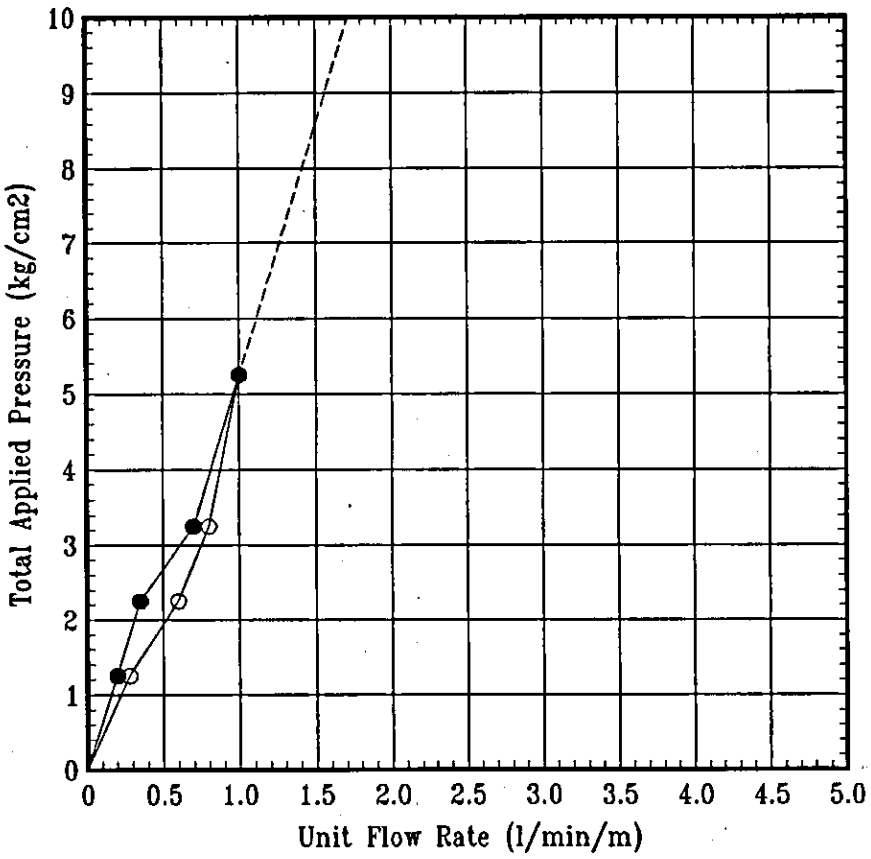
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.1

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 40 °
Location	: Dam Site (Alternative A)		
Borehole No.	: 5	Borehole Diameter	: 7.6 cm
Testing Depth	: From 60 m to 65 m	Distance of Pressure Gauge to the Ground	: 1.45 m
Ground Elevation	: 18.06 m		
Ground Water Table	: GL - 1.40 m	Tested by	: Uus Kuswara
Date	: Jan 14, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	1.00	0.0044	1.25	0.20	2.1E-05
2	2	1.75	0.0077	2.25	0.35	2.0E-05
3	3	3.50	0.0154	3.25	0.70	2.8E-05
4	5	5.00	0.0221	5.25	1.00	2.5E-05
5	3	4.00	0.0176	3.25	0.80	3.2E-05
6	2	3.00	0.0132	2.25	0.60	3.4E-05
7	1	1.40	0.0062	1.25	0.28	2.9E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

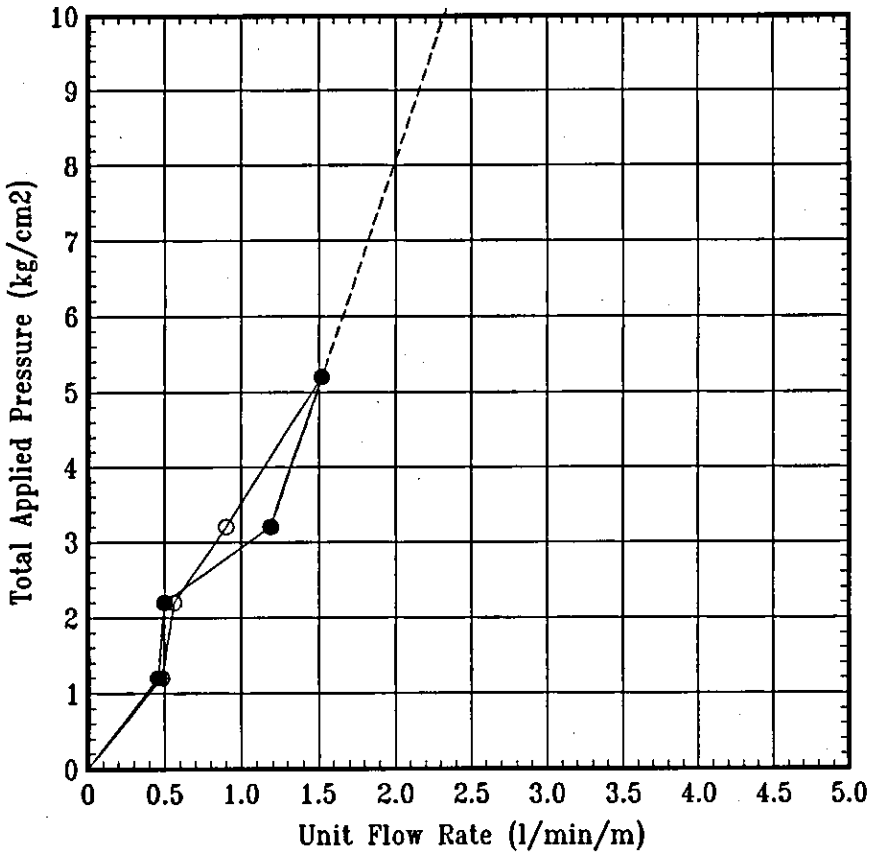
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 1.7

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical : 40 ^{o}	
Location : Dam Site (Alternative A)			
Borehole No. : 5		Borehole Diameter : 7.6 cm	
Testing Depth : From 65 m to 70 m		Distance of Pressure Gauge to the Ground : 1.2 m	
Ground Elevation : 18.06 m			
Ground Water Table : GL - 1.10 m		Tested by : Uus Kuswara	
Date : Jan 15, '95		Supervisor : Teddy	

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	2.30	0.0111	1.20	0.46	4.9E-05
2	2	2.50	0.0121	2.20	0.50	2.9E-05
3	3	5.95	0.0287	3.20	1.19	4.8E-05
4	5	7.60	0.0367	5.20	1.52	3.8E-05
5	3	4.50	0.0217	3.20	0.90	3.6E-05
6	2	2.80	0.0135	2.20	0.56	3.3E-05
7	1	2.40	0.0116	1.20	0.48	5.2E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

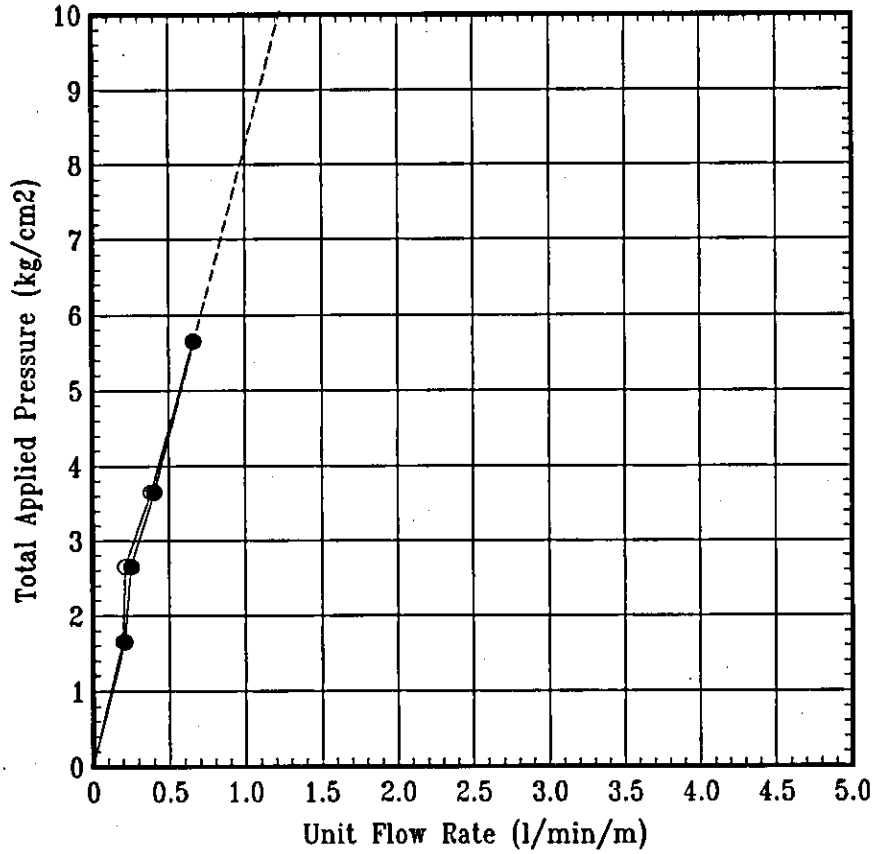
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.3

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 0 °
Location : Dam Site (Alternative A)			
Borehole No.	: 6	Borehole Diameter	: 7.6 cm
Testing Depth	: From 5 m to 10 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 35.78 m		
Ground Water Table	: GL - 5.00 m	Tested by	: Uli Sadeli
Date : Jan 10, '95		Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	1.05	0.0007	1.65	0.21	1.6E-05
2	2	1.27	0.0008	2.65	0.25	1.2E-05
3	3	2.02	0.0013	3.65	0.40	1.4E-05
4	5	3.30	0.0021	5.65	0.66	1.5E-05
5	3	1.92	0.0012	3.65	0.38	1.4E-05
6	2	1.07	0.0007	2.65	0.21	1.0E-05
7	1	0.99	0.0006	1.65	0.20	1.6E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

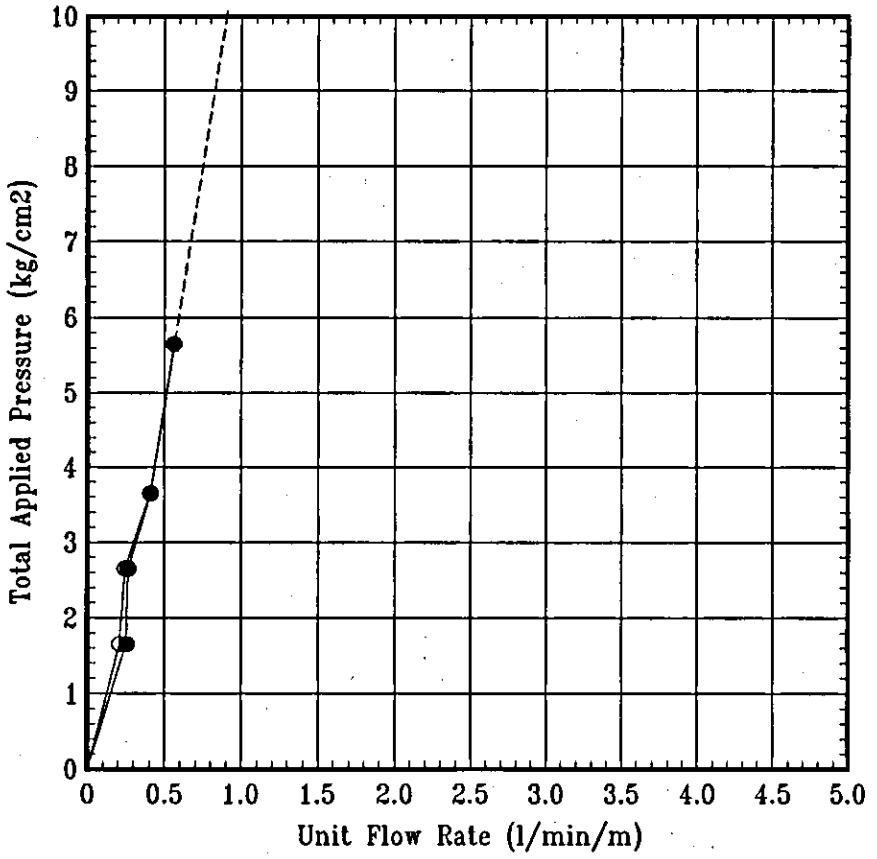
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 1.2

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 0 ^{o}
Location	: Dam Site (Alternative A)		
Borehole No.	: 6	Borehole Diameter	: 7.6 cm
Testing Depth	: From 10 m to 15 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 35.78 m		
Ground Water Table	: GL - 5.00 m	Tested by	: Uli Sadeli
Date	: Jan 10, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	1.28	0.0012	1.65	0.26	2.0E-05
2	2	1.33	0.0013	2.65	0.27	1.3E-05
3	3	2.06	0.0019	3.65	0.41	1.5E-05
4	5	2.80	0.0026	5.65	0.56	1.3E-05
5	3	2.06	0.0019	3.65	0.41	1.5E-05
6	2	1.22	0.0012	2.65	0.24	1.2E-05
7	1	1.04	0.0098	1.65	0.21	1.6E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

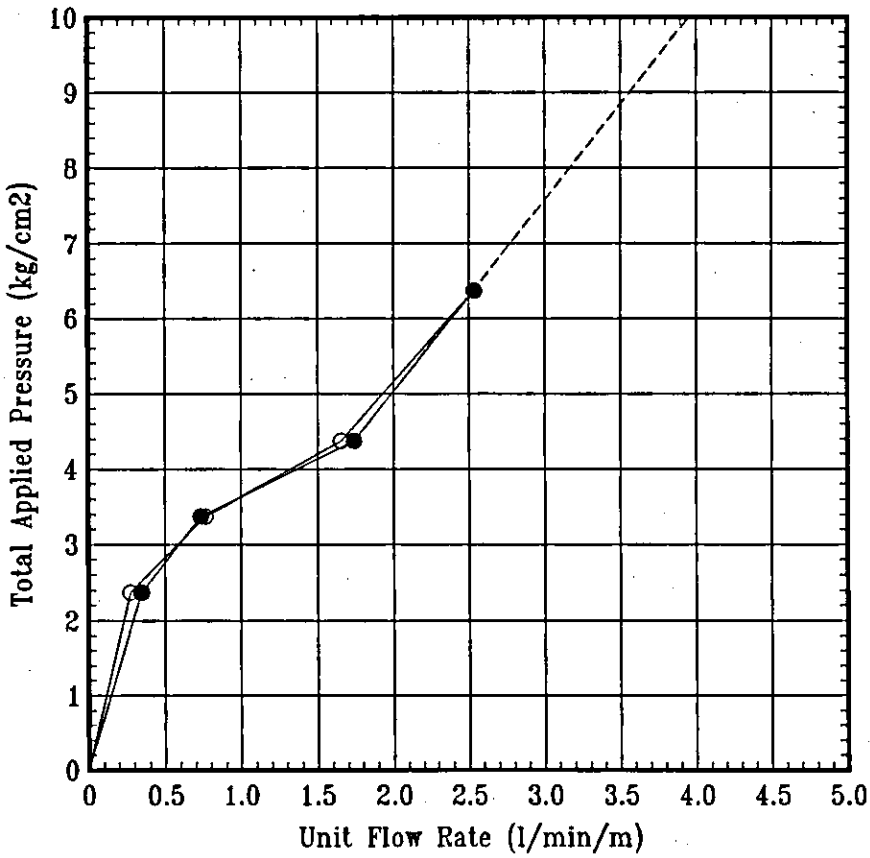
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 0.9

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 0 °
Location	: Dam Site (Alternative A)		
Borehole No.	: 6	Borehole Diameter	: 7.6 cm
Testing Depth	: From 15 m to 20 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 35.78 m		
Ground Water Table	: GL - 12.20 m	Tested by	: Uli Sadeli
Date	: Jan 11, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	1.73	0.0012	2.37	0.35	1.9E-05
2	2	3.67	0.0013	3.37	0.73	2.8E-05
3	3	8.70	0.0019	4.37	1.74	5.2E-05
4	5	12.67	0.0026	6.37	2.53	5.1E-05
5	3	8.27	0.0019	4.37	1.65	4.9E-05
6	2	3.83	0.0012	3.37	0.77	2.9E-05
7	1	1.37	0.0098	2.37	0.27	1.5E-05
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

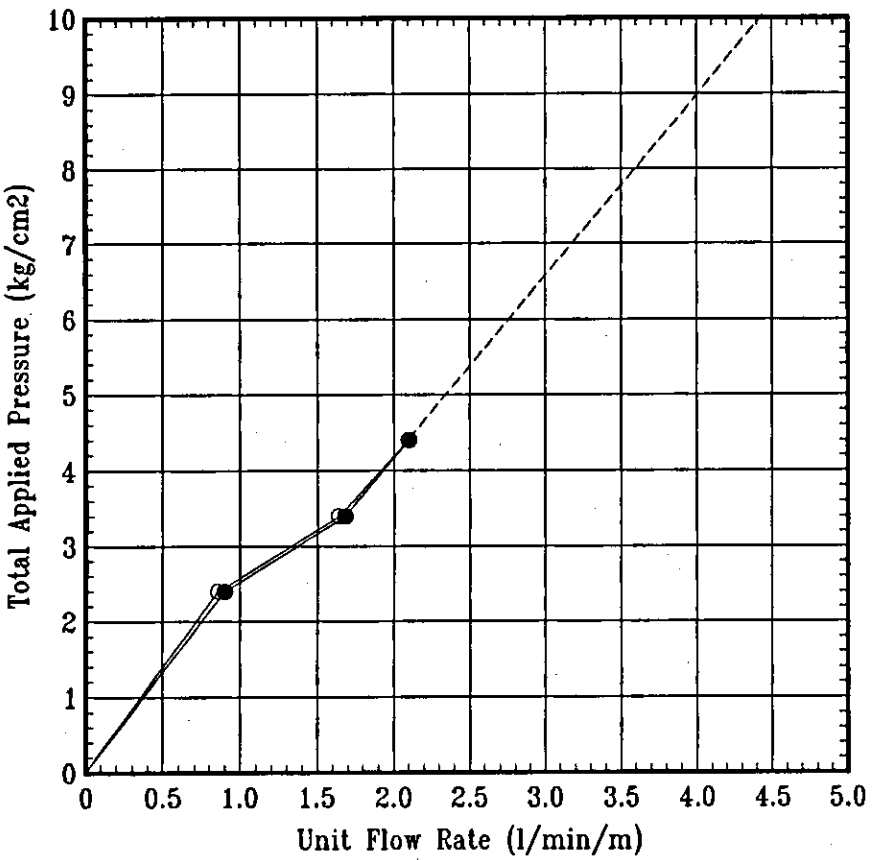
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value =	3.9

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 0 °
Location : Dam Site (Alternative A)			
Borehole No. : 8		Borehole Diameter	: 7.6 cm
Testing Depth : From 10 m to 15 m		Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation : 59.91 m			
Ground Water Table : GL - 12.50 m		Tested by	: Asep D.
Date : Jan 1, '95		Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	4.50	0.0043	2.40	0.90	4.9E-05
2	2	8.40	0.0079	3.40	1.68	6.4E-05
3	3	10.50	0.0099	4.40	2.10	6.2E-05
4	2	8.20	0.0077	3.40	1.64	6.2E-05
5	1	4.30	0.0041	2.40	0.86	4.6E-05
6						
7						
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

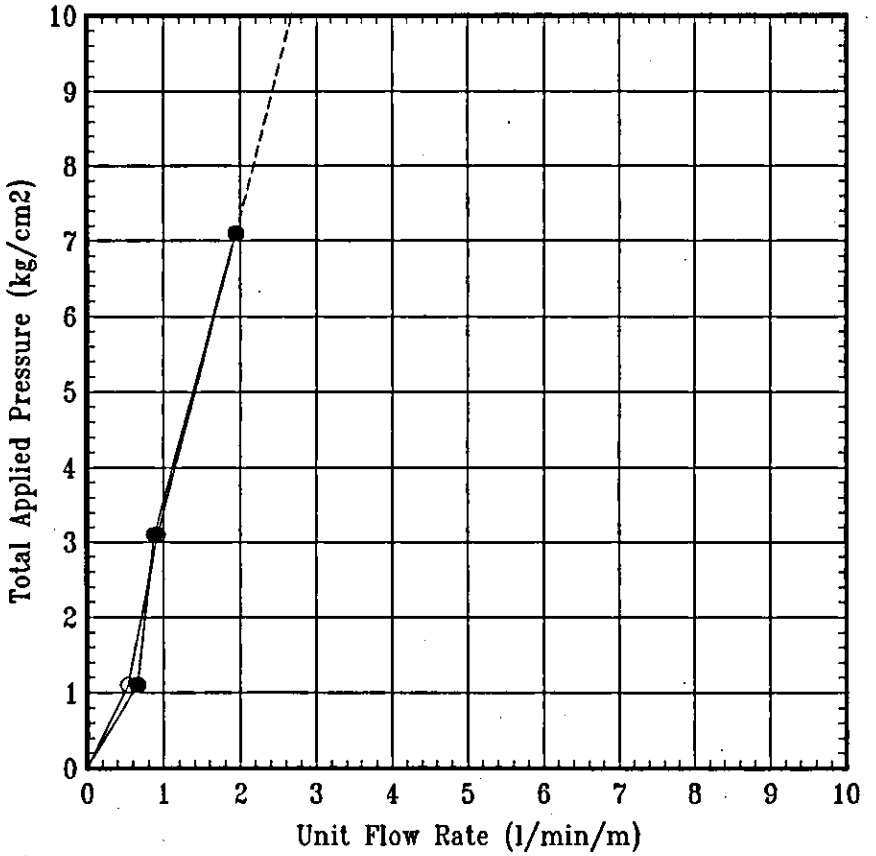
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 4.4

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 0 °
Location : Power House			
Borehole No.	: 10	Borehole Diameter	: 7.6 cm
Testing Depth	: From 5 m to 10 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 4.22 m		
Ground Water Table	: GL + 0.50 m	Tested by	: Asep D.
Date	: Dec 12, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	3.30	0.0021	1.10	0.66	7.8E-05
2	3	4.40	0.0028	3.10	0.88	3.7E-05
3	7	9.70	0.0061	7.10	1.94	3.5E-05
4	3	4.60	0.0029	3.10	0.92	3.8E-05
5	1	2.70	0.0017	1.10	0.54	6.4E-05
6						
7						
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

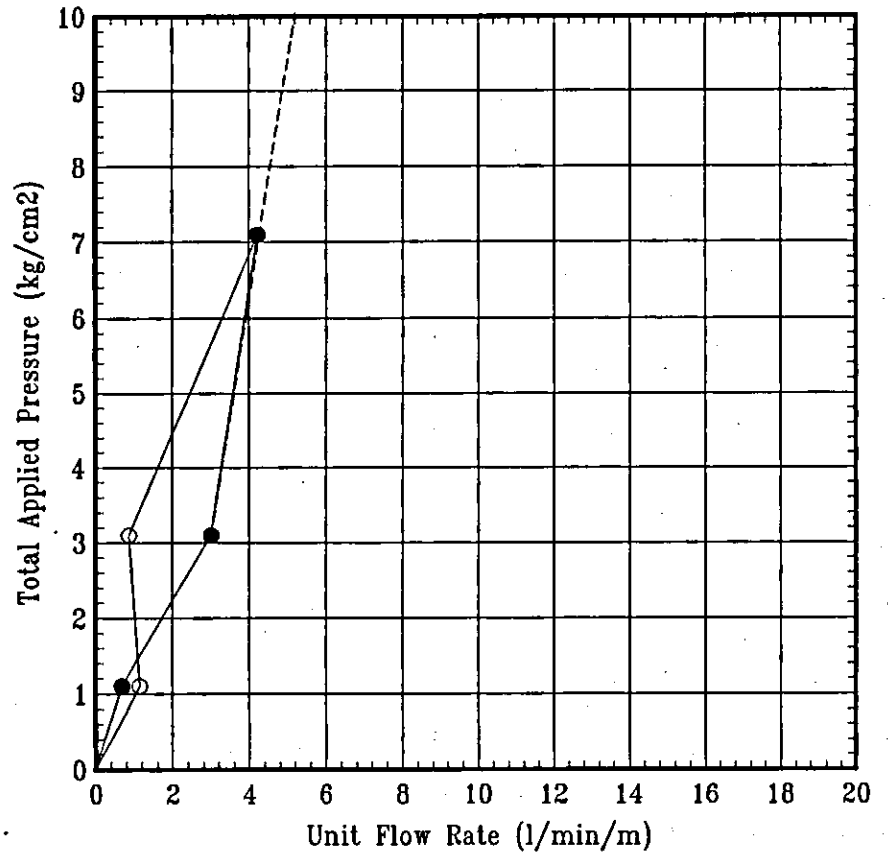
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.6

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 0 °
Location	: Power House		
Borehole No.	: 10	Borehole Diameter	: 7.6 cm
Testing Depth	: From 10 m to 15 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 4.22 m		
Ground Water Table	: GL + 0.50 m	Tested by	: Asep D.
Date	: Dec 13, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	3.40	0.0032	1.10	0.68	8.0E-05
2	3	15.00	0.0142	3.10	3.00	1.3E-04
3	7	21.10	0.0199	7.10	4.22	7.7E-05
4	3	4.34	0.0041	3.10	0.87	3.6E-05
5	1	5.72	0.0054	1.10	1.14	1.3E-04
6						
7						
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

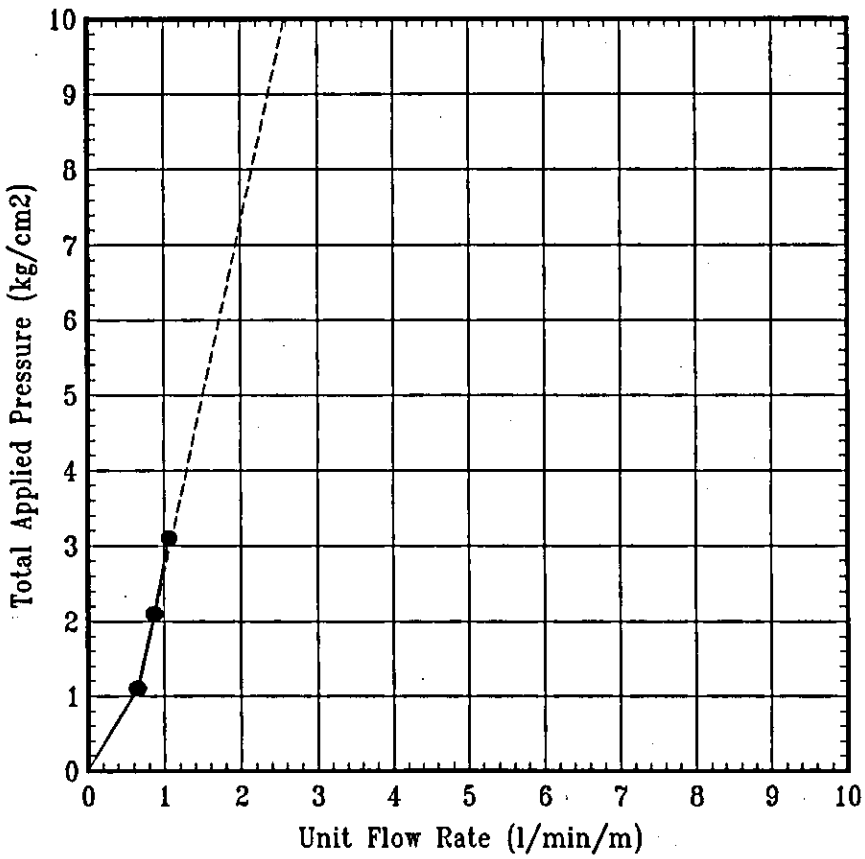
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value =	5.2

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 0 °
Location	: Power House		
Borehole No.	: 10	Borehole Diameter	: 7.6 cm
Testing Depth	: From 15 m to 20 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 4.22 m		
Ground Water Table	: GL + 0.50 m	Tested by	: Asep D.
Date	: Dec 15, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	3.20	0.0040	1.10	0.64	7.5E-05
2	2	4.30	0.0054	2.10	0.86	5.3E-05
3	3	5.30	0.0067	3.10	1.06	4.4E-05
4	2	4.40	0.0055	2.10	0.88	5.4E-05
5	1	3.30	0.0042	1.10	0.66	7.8E-05
6						
7						
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

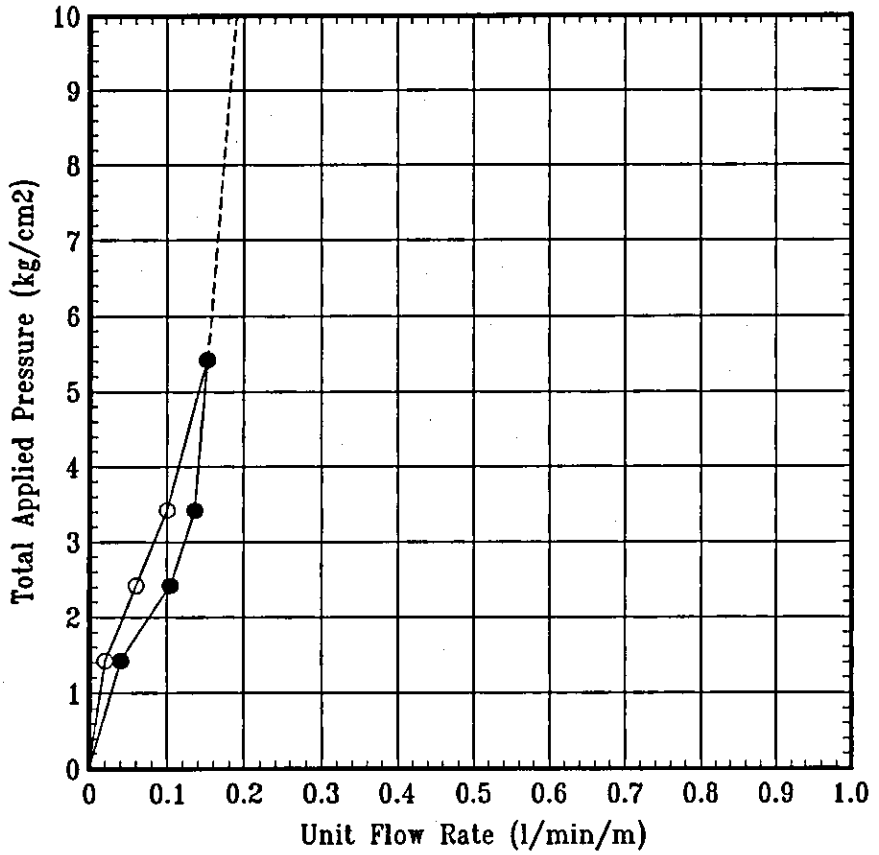
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 2.6

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 0 °
Location : Saddle Dam			
Borehole No.	: 12	Borehole Diameter	: 7.6 cm
Testing Depth	: From 5 m to 10 m	Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation	: 48.78 m		
Ground Water Table	: GL - 3.00 m	Tested by	: Kosasih
Date	: Jan 3, '95	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	0.20	0.0001	1.42	0.04	3.6E-06
2	2	0.52	0.0003	2.42	0.10	5.6E-06
3	3	0.68	0.0004	3.42	0.14	5.1E-06
4	5	0.76	0.0005	5.42	0.15	3.6E-06
5	3	0.50	0.0003	3.42	0.10	3.8E-06
6	2	0.30	0.0002	2.42	0.06	3.2E-06
7	1	0.10	0.0001	1.42	0.02	1.8E-06
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

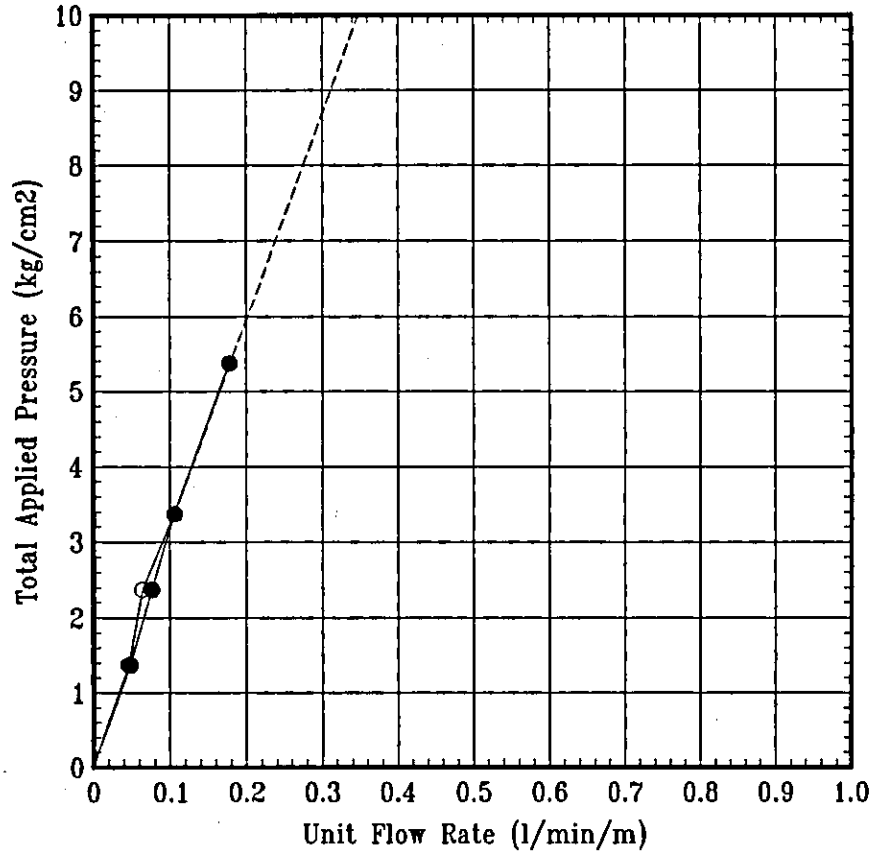
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 0.2

LUGEON TEST

Project : Warsamson HEPP Feasibility Study		Borehole Axis to Vertical	: 0 °
Location : Saddle Dam			
Borehole No.	: 12	Borehole Diameter	: 7.6 cm
Testing Depth	: From 10 m to 15 m	Distance of Pressure Gauge to the Ground	: 1.25 m
Ground Elevation	: 48.78 m		
Ground Water Table	: GL - 2.50 m	Tested by	: Kosasih
Date : Jan 4, '95		Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	0.24	0.0002	1.37	0.05	4.5E-06
2	2	0.38	0.0004	2.37	0.08	4.1E-06
3	3	0.53	0.0005	3.37	0.11	4.1E-06
4	5	0.89	0.0008	5.37	0.18	4.3E-06
5	3	0.53	0.0005	3.37	0.11	4.1E-06
6	2	0.32	0.0003	2.37	0.06	3.5E-06
7	1	0.23	0.0002	1.37	0.05	4.3E-06
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

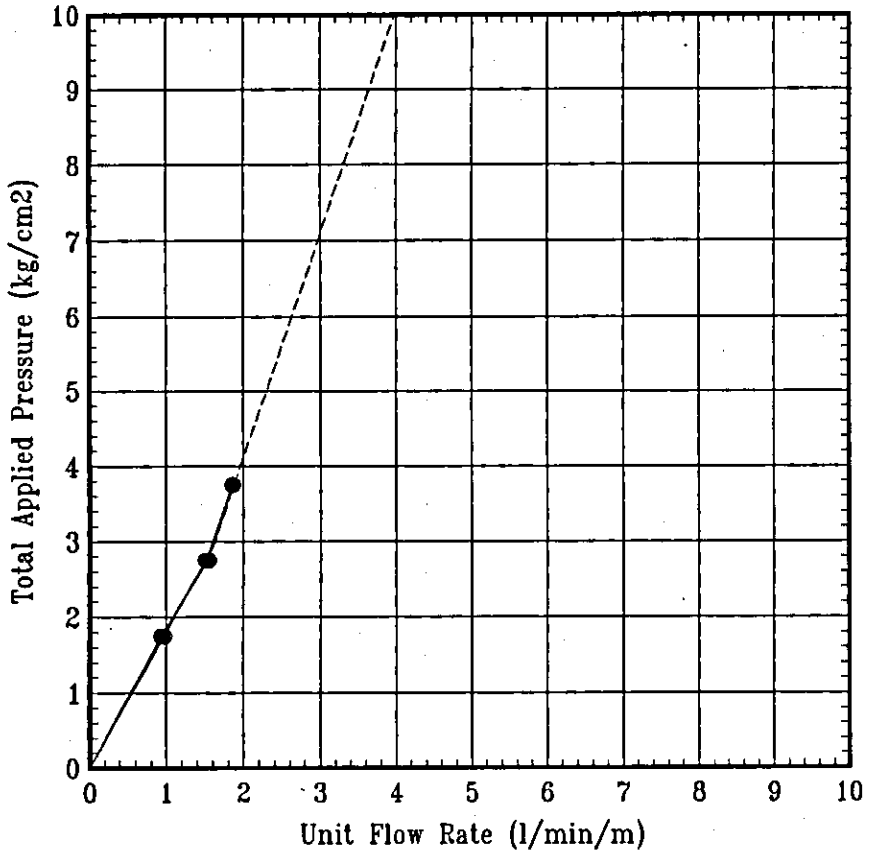
k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value = 0.35

LUGEON TEST

Project	: Warsamson HEPP Feasibility Study	Borehole Axis to Vertical	: 0 °
Location	: Surge Tank / Penstock		
Borehole No.	: 13	Borehole Diameter	: 7.6 cm
Testing Depth	: From 16.5 m to 20 m	Distance of Pressure Gauge to the Ground	: 1.5 m
Ground Elevation	: 70.00 m		
Ground Water Table	: GL - 6.00 m	Tested by	: Asep D.
Date	: Dec 27, '94	Supervisor	: Teddy

No.	Gauge Reading (kg/cm2)	Measured Flow Rate (l/min)	Head Loss Correction (m)	Total Applied Pressure (kg/cm2)	Unit Flow Rate (l/min/m)	Permeability k (cm/sec)
1	1	3.30	0.0045	1.75	0.94	6.5E-05
2	2	5.40	0.0074	2.75	1.54	6.7E-05
3	3	6.50	0.0089	3.75	1.86	5.9E-05
4	2	5.30	0.0072	2.75	1.51	6.6E-05
5	1	3.40	0.0046	1.75	0.97	6.7E-05
6						
7						
8						



$$k = \frac{Q}{2\pi HL} \ln \frac{L}{r}$$

k = Permeability
Q = Flow rate
H = Total pressure head
L = Length of test section
r = Radius of test section

Lugeon value =	4.0

Constant Head Test

RESULTS OF CONSTANT HEAD PERMEABILITY TESTS (PAGE 1/4)

BOREHOLE NO	TEST DEPTH (m) (Section of open hole) FROM – TO	GROUNDWATER LEVEL (m)	CASING RADIUS (cm)	CASING ABOVE GROUND (m)	READING TIME (min)	READING VOLUME (litre)	WATER HEAD H (cm)	PERMEABILITY k (cm/sec)	PERMEABILITY AVERAGE k (cm/sec)
BH–8	9.0 – 10.0	8.00	4.45	1.00	1.0	10.20	900	9.36E–04	9.29E–04
					2.0	20.00	900	9.17E–04	
					3.0	29.60	900	9.05E–04	
					4.0	40.90	900	9.38E–04	
					5.0	51.20	900	9.39E–04	
					6.0	61.50	900	9.40E–04	
					7.0	70.80	900	9.28E–04	

RESULTS OF CONSTANT HEAD PERMEABILITY TESTS (PAGE 2/4)

BOREHOLE NO	TEST DEPTH (m) (Section of open hole) FROM	–	TO	GROUNDWATER LEVEL (m)	CASING RADIUS (cm)	CASING ABOVE GROUND (m)	READING TIME (min)	READING VOLUME (litre)	WATER HEAD H (cm)	PERMEABILITY k (cm/sec)	PERMEABILITY AVERAGE k (cm/sec)
BH–11	9.5	–	10.0	4.75	4.45	1.25	1.0	9.80	600	2.10E–03	2.20E–03
							1.0	10.60	600	2.27E–03	
							1.0	10.40	600	2.22E–03	
							1.0	10.60	600	2.27E–03	
							1.0	10.10	600	2.16E–03	
	14.5	–	15.0	5.25	4.45	0.30	1.0	3.20	555	7.40E–04	7.85E–04
							2.0	6.30	555	7.28E–04	
							3.0	9.70	555	7.48E–04	
							4.0	14.10	555	8.15E–04	
							5.0	17.80	555	8.23E–04	
							7.0	24.25	555	8.01E–04	
							10.0	36.35	555	8.41E–04	
	19.5	–	20.0	5.30	4.45	0.40	1.0	2.30	570	5.18E–04	5.25E–04
							2.0	4.40	570	4.95E–04	
							3.0	7.20	570	5.40E–04	
							4.0	9.40	570	5.29E–04	
							5.0	12.10	570	5.45E–04	
							7.0	16.60	570	5.34E–04	
							10.0	22.90	570	5.16E–04	
	20.0	–	25.0	5.40	4.45	0.50	1.0	3.10	590	1.32E–04	1.30E–04
							2.0	6.00	590	1.27E–04	
							3.0	9.20	590	1.30E–04	
							4.0	12.40	590	1.32E–04	
							5.0	15.40	590	1.31E–04	
							7.0	21.20	590	1.29E–04	
							10.0	29.90	590	1.27E–04	
	30.0	–	35.0	5.40	4.45	0.70	32.0	2.00	610	2.57E–06	2.57E–06
							31.8	2.00	610	2.58E–06	
	30.0	–	40.0	5.40	4.45	0.70	34.4	2.00	610	1.37E–06	1.36E–06
							34.8	2.00	610	1.35E–06	

RESULTS OF CONSTANT HEAD PERMEABILITY TESTS (PAGE 3/4)

BOREHOLE NO	TEST DEPTH (m) (Section of open hole) FROM – TO	GROUNDWATER LEVEL (m)	CASING RADIUS (cm)	CASING ABOVE GROUND (m)	READING TIME (min)	READING VOLUME (litre)	WATER HEAD H (cm)	PERMEABILITY k (cm/sec)	PERMEABILITY AVERAGE k (cm/sec)
BH–12	15.0 – 20.0	1.25	4.45	0.30	41.4	2.00	155	7.80E–06	7.84E–06
					41.0	2.00	155	7.88E–06	
	15.0 – 25.0	2.36	4.45	0.30	49.0	2.00	266	2.20E–06	2.16E–06
					51.1	2.00	266	2.12E–06	
	15.0 – 30.0	2.36	4.45	0.30	44.0	2.00	266	1.76E–06	1.75E–06
					44.5	2.00	266	1.74E–06	

RESULTS OF CONSTANT HEAD PERMEABILITY TESTS (PAGE 4/4)

BOREHOLE NO	TEST DEPTH (m) (Section of open hole) FROM	–	TO	GROUNDWATER LEVEL (m)	CASING RADIUS (cm)	CASING ABOVE GROUND (m)	READING TIME (min)	READING VOLUME (litre)	WATER HEAD H (cm)	PERMEABILITY k (cm/sec)	PERMEABILITY AVERAGE k (cm/sec)
BH–13	9.5	–	10.0	3.00	4.45	0.60	1.0	1.20	360	4.28E–04	4.22E–04
							1.0	1.20	360	4.28E–04	
							1.0	1.20	360	4.28E–04	
							1.0	1.10	360	3.92E–04	
							1.0	1.20	360	4.28E–04	
							1.0	1.20	360	4.28E–04	
	14.5	–	15.0	3.00	4.45	0.50	1.0	2.00	350	7.33E–04	8.86E–04
							2.0	3.20	350	5.87E–04	
							3.0	6.20	350	7.58E–04	
							4.0	12.10	350	1.11E–03	
							5.0	14.10	350	1.03E–03	
							6.0	16.10	350	9.84E–04	
							7.0	18.20	350	9.53E–04	
							8.0	20.10	350	9.21E–04	
							9.0	22.10	350	9.00E–04	
							10.0	24.10	350	8.84E–04	

Falling Head Test

RESULTS OF FALLING HEAD PERMEABILITY TESTS (PAGE 1/4)

BOREHOLE NO	TEST DEPTH (m) (Section of open hole) FROM	–	TO	GROUNDWATER LEVEL (m)	CASING RADIUS (cm)	CASING ABOVE GROUND (m)	READING TIME (min)	READING DRAWDOWN (cm)	WATER HEAD H1 (cm)	WATER HEAD H2 (cm)	PERMEABILITY k (cm/sec)	PERMEABILITY AVERAGE k (cm/sec)
BH–8	4.5	–	5.0	4.00	4.45	0.50	1	3.20	450	446.80	5.70E–05	5.23E–05
							2	6.90	450	443.10	6.17E–05	
							3	9.90	450	440.10	5.92E–05	
							4	10.10	450	439.90	4.53E–05	
							5	13.30	450	436.70	4.79E–05	
							6	16.60	450	433.40	5.00E–05	
							7	19.30	450	430.70	5.00E–05	
							8	22.60	450	427.40	5.14E–05	
							9	25.90	450	424.10	5.26E–05	
							10	26.20	450	423.80	4.79E–05	

RESULTS OF FALLING HEAD PERMEABILITY TESTS (PAGE 2/4)

BOREHOLE NO	TEST DEPTH (m) (Section of open hole) FROM – TO	GROUNDWATER LEVEL (m)	CASING RADIUS (cm)	CASING ABOVE GROUND (m)	READING TIME (min)	READING DRAWDOWN (cm)	WATER HEAD H1 (cm)	WATER HEAD H2 (cm)	PERMEABILITY k (cm/sec)	PERMEABILITY AVERAGE k (cm/sec)
BH-11	3.5 – 4.0	3.20	4.45	1.00	1	9.00	420	411.00	1.73E-04	1.51E-04
					2	19.00	420	401.00	1.85E-04	
					3	22.00	420	398.00	1.43E-04	
					5	35.00	420	385.00	1.39E-04	
					7	45.00	420	375.00	1.29E-04	
					10	66.00	420	354.00	1.36E-04	
	30.0 – 30.0	5.40	4.45	0.70	1	4.00	610	606.00	2.79E-04	2.42E-04
					2	7.10	610	602.90	2.48E-04	
					3	9.70	610	600.30	2.26E-04	
					4	13.20	610	596.80	2.32E-04	
					5	17.00	610	593.00	2.39E-04	
					7	23.60	610	586.40	2.39E-04	
					10	32.40	610	577.60	2.31E-04	

RESULTS OF FALLING HEAD PERMEABILITY TESTS (PAGE 3/4)

BOREHOLE NO	TEST DEPTH (m) (Section of open hole) FROM	–	TO	GROUNDWATER LEVEL (m)	CASING RADIUS (cm)	CASING ABOVE GROUND (m)	READING TIME (min)	READING DRAWDOWN (cm)	WATER HEAD H1 (cm)	WATER HEAD H2 (cm)	PERMEABILITY k (cm/sec)	PERMEABILITY AVERAGE k (cm/sec)
BH–13	4.5	–	5.0	2.20	4.45	0.20	1	3.50	240	236.50	1.17E–04	8.94E–05
							2	6.50	240	233.50	1.10E–04	
							3	9.50	240	230.50	1.07E–04	
							5	12.00	240	228.00	8.19E–05	
							6	13.00	240	227.00	7.41E–05	
							7	14.50	240	225.50	7.11E–05	
							10	18.50	240	221.50	6.40E–05	

RESULTS OF FALLING HEAD PERMEABILITY TESTS (PAGE 4/4)

BOREHOLE NO	TEST DEPTH (m) (Section of open hole) FROM – TO	GROUNDWATER LEVEL (m)	CASING RADIUS (cm)	CASING ABOVE GROUND (m)	READING TIME (min)	READING DRAWDOWN (cm)	WATER HEAD H1 (cm)	WATER HEAD H2 (cm)	PERMEABILITY k (cm/sec)	PERMEABILITY AVERAGE k (cm/sec)
BH–14	5.0 – 5.0	4.00	4.45	1.00	1	2.50	500	497.50	2.12E–04	1.95E–04
					2	5.00	500	495.00	2.13E–04	
					3	7.00	500	493.00	1.99E–04	
					4	9.50	500	490.50	2.03E–04	
					5	11.00	500	489.00	1.88E–04	
					6	13.50	500	486.50	1.93E–04	
					7	15.50	500	484.50	1.91E–04	
					8	17.00	500	483.00	1.83E–04	
					9	19.00	500	481.00	1.82E–04	
					10	21.00	500	479.00	1.82E–04	
	10.0 – 10.0	2.70	4.45	0.50	20	0.15	320	319.85	9.93E–07	9.93E–07
	15.0 – 15.0	10.00	4.45	0.20	1	0.50	1,020	1,019.50	2.08E–05	2.08E–05
					2	1.00	1,020	1,019.00	2.08E–05	
					3	1.50	1,020	1,018.50	2.08E–05	
					4	2.00	1,020	1,018.00	2.08E–05	
					5	2.50	1,020	1,017.50	2.08E–05	
					6	3.00	1,020	1,017.00	2.08E–05	
					7	3.50	1,020	1,016.50	2.08E–05	
					8	4.00	1,020	1,016.00	2.08E–05	
					9	4.50	1,020	1,015.50	2.08E–05	
					10	5.00	1,020	1,015.00	2.08E–05	
	20.0 – 20.0	10.00	4.45	1.00	1	0.50	1,100	1,099.50	1.93E–05	2.67E–05
					2	2.00	1,100	1,098.00	3.85E–05	
					3	2.50	1,100	1,097.50	3.21E–05	
					4	3.00	1,100	1,097.00	2.89E–05	
					5	3.50	1,100	1,096.50	2.70E–05	
					6	4.00	1,100	1,096.00	2.57E–05	
					7	4.50	1,100	1,095.50	2.48E–05	
					8	5.00	1,100	1,095.00	2.41E–05	
					9	5.50	1,100	1,094.50	2.36E–05	
					10	6.00	1,100	1,094.00	2.32E–05	
	25.0 – 25.0	1.70	4.45	0.30	1	4.00	200	196.00	8.56E–04	6.83E–04
					2	7.00	200	193.00	7.55E–04	
					3	10.00	200	190.00	7.24E–04	
					4	13.00	200	187.00	7.12E–04	
					5	16.00	200	184.00	7.06E–04	
					6	19.00	200	181.00	7.05E–04	
					7	20.10	200	179.90	6.41E–04	
					8	22.00	200	178.00	6.17E–04	
					9	23.00	200	177.00	5.75E–04	
					10	24.00	200	176.00	5.42E–04	

APPENDIX C.2

Field Density Test

FIELD DENSITY TEST - SAND CONE METHOD

PROJECT : WARSAMSON HEPP
LOCATION : SORONG, IRIAN JAYA
DATE,MO.,YR : JANUARY 1995

TESTED BY : SUDARSONO
SUPERVISED BY : IR. TEDDY

No.	ITEM	BH-11	BH-12	BH-13	BH-14	BH-14A
1	Weight of sand + Jar (gr)	7675	7680	7617	7885	7775
2	Weight residue + Jar (gr)	4560	4585	4537	4671	4651
3	Weight sand used (1) - (2) (gr)	3115	3095	3080	3214	3124
4	Weight sand in Cone & Plate(gr)	1475	1475	1475	1475	1475
5	Weight sand in Hole (3) - (4) (gr)	1640	1620	1605	1739	1649
6	Density of sand (gr/cm3)	1.54	1.54	1.54	1.54	1.54
7	Weight of Soil (gr)	1685	1610	1647	1795	1735
8	Volume of Hole (5)/(6) (cm3)	1064.94	1051.95	1042.21	1129.22	1070.78
9	Wet density (7)/(8) (gr/cm3)	1.58	1.53	1.58	1.59	1.62
10	Moisture Content, (%)	15.35	16.97	14.18	16.31	17.48
11	Dry density ((9)/(1+(10)) (gr)	1.37	1.31	1.38	1.37	1.38