2.4 Foundation of diversion weir site

The contemplated diversion weir site is located about 200 m downstream from the damsite. The axes of the weir are across the Amban Ganga and the western channel of the sub-dam No.1.

The bed rock is gneiss with garnet and foundation conditions are very similar to those in the damsite. Acceptable firm rock of the slightly weathered zone (2.0 - 2.2 km/sec. in P-wave velocity) is reached at 10 to 20 m of depth, through the intensively and moderately weathered zones overlying it. Unconsolidated residual soil covering the slopes is only 1 or 2 m thick. The bottoms of both the Amban Ganga and the western channel are filled with river deposit, composed of sand or sandy silt, at 7 to 10 m thickness.

No low velocity zones were detected in seismic exploration along the dam axis, suggesting no serious fracturing or weak zone in the foundation.

2.5 Geology of the reservoir area

The reservoir area covers approximately 40 km^2 (depending on the high water level) within about 20 km upstream from the damsite. In this area the Amban Ganga flows meandering from west to east, with tributaries Ma Oya and Kalugalatta Oya from north, and Kambaraua Ganga and Galboda Oya from south. These tributaries trend nearly north-south, reflecting the geological structures. Ridges at 1,000 to 1,500 m in altitude, around and across the reservoir area, also show north-sough trends. Along the Amban Ganga and the tributaries develop narrow cultivated lands, and the rest parts are covered by jungle.

Topographically, this area shows characteristics of the valley in late mature stage. By developed side erosion the valleys are wide open, though slopes on the hillsides are fairly steep.

Geologically, the bed rocks in the reservoir area are gneisses of various mineral composition, charnockite, quartzite, calc gneiss and crystalline limestone, all of the pre-Cambrian Highland Series (See Fig. II.2.6). Quaternary unconsolidated deposits, such as river sand and silt, residual soil from weathering of rock and talus deposits, are rather thin. The rockbeds strike N-S to N40°E and dip horizontal to 40° westward in general, except in foldings.

Very gently warping folds are found to the north and to the south of the damsite, with axes roughly stretching north-southward. Faults with NE-SW trend and the others with NW-SE trend are assumed geomorphologically in the area of Kambaraua Ganga, Galboda Oya, Mt. Moragahakanda and the damsite, that is, in the eastern area of the reservoir.

Due to the mentioned thinness of unconsolidated Quaternary deposits and the high solidity of bed rocks, no possibility is conceivable for land sliding. As for possibility of water leakage from the reservoir, the Solution cavities in calcareous rocks should be drawn to attention. Those calcareous rocks, i.e. crystalline limestone and calc gneiss, are ordinarily solid, scarcely cracked and watertight, if they do no bear those solution cavities as observed in drilling and aditting on the left bank of the sub-dam No.1. The cavities, formed by solution of calcium carbonates into water during a long geological span of time, develop so

Fig II.2.6 Geological map of the reservoir area

irregularly that it is not easy to trace their stretchings and it is extremely difficult to obtain a comprehensive picture of their exact development and distribution in a certain area.

What can be said about this problem in this reservoir area is the followings.

(1) Development of calcareous rock beds is limitted in certain localities in the reservoir area, that is, two strata at about 300 m of thickness in the area upstream from the confluence of Ma Oya and one through the sub-damsite to the western slope of the right bank ridge along the Kambaraua Ganga, all of which beds stretch in the north-south direction. Thickness of the watershed in the north and south where these calcareous rock beds pass out of the reservoir area is more than 500 m at high water level. Only in the sub-damsite and on the eastern slope of Mt. Moragahakanda, a calcareous rock bed runs out from the reservoir in a short distance. The calcareous bed in the sub-damsite will be treated as described in Section 2.3.4.

(2) Development of cavities is rather limitted in certain localities in the calcareous rock beds, and not prevalent in those beds. In geological investigations carried out so far, cavities were found rather rarely; only on the left bank of the sub-damsite No.1 and on the eastern slope of Nt. Moragahakanda. The former were encountered by drilling and aditting. The latter are exposed on the ground surface; one is thin crevice-shaped openings with 20 to 30 cm of width around EL.190 m and another is a group of developed narrow cavities at the zone far higher than the planned dam crest. Vertical development of the cavities is within 35 m, in so far as known about those in the sub-dam No.1.

(3) In drillings at the damsite, no extraordinary disturbance or depression of groundwater table was observed in spite of those cavities as mentioned above. On the eastern slope of Mt. Moragahakanda where some cavities are found, a drilling DM39 from EL.352 m for research of quarry revealed that the groundwater table was about 100 m higher than the contemplated high water level. All of the above suggest that those cavities are not so influential as to cause serious water leakage.

(4) While some cavities are encountered as mentioned above, no kharstic topography worth noting is observed in the reservoir area. Neither noticeable water springs are seen.

The above situations releave fairly the fear of water loss from reservoir through the solution cavities. Foundation treatment in the damsite will be the only work required for the problem of cavities.

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3. Construction Materials

3.1 Outline of Investigations

Topographic characteristics of the Moragahakanda damsite necessitate two sabdams besides the main dam. As the construction materials, the proposed Concrete Gravity Type Dam will need fine and coarse aggregates while the proposed Rockfill Type Dam will require impervious core material, filter material and rock material, whereas earth material will be necessary for the proposed Earthfill Type Dam.

The present material investigation was conducted in order to collect the available data of previous investigations conducted on these construction materials since 1961 and to clarify the available quantity and the characteristics of each of these construction materials based on the results of field investigation and laboratory tests conducted afresh after thorough field reconnaissance and analysis of the results of previous survey.

All the field tests and laboratory tests in this investigation were conducted by the staff of the Material Testing Laboratory of the Irrigation Department of Sri Lanka.

Material investigations for Moragahakanda Dam were conducted at four different stages including the initial survey made by UNDP/FAO in 1961 and the present investigation conducted by JICA. (see D. II.17, D. II.18).

Therefore, the present study consisted of the collection and analysis of the available data of the previous investigations and the additional field investigation and laboratory tests to confirm and supplement the previous investigations.

All the available data collected are as listed in Table II.3.1.

The present field investigation added 4 test pits and 28 auger holes for soil materials, 6 pits for the extraction of samples for filter materials and for the fine concrete aggregrates, 4 holes of core drillings (DM29, DM39, DM40 and DM41) and blasting at 2 points for the extraction of samples for rock material and coarse concrete aggregates (See D. II.18 for location of investigation).

The laboratory tests conducted on the samples extracted in this way are shown in Table II.3.2, II.3.3, and II.3.4.

Large Scale Shearing Tests on rock materials using an adit in the damsite are also being carried out.

TABLE II.3.1. LIST OF DATA COLLECTED ON PREVIOUS SOIL SURVEY

1. Map of Dam Site and Vicinity with Location of Soil Survey, Scale: 1/10,000.

2. Report on the Preliminary Soil Investigation for Moragahakanda Reservoir Project, Oct. 1960.

   2-1. Location Map of Auger Holes.
   2-2. Field Notes and Summarized Data on Logs of Auger Holes; 31 holes.
   2-3. Summary of Laboratory Test Results.

3. Report on the Investigation of Earth Materials for the Moragahakanda Reservoir Scheme, 1961.

   3-1. Location Map of Test Pits; 49 pits.
   3-2. Summary of Laboratory Test Results.

4. Report on the Subsoil Investigation of Moragahakanda Reservoir, 1966.

   4-1. Location Map of Auger Holes and Test Pits.
   4-2. Logs of Upstream Test Pits; 4 pits.
   4-3. Logs of Upstream Auger Holes; 29 holes.
   4-4. Logs of Downstream Test Pits; 9 pits.
   4-5. Logs of Downstream Auger Holes; 97 holes.

5. Moragahakanda Dam Axis Soil Investigation, May 1978.

   5-1. Logs of Auger Holes; 25 holes.

6. Moragahakanda Borrow Area Soil Investigation, Jul.-Nov. 1978.

   6-1. Sketch of the Location of Test Pits
   6-2. Logs of Test Pits; 44 pits.
   6-3. Results of Laboratory Tests.
   6-4. Summary of Laboratory Test Results.
   6-5. Results of the Investigation of Riverbed Material.

LABORATORY TESTS CONDUCTED FOR INVESTIGATIONS BY JICA (1978/79)

TABLE II.3.2. NUMBER OF LABORATORY TESTS CONDUCTED ON IMPERVIOUS MATERIAL

TEST ITEM \ BORROW AREA		A		B		C1		C2		D		E		F		Total	
		Auger Holes	Test Pits	Auger Holes	Test Pits	Auger Holes	Test Pits	Auger Holes	Test Pits	Auger Holes	Test Pits	Auger Holes	Test Pits	Auger Holes	Test Pits	Auger Holes	Test Pits
Specific Gravity		3		3		3		3		3		3		10	3	28	3
Field Moisture Content		3		3		3		3		3		3		10	3	28	3
Gradation		3		3		3		3		3		3		10	3	28	3
Atterberg Limits		3		3		3		3		3		3		10	3	28	3
Compaction	Ec=100%														3		3
	Ec=300%														3		3
Permeability	at O.M.C.														3		3
	Dry at O.M.C.-4%														3		3
	Wet at O.M.C.+4%														3		3
Triaxial Compression (SCU)	at O.M.C.														3		3
	Dry at O.M.C.-4%														3		3
	Wet at O.M.C.+4%														3		3
Consolidation	at O.M.C.														3		3
	Dry at O.M.C.-4%														3		3
	Wet at O.M.C.+4%														3		3

TABLE II.3.3. NUMBER OF LABORATORY TESTS CONDUCTED ON FILTER MATERIAL AND FINE AGGREGATES.

TEST ITEM \ LOCATION	Upstream Riverbed	
Specific Gravity	7	
Gradation	7	
Density (Maximum, Minimum and Relative)	2	
Triaxial (SCU) at 65% Relative Density	2	

TABLE II.3.4 NUMBER OF LABORATORY TESTS CONDUCTED ON COARSE AGGREGATES AND ROCK-FILL MATERIAL

TEST ITEM \ LOCATION	Q-I	Q-III	DAM AXIS
Specific Gravity	Boring Core 10 Blastings 2	Boring Core 2 Blastings 2	Boring Core 9
Absoption	Boring Core 10	Boring Core 2	Boring Core 9
Compression	Boring Core 10	Boring Core 2	Boring Core 9
Sodium Sulphate Soundness	Boring Core 2	Boring Core 2	
Los Angeles Abrasion	Boring Core 2	Boring Core 2	
Unit Weight	Boring Core 2	Boring Core 2	

* In addition to these, Large Scale Direct Shear Tests are conducted for Rock Materials.

3.2 Soil Materials

3.2.1 Available Quantity of Soil Materials and the Selection of Borrow Areas

Borrow areas of impervious core material for the rockfill dam and earth materials for the earthfill dam were investigated in the upstream and downstream areas within reach of about 6 km from damsite. In the first investigation, conducted in 1961, an area in the upstream within a radius of about 3 km from damsite was investigated with 49 test pits allocated at intervals of 400 m. (see D. II.17) Although the detailed data of this investigation could not be collected during the present investigation, the Summary Report, shows that the upstream borrow areas cover 5,600,000 m^2 on the left bank and 2,400,000 m^2 on the right bank and the effective thickness of the layer of earth material overlying the decomposed rock stratum is about 1.5 - 2.5 m. The soil is composed mainly of SC material (by Unified Soil Classification) and a small quantity of GC material and CL material. Except for a very small amount of CL material with a high clay content, all these materials are suitable as impervious core material and earth material. The quantity of soil materials available in the upstream borrow area is estimated to be about 2,500,000 m^3.

The second investigation was conducted in 1965 on the advice of UN Engineering Geologist Dr. J.B.Auden. In this investigation, importance was given to the downstream borrow area where 9 test pits and 97 auger holes were distributed. At the same time 4 test pittings and 29 augerings were also made in the upstream borrow area. Although detailed results of laboratory tests are not available, the downstream borrow area covers more than 1,600,000 m^2 and the average thickness of soil is estimated to be 2.4 m (see D. II.17), according to the Summary Report. Almost all of the soil samples were classified as SC materials and the available quantity of earth material was estimated to be about 3,800,000 m^3.

The third investigation was started in May 1978 by the Material Testing Laboratory of the Irrigation Department. This investigation was conducted in the downstream borrow area to confirm and supplement the results of the second investigation made 12 years before (see D. II.18).

Up to the present, 45 test pittings and 25 augerings have already been made while gradation tests of 31 samples, several tests for the determination of the specific gravity of soil particles and several compaction tests have been completed.

According to their results, the downstream borrow area consists of mainly SC materials though some CL materials and GC materials can also be seen. All these materials are suitable for impervious core material and earth material. The thickness of soil layer is about 1.5 - 2.5 m and the soil types agree well with the results of the second investigation.

In the present investigation, field survey was limited to 4 test pits and 28 auger holes to confirm and supplement the investigations conducted so far, while detailed tests were conducted with emphasis laid on soil test (see D. II.18).

The soil types agree well with the results of the previous three investigations with the majority covered by brown or reddish brown SC material, and small quantities of reddish brown GC material (Quartz gravel mixed) and light brown CH material.

Since the borrow areas proposed in the four investigations cover a wide extent in both downstream and upstream of the damsite, hereinafter they will be refered to as follows. Upstream borrow area on the left bank is divided into Borrow Area A and B, while that on the right bank is divided into Borrow Areas C_1 and C_2. Downstream borrow area on the ritht bank is denoted as Borrow Area D while those on the left bank are divided into Borrow Areas E, F_1, F_2, F_3 and G (see D. II.17).

The details of each borrow area is given in Table II.3.5.

According to Dr. J.B.Auden (1965), with regards to the Borrow Areas A, B, C_1 and C_2, since the base rock is limestone, the selection of borrow area in the upstream and the removal of natural blanket in the reservoir basin can lead to future leakage of reservoir. Although this is a problem of possibility, it is not necessary to persist on the upstream borrow areas when the same type of materials can be obtained under the same conditions in both upstream and downstream borrow areas.

The downstream Borrow Area D is located on the right bank and the hauling distance can become extremely large depending on the site selected for the bridge over Amban Ganga. Moreover, since it is very close to the river and is relatively a low area at E.L. 145 m - 150 m, this area cannot be considered suitable as a borrow area when considering the problems such as drainage during the rainy season.

Borrow Area G too is far from the damsite and partly has a low lying area where drainage will be a problem. Considering these factors, Borrow Areas E and F are considered the most preferable. Out of these, specially Borrow Area F_1 is located in a short distance (about 1.4 km) to the damsite and has a gentle slope throughout its area with favourable drainage condition. Therefore, Borrow Area F_1 can be considered as the most suitable borrow area.

The next favourable borrow area in a reasonable distance to the damsite is Borrow Area E although outcrops of limestone is seen here and there. If this area is further extended to Borrow Area F_2, it is possible to collect 3,500,000 m^2 of soil material.

However, problem is that clearing of the thick jungle and removal of topsoil will largely influence the unit price of excavation since the layer of soil materials is very thin. But, as better areas are not found within a radius of 5 km from the damsite, Borrow Areas F_1, F_2 and E can be the most suitable borrow areas in the region.

The typical geological profile of these borrow areas is shown in D. II.19.

TABLE II.3.5. AVAILABILITY OF IMPERVIOUS MATERIAL IN EACH BORROW AREA

Borrow Area		A	B	C1	C2	D	E	F1	F2	F3	G
Location	Left Bank or Right Bank	L.B.	L.B.	R.B.	R.B.	R.B.	L.B.	L.B.	L.B.	L.B.	L.B.
	Upstream or Downstream	U/S	U/S	U/S	U/S	D/S	D/S	D/S	D/S	D/S	D/S
Aerial Distance to the Dam Site from the Center of Borrow Area (km)		2.0	2.4	1.3	2.8	1.3	1.4	1.4	2.2	2.2	2.8
Elevation (m)	from	150	150	145	150	145	150	175	175	150	140
	to	200	175	155	165	160	175	200	200	175	155
Area (x 1,000 m^2)		1,200	560	450	650	420	850	1,000	520	520	1,100
Possible Depth of Excavation (m)	from	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	to	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Thickness of Top Soil (m)		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Minimum Volume of Impervious Material Available (x 1,000 m^3)		1,800	840	675	975	630	1,300	1,500	780	780	1,650

Note: See II-29, 30 for the location of Borrow Areas

3.2.2 Physical and Mechanical Properties

The laboratory test results in previous investigations and the present ones (Figs. II.3.1, II.3.2, II.3.3 and II.3.4 and Tables II.3.6, II.3.7 and II.3.8) clearly show that the grain size and physical properties of each soil type are almost the same in Borrow Areas A, B, C, D, E, and F. Therefore, the soil material in the borrow areas within a radius of 6 km, both in the upstream and downstream of the damsite, could be represented at large by three soil types; SC materials, GC materials and CH. CL materials.

SC Material:

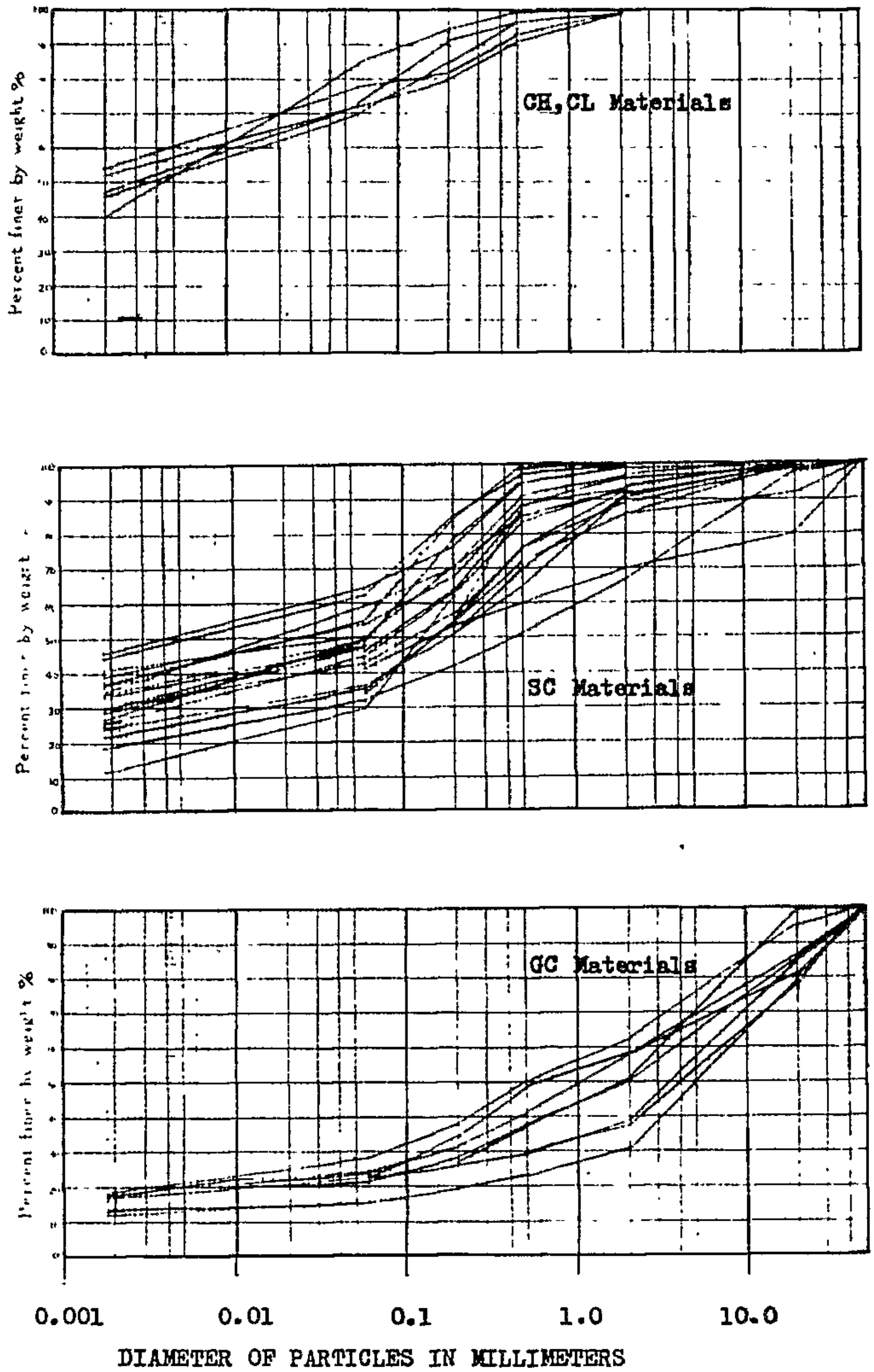
SC material is widely distributed throughout this region in large quantities. It is generally brown or reddish brown in colour and has a grain size distribution with 20 - 30 % Clay content, 10 - 20 % silt content and 50 - 70 % Sand and Gravel content. The specific gravity of soil particles is about 2.66. It is very plastic owing to the high clay content and has a field moisture content of 12 - 20 % and a plastic index of 12 - 27 %.

The mechanical properties of SC material are represented by MK-51 (in Table II.3.9 and Fig. II.3.5 (3)). These Tables and Figures show the results of tests conducted to verify the variation of mechanical properties of soil with the change of moisture content, within a range of about ±4 % from the Optimum Moisture Content.

The results of tests conducted in the present investigation show strength characteristics somewhat differ from those in the previous investigations (see Table II.3.7). However, this is due to the fact that new triaxial compression tests were conducted in Saturated Consolidated Undrained condition while the previous tests were conducted in Non-saturated Unconsolidated Undrained condition.

As clear from Fig. II. 3.5 (3) , the compaction of SC material is very effective showing a dry density of 1.78 - 1.87 t/m^3 within a range of ±3 % of the optimum moisture content, that is 14 % and is slightly on the dry side of the field moisture content.

FIG. II.3.1. GRAIN SIZE DISTRIBUTION CURVES OF SOILS IN UPSTREAM BORROW AREAS (1961 ID)



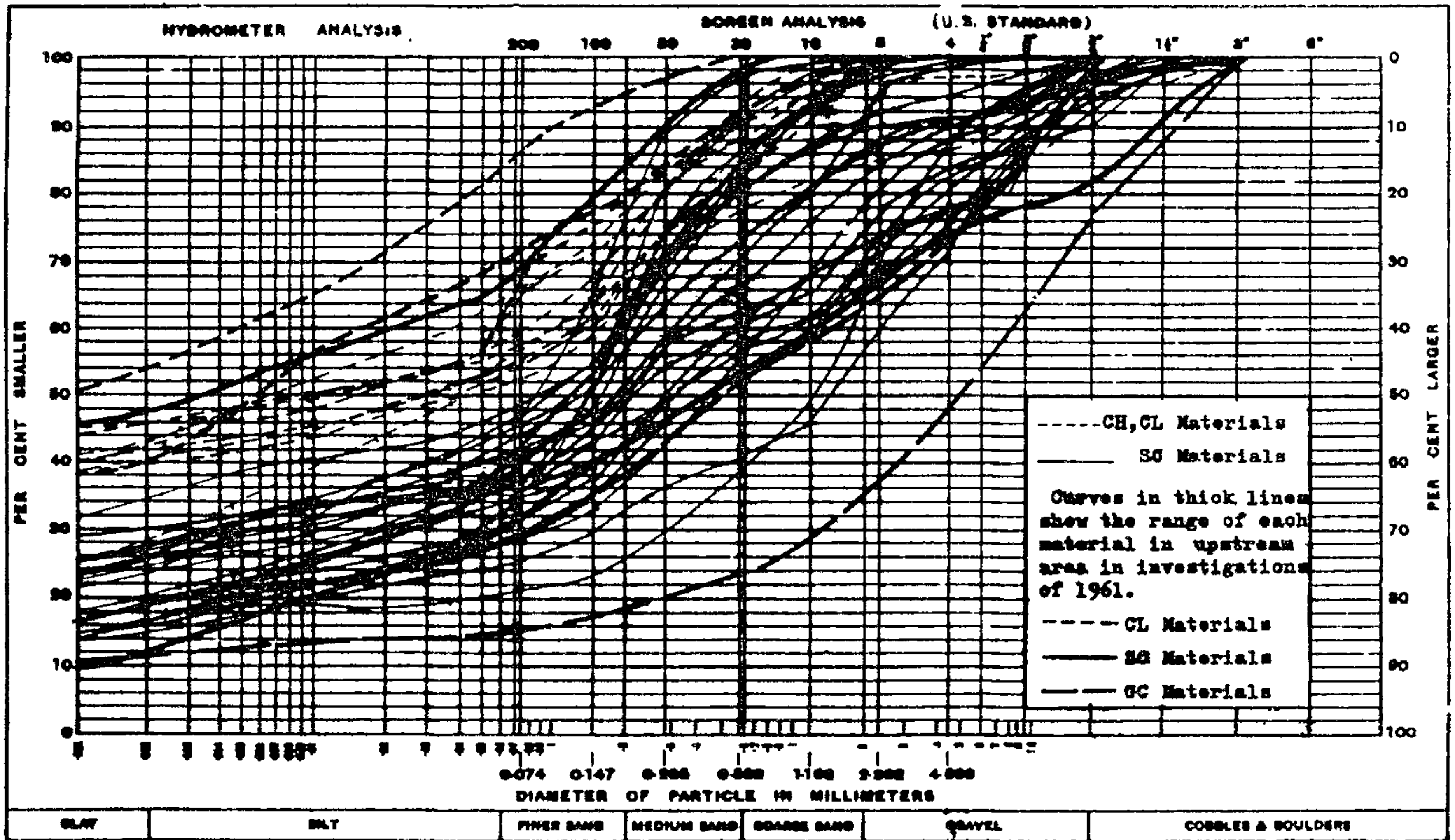


FIG.II.3.2. GRAIN SIZE DISTRIBUTION CURVES OF SOILS IN BORROW AREA B (1978 ID)

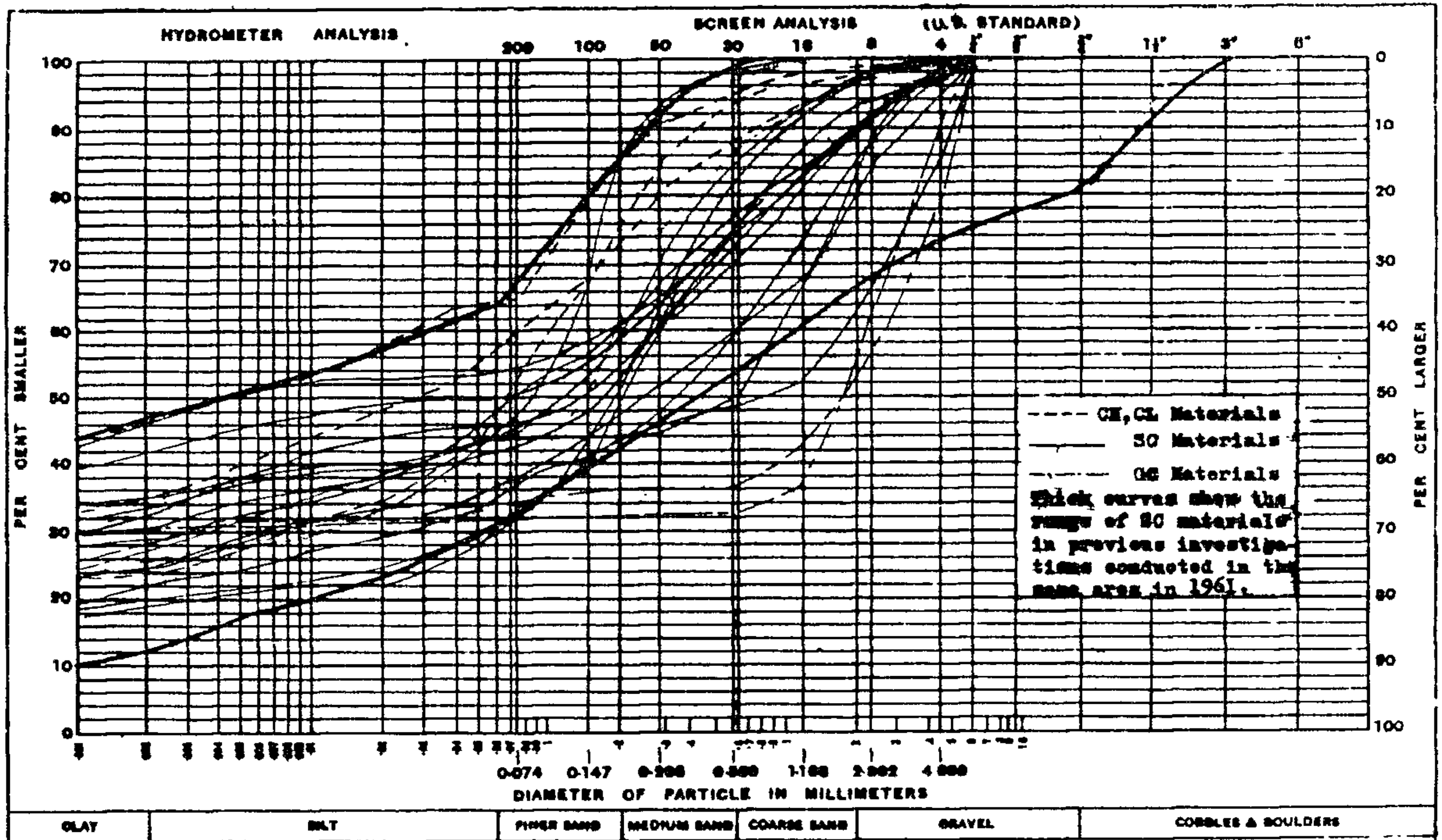


FIG. II.3.3. GRAIN SIZE DISTRIBUTION CURVES OF SOILS IN BORROW AREAS A,B,C1,C2,D and E (1978/79 JICA)

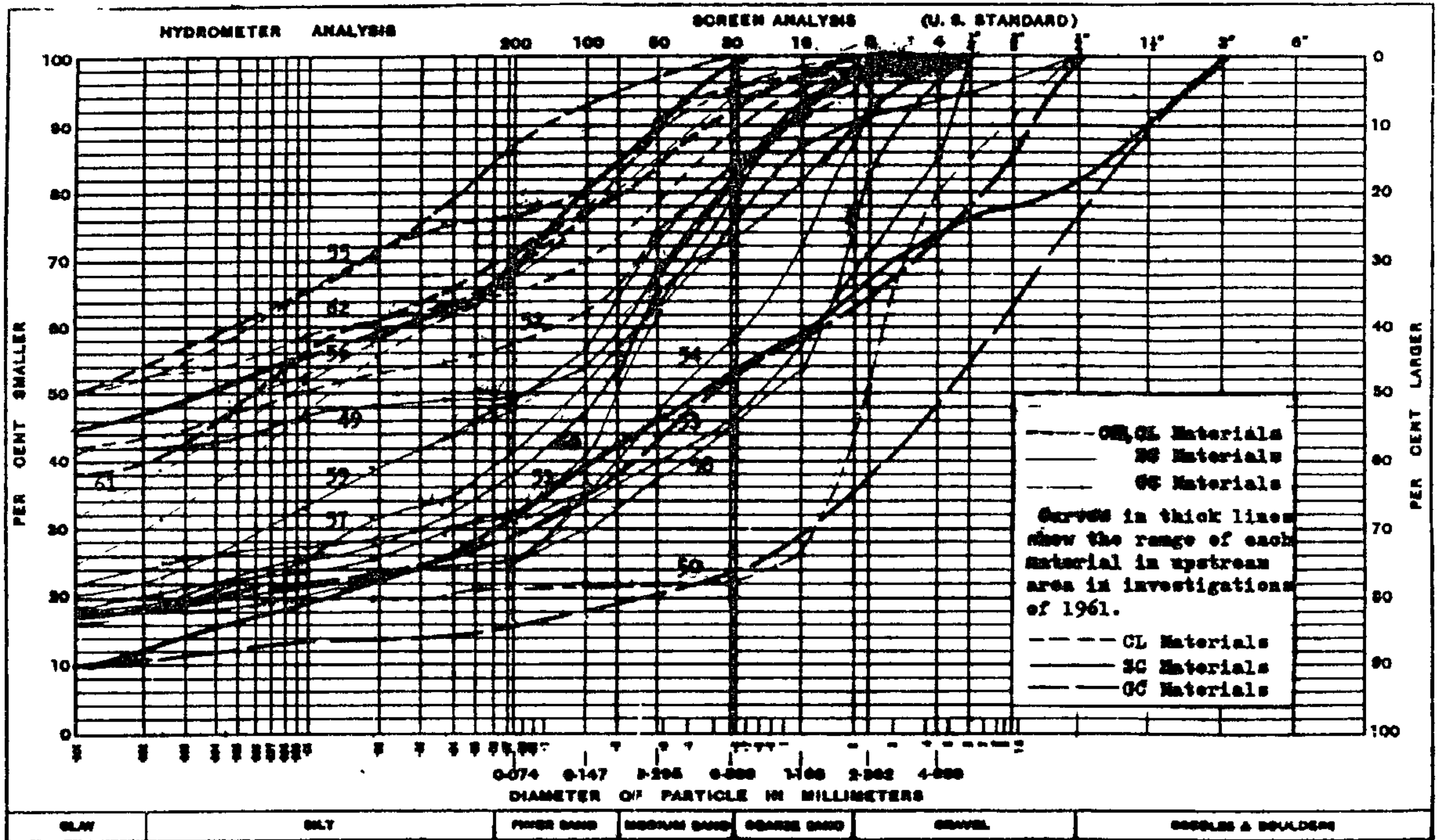


FIG II.3.4. GRAIN SIZE DISTRIBUTION CURVES OF SOILS IN BORROW AREA F (1978/79 JICA)

TABLE II.3.6. SUMMARY OF LABORATORY TEST RESULTS FOR SOILS IN UPSTREAM BORROW AREAS (1961 ID)

Borrow Area	Borrow Area I on Left Bank												Borrow Area II on Right Bank							
Soil Classification	SC Material				GC Material				CH,CL Material				SC Material				GC Material			
	Mean	Max	Min	N	Mean	Max	Min	N	Mean	Max	Min	N	Mean	Max	Min	N	Mean	Max	Min	N
Gradation				20				4				5				9				4
Clay (smaller than 2μ) %	31	46	12		14	17	12		48	54	40		32	42	22		15	18	12	
Silt (5μ - 60 μ) %	14	22	9		9	12	6		25	44	14		18	28	13		7	11	4	
Sand Fine (60μ -200μ) %	17	32	4		7	11	3		13	18	8		24	40	11		5	10	2	
Sand Medium (200μ-600μ) %	18	30	6		10	15	4		9	13	5		18	23	11		7	12	3	
Sand Coarse (600μ-2.0mm) %	10	24	1		12	16	8		4	8	1		6	14	0		11	14	8	
Gravel (2.0mm -19.0mm) %	7	31	1		32	41	23		1	1	0		2	7	0		43	48	33	
Cobbles (larger than 19 mm) %	3	20	0		16	21	13		0	0	0		0	0	0		11	21	1	
Specific Gravity	2.67	2.73	2.60	20	2.65	2.69	2.55	4	2.72	2.76	2.68	5	2.66	2.71	2.58	9	2.68	2.72	2.62	4
Liquid Limit %	39	56	27		36	40	32		46	52	43		35	43	30		40	47	31	
Plastic Limit %	20	33	9	20	20	23	18	4	24	32	21	5	19	22	16	9	22	24	18	4
Plastic Index	19	25	15		16	21	11		22	27	20		16	21	13		18	23	13	
Triaxial Compression Test				6				1				2				3				
Cohesion kg/cm²	0.70	0.91	0.56		0.56				0.77	1.12	0.42		0.70	1.01	0.56					
Angle of Internal Friction Deg	22	26	17		23				11	12	9		22	26	18					
Compaction				20				3				5				9				3
Optimum Moisture Content %	16.1	21.0	13.5		14.4	15.7	13.6		23.7	29.0	22.0		16.5	18.8	14.7		13.6	13.1	14.0	
Maximum Dry Density g/cm³	1.80	1.89	1.63		1.84	1.87	1.81		1.57	1.63	1.38		1.78	1.86	1.62		1.92	1.87	1.97	
Penetration Resistance Kg/cm²	41.8	70.3	28.1		28.1	31.6	19.3		29.5	35.1	24.6		49.2	91.4	31.6		51.3	56.2	49.7	
Permeability x 10-8cm/sec	5.8	9.6	1.0	20	19.3	21.3	8.7	3	2.9	4.8	1.0	4	8.7	19.3	1.9	7	22.2	44.3	8.7	3
Consolidation %	4.8	6.8	3.2	20	4.9	6.0	4.3	3	3.8	4.8	2.8	4	5.4	7.1	4.5	7	3.5	4.3	2.9	3

Note: Figures shown in column N show the number of tests conducted.

TABLE II.3.7. COMPARISON OF LABORATORY TEST RESULTS OF SOILS IN PREVIOUS AND RECENT INVESTIGATIONS

BORROW AREA	UPSTREAM BORROW AREAS I AND II (1961, IB)									BORROW AREAS A,B,C,D,E AND F (1978/9,JICA)								
Soil Classification	SC Material			GC Material			CH,CL Material			SC Material			GC Material			CH,CL Material		
	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.
Gradation																		
Clay (smaller than 2μ) %	31	46	12	15	18	12	48	54	40	22	34	17	26	35	18	43	61	23
Silt (5μ-60μ) %	16	28	9	8	12	4	25	44	14	15	26	9	4	7	1	18	34	6
Sand Fine (60μ-200μ) %	17	40	4	6	11	2	13	18	8	16	35	9	3	8	0	13	24	6
Sand Medium(200μ-600μ) %	17	30	6	8	15	3	9	13	5	19	28	6	5	13	0	14	20	10
Sand Coarse(600μ-2.0mm)%	9	24	0	11	16	8	4	8	1	18	32	1	22	29	15	10	21	3
Gravel (2.0mm-19.0mm) %	5	31	0	38	48	23	1	1	0	8	20	0	34	55	14	2	10	0
Cobbles(larger than 19mm)%	2	20	0	14	21	1	0	0	0	0	0	0	0	0	0	0	0	0
Specific Gravity	2.67	2.73	2.58	2.66	2.69	2.55	2.72	2.76	2.68	2.65	2.85	2.60	2.64	2.67	2.61	2.67	2.70	2.61
Field Moisture Content %										15.8	20.7	12.6	11.6	12.5	8.1	23.0	31.1	17.1
Liquid Limit %	38	56	27	38	47	31	46	52	43	34.8	51	27	44.3	56	31	48.9	61	28
Plastic Limit %	20	33	9	21	24	18	24	32	21	17.4	24	12	21.9	24	19	23.8	27	17
Plasticity Index	18	25	13	17	21	1	22	27	20	17.4	27	12	22.4	33	12	25.1	33	11
No. of Test Samples	29			8			5			15			6			12		

TABLE II.3.8 . SUMMARY OF LABORATORY TEST RESULTS (JICA - 1978)

Sample No.	Borrow Area	Auger Hole/Test Pit No.	Depth Below Ground Level (m)	Soil Classification	Field Moisture Content %	Consistency: Liquid Limit %	Consistency: Plastic Limit %	Consistency: Plasticity Index	Gradation: % Clay (0.002 mm)	Gradation: % Silt (0.002 - 0.06 mm)	Gradation: % Fine Sand (0.06 - 0.2 mm)	Gradation: % Medium Sand (0.2 - 0.6 mm)	Gradation: % Coarse Sand (0.6 - 2.0 mm)	Gradation: % Gravel (2.0 - 19.0 mm)	Gradation: % Cobbles (19.0 mm)	Gradation: % Passing 19.0mm Mesh	Gradation: % Passing 200 Mesh	Specific Gravity of Soil Particles
MK 49	F	T1	1.0-2.0	CH	17.1	50.8	24.2	26.6	42	7	16	20	13	2	0	100	49	2.66
MK 50	F	T2	0.5-1.0	GC	12.5	46.9	24.2	22.7	19	2	1	0	23	55	0	85	21	2.70
MK 51	F	T3	1.0-2.0	SC	20.4	27.4	12.9	14.5	21	10	21	28	11	9	0	94	32	2.66
MK 52	F	1	1.0-2.0	CH	23.4	48.0	24.6	23.4	44	13	11	16	14	2	0	100	58	2.62
MK 53	F	4	0 -1.0	GC	12.3	31.2	18.9	12.3	18	7	8	13	22	32	0	100	25	2.66
MK 54	F	5	1.0-1.5	SC	16.6	36.0	16.9	19.1	17	12	11	18	32	10	0	100	30	2.85
MK 55	F	6	1.0-2.0	CH	31.0	61.0	32.3	28.7	52	25	8	10	4	1	0	100	78	2.66
MK 56	F	10	1.0-2.0	CL	28.3				38	30	12	14	6	0	0	100	70	2.66
MK 57	F	13	1.0-2.0	SC	17.5	29.1	16.2	12.9	18	20	22	25	13	2	0	100	38	2.61
MK 58	F	17	1.0-2.0	SC	12.4	42.9	21.9	21.0	25	6	5	10	29	25	0	100	32	2.75
MK 59	F	22	0 -1.0	SC	17.8	37.1	21.6	15.5	22	26	12	19	17	4	0	100	49	2.60
MK 60	F	24	0 -1.0	SC	20.6	31.7	15.2	16.5	18	18	19	19	16	10	0	100	38	2.64
MK 61	F	25	0 -1.0	SC	27.7	46.6	24.2	22.4	30	34	19	12	4	1	0	100	71	2.61
MK 62	F	26	1.0-2.0	CH	23.8	59.8	26.8	33.0	53	12	9	15	10	1	0	100	65	2.61
MK 63	A	1	1.0-2.0	SC	16.5	29.8	14.9	14.9	25	20	35	19	1	0	0	100	47	2.63
MK 64	A	2	0 -1.0	CL	21.1	44.8	21.9	22.9	35	22	17	13	10	3	0	100	63	2.63
MK 65	E	1	1.0-2.0	SC	15.8	35.2	17.4	17.8	27	18	17	24	12	2	0	100	46	2.64
MK 66	E	2	1.0-2.0	SC	10.9	27.2	14.8	12.4	19	10	19	26	19	7	0	100	30	2.64
MK 67	E	3	1.0-2.0	SC	12.5	27.2	12.3	14.9	20	11	27	28	18	2	0	100	31	2.65
MK 68	A	3	0 -2.0	CH	18.9				47	17	18	14	3	1	0	100	65	2.64
MK 69	B	1	0 -2.0	CH	21.9	49.7	22.6	27.1	61	6	7	12	12	2	0	100	67	2.62
MK70A	B	2	0-0.75	SC	18.3	40.5	20.1	20.4	29	19	12	14	15	11	0	100	50	2.64
MK70B	B	2	0.75-2.0	SC	18.8	28.1	17.3	10.8	23	29	24	17	6	1	0	100	61	2.67
MK 71	B	3	0-1.25	SC	14.2	37.9	19.3	18.6	25	11	10	14	24	16	0	100	37	2.71
MK 72	C1	1	0-0.75	SC	14.2				35	5	3	6	15	36	0	100	40	2.61
MK 73	C1	2	0 -2.0	SC	15.3	34.0	17.1	16.9	22	11	13	14	24	16	0	100	34	2.68
MK 74	C1	3	0 -1.0	SC	13.9	50.7	24.1	26.6	34	9	1	6	30	20	0	100	40	2.62
MK 75	D	1	0 -1.5	SC	10.2	44.0	21.6	22.4	29	5	2	0	20	44	0	100	35	2.67
MK 76	D	2	0 -1.5	SC	14.5	39.2	16.5	22.7	31	17	13	21	17	7	0	100	43	2.60
MK 77	D	3	0 -0.6	SC	12.8	38.8	22.2	16.6	32	14	9	16	18	11	0	100	46	2.61
MK 78	C2	1	0 -1.5	CL	20.0	50.6	21.7	28.9	42	8	10	14	16	10	0	100	50	2.66
MK 79	C2	2	0 -1.5	GC	8.1	56.4	23.1	33.3	30	1	0	1	23	45	0	100	31	2.61
MK 80	C2	3	0 -1.5	CL	23.0	50.0	22.6	27.4	47	7	6	14	21	5	0	100	54	2.63

Notes: 1) Samples MK 49 - 51 are extracted from test pits and all remaining samples are extracted from auger holes.
2) See also Table 2.5. for the results of mechanical tests conducted with samples MK 49 - 51.

FIG.II.3.5(1) RELATION BETWEEN MOISTURE CONTENT AND DRY DENSITY, COHESION ANGLE OF INTERNAL FRICTION AND COEFFICIENT OF PERMEABILITY

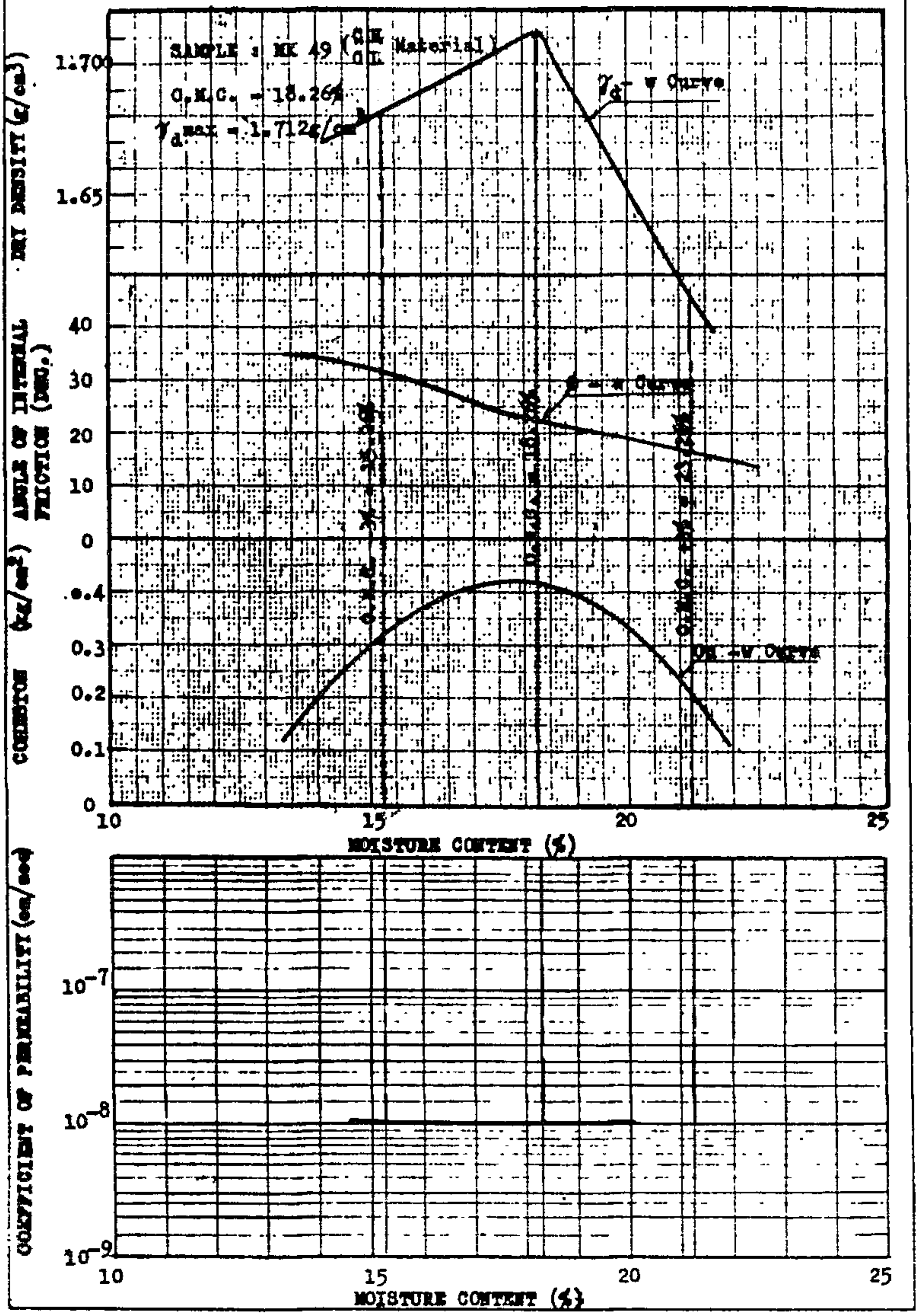


FIG.II.3.5(2) RELATION BETWEEN MOISTURE CONTENT AND DRY DENSITY, COHESION ANGLE OF INTERNAL FRICTION AND COEFFICIENT OF PERMEABILITY

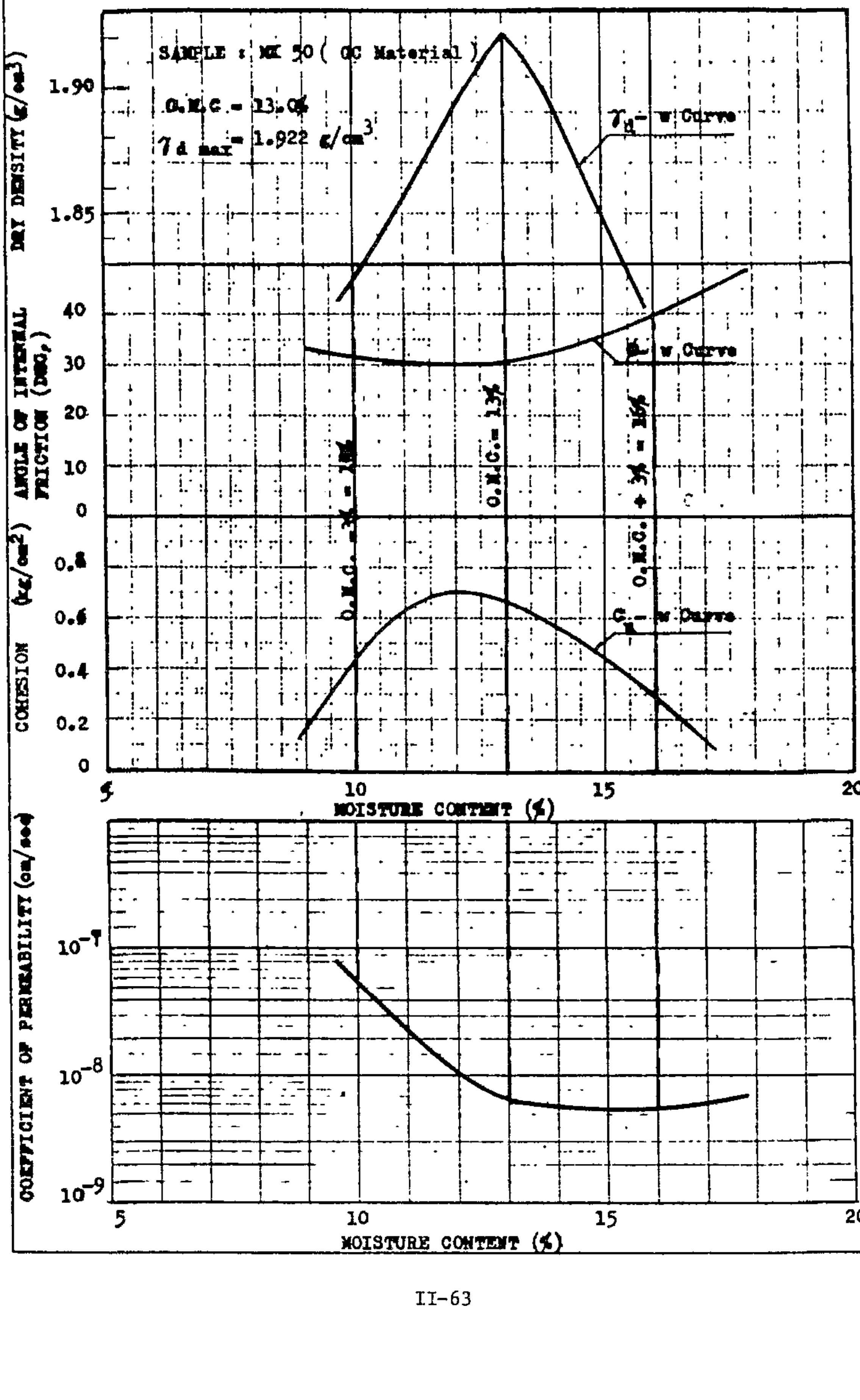


FIG. II35(3) RELATION BETWEEN MOISTURE CONTENT AND DRY DENSITY, COHESION ANGLE OF INTERNAL FRICTION AND COEFFICIENT OF PERMEABILITY

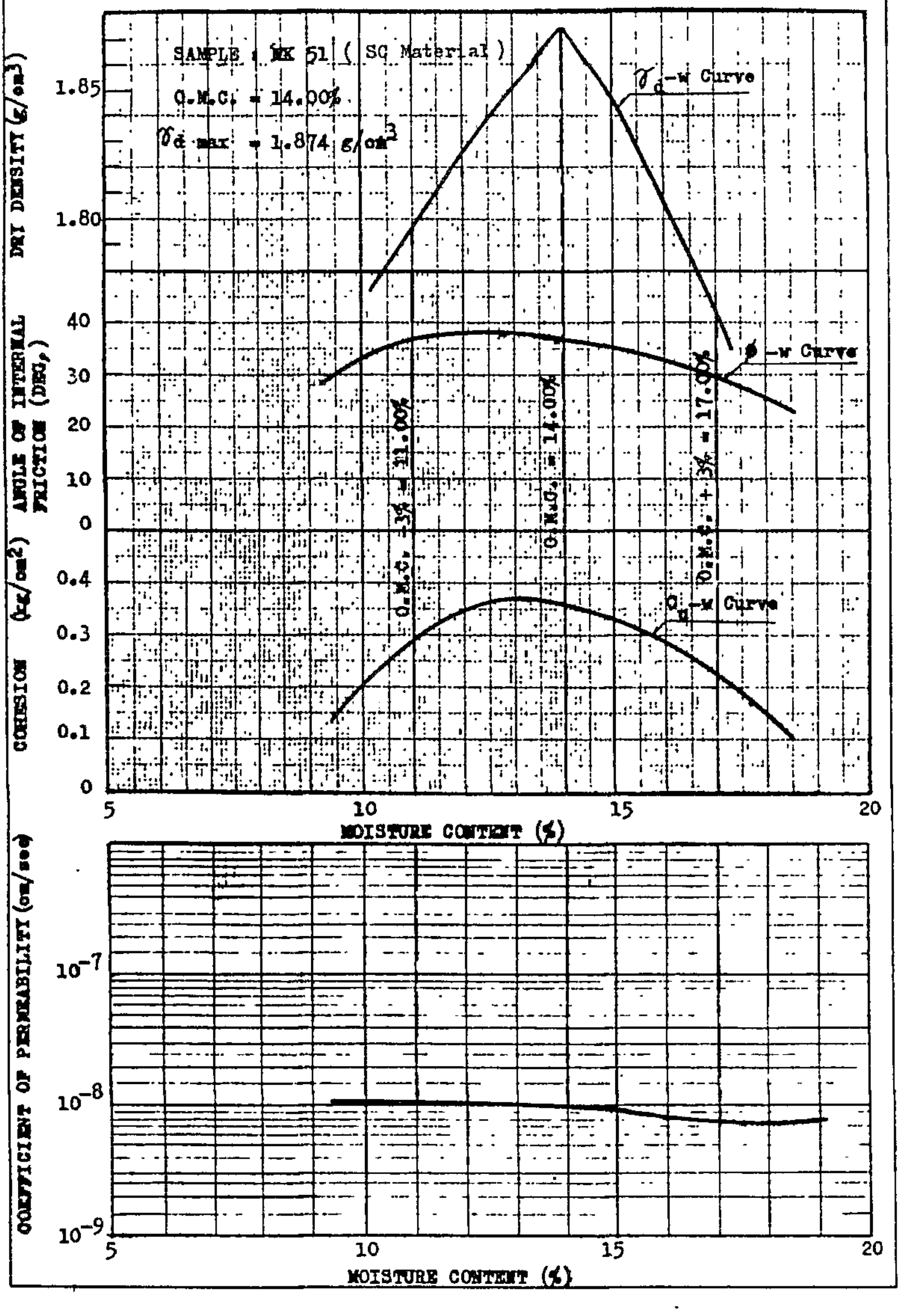


TABLE II.3.9. SUMMARY OF MECHANICAL TESTS ON IMPERVIOUS MATERIAL

Sample No.			MK 49 (CH.CL)					MK 50 (GC)					MK 51 (SC)				
Compaction	Std.	Moisture Content %	16.55	17.65	18.18	19.39	20.40	12.17	12.36	14.47	15.24	15.80	11.79	12.90	13.71	14.80	16.64
		Dry Density (g/cm³)	1.695	1.707	1.712	1.678	1.640	1.894	1.903	1.872	1.839	1.809	1.818	1.847	1.868	1.853	1.780
	300%	Moisture Content %	13.70	14.70	15.50	16.51	17.50	9.30	10.46	11.10	13.00	15.00	9.70	10.90	11.50	12.10	13.30
		Dry Density (g/cm³)	1.813	1.826	1.852	1.810	1.792	1.970	1.997	2.020	1.948	1.[illegible]76	1.953	1.967	1.981	1.967	1.921
Triaxial	SCU Test	Moisture Content %	13.82		18.40		22.03	9.12		12.70		16.84	9.64		14.33		17.67
		Cohesion (kg/cm²)	0.18		0 42		0.11	0.21		0.70		0.14	0.18		0.35		0.17
		Angle of Internal Friction (deg)	34°18'		22°23'		15°10'	33°6'		30°35'		43°50'	30°56'		36°1'		27°45'
(1)		Moisture Content %	15.20		18.30		22.50	9.70		13.10		17.00	9.90		14.90		18.40
		Rate of Percolation x 10⁻⁸ (cm/sec)	1.02		1.03		-	7.15		0.65		0.62	1.01		0.93		0.74
		Consolidation %	3.00		3.55		8.00	2.60		3.62		7.53	4.05		6.68		6.22
(2)		Moisture Content %	14.23		17.71		21.11	9.33		12.41		16.73	9.70		13.90		18.50
		Coef. of Permeability x 10⁻⁶ (cm/sec)	1.30		1.15		1.20	1.90		0.3[illegible]		0.91	0.76		0.61		0.71
Max Dry Density (g/cm³)			1.712 (at O.M.C.= 18.26%)					1.922 (at O.M.C.= 13.00%)					1.874 (at O.M.C.= 14.00%)				

Remarks: I. Compaction tests are conducted for Eo=100% and 300% (Hammer weight: 5 1/2 lb, Hammer Drop: 12" Number of Layers: 3, Number of Blows per Layer: 25 for Eo=100 % and 75 for Eo=300%)

II. Triaxial tests are conducted under Saturated Consolidated Undrained Condition (SCU)

III. (1) Results of Consolidation and Percolation Tests (Consolidated Load: 1.397kg/cm²)

IV. (2) Results of Consolidation Tests (Consolidated Load : 1.40 kg.cm²)

The compression tests show an angle of internal friction ø' of over 30° and a cohesion C' of over 2 t/m^2. The coefficient of permeability is not very much affected by the density of compaction due to the high clay content and is very low at 10^{-8} cm/sec. showing that this soil is a very impervious material suitable for core material.

GC Material:

GC material is distributed only in some parts of the upstream and downstream borrow areas, at depths comparatively close to the topsoil. It is generally reddish brown in colour and is composed of 15 - 25 % Clay content, 5 - 10 % Silt content, 15 - 45 % Sand content and 15 - 50 % Gravel content. The specific gravity of soil particles is about 2.66. The soil is plastic with a field moisture content of 8 - 12 % and a plasticity Index of 12 - 33 %.

The mechanical properties of GC material are represented by Mk 50 (in Table II.3.9 and Fig. II.3.5 (2)).

As seen in Fig. II.3.5 (2), compaction of GC material is extremely good with a dry density of 1.81 - 1.92 t/m^3 within a range of 3 % of the optimum moisture content. The optimum moisture content is 13 % and is about the same as the field moisture content.

This material has an angle of internal friction ø' of over 30° and a cohesion of over 3 t/m^2. The coefficient of permeability is very low at 10^{-8} cm/sec. owing to the high content of clay. This material is the most suitable for core material.

CH. CL Material:

This material is widely destributed in the upstream and downstream borrow areas at relatively shallow depths in moderate quantity. It is generally brown or light brown in colour and has a grain size distribution of 25 - 55 % Clay content, 10 - 30 % Silt content and 15 - 40 % Sand and Gravel content. The specific gravity of soil particles is about 2.68. The field moisture content has a wide range of 17 - 31 %, but the soil is plastic with a plasticity index of 11 - 33 %.

The mechanical properties of CH. CL material are represented by MK 49 in Table II.3.9 and Fig. II.3.5 (1).

The dry density in the compaction test within a range of ±3 % of the optimum moisture content is comparatively low at 1.61 - 1.71 t/m^3. The optimum moisture content is 18 % and is on the dry side of the field moisture content.

Within the same range of moisture content, the angle of internal friction ϕ' is over 17° and the cohesion C' is over 2 t/m^2. The coefficient of permeability is not affected by compaction due to high content of clay and is 10^{-8} cm/sec. This very impervious material can be used as core material, but its strength is comparatively low.

3.2.3 Suitability as Impervious Material

Judging from the physical and mechanical characteristics of each soil type, GC material is rated as the best suited soil material to be used as impervious core material in the rockfill dam or as earth material in the earthfill dam, followed by SC material and CH. CL material in that order.

Out of the above three soil types, even the inferior CH. CL material is not necessarily judged as not suitable for the impervious core material or earth material. Its impermeability is excellent and moreover, the field moisture content is very close to the optimum moisture content. In the compaction test, dry density show an increase when the compaction energy is raised to 300 % of the standard compaction energy, showing no problems due to overcompaction (see Fig. II.3.6 and II.3.7). With an average plasticity index of 25, this material has sufficient resistance against piping. The strength is somewhat low, nevertheless, this material could be rated as sufficiently suitable for a dam with height less than 70 m.

Among the three soil types, the available quantity of SC material is the largest while that of GC material is the smallest. Moreover, since GC material is distributed very close to the ground surface, it is difficult to depend on this quantity. Therefore, when Borrow Areas E and F are selected, SC material becomes the main material accompanied by some CH. CL material. Anyway, since these soils are distributed only within a small depth making it necessary to collect the soil material from a wide area, it is virtually impossible to differenciate the soils of those three categories in the site.

Therefore, the various design criteria for the basic design of the dam should be determined with respect to the inferior CH. CL material.

Considering that the moisture content is controlled within a range of ±3 % of the optimum moisture content, the minimum values in this range are taken as the design values of the CH. CL material. However, since all the new triaxial compression tests were conducted in saturated condition, the strength in the unsaturated condition was estimated at

FIG. II.3.6 RELATION BETWEEN FIELD MOISTURE CONTENT AND OPTIMUM MOISTURE CONTENT

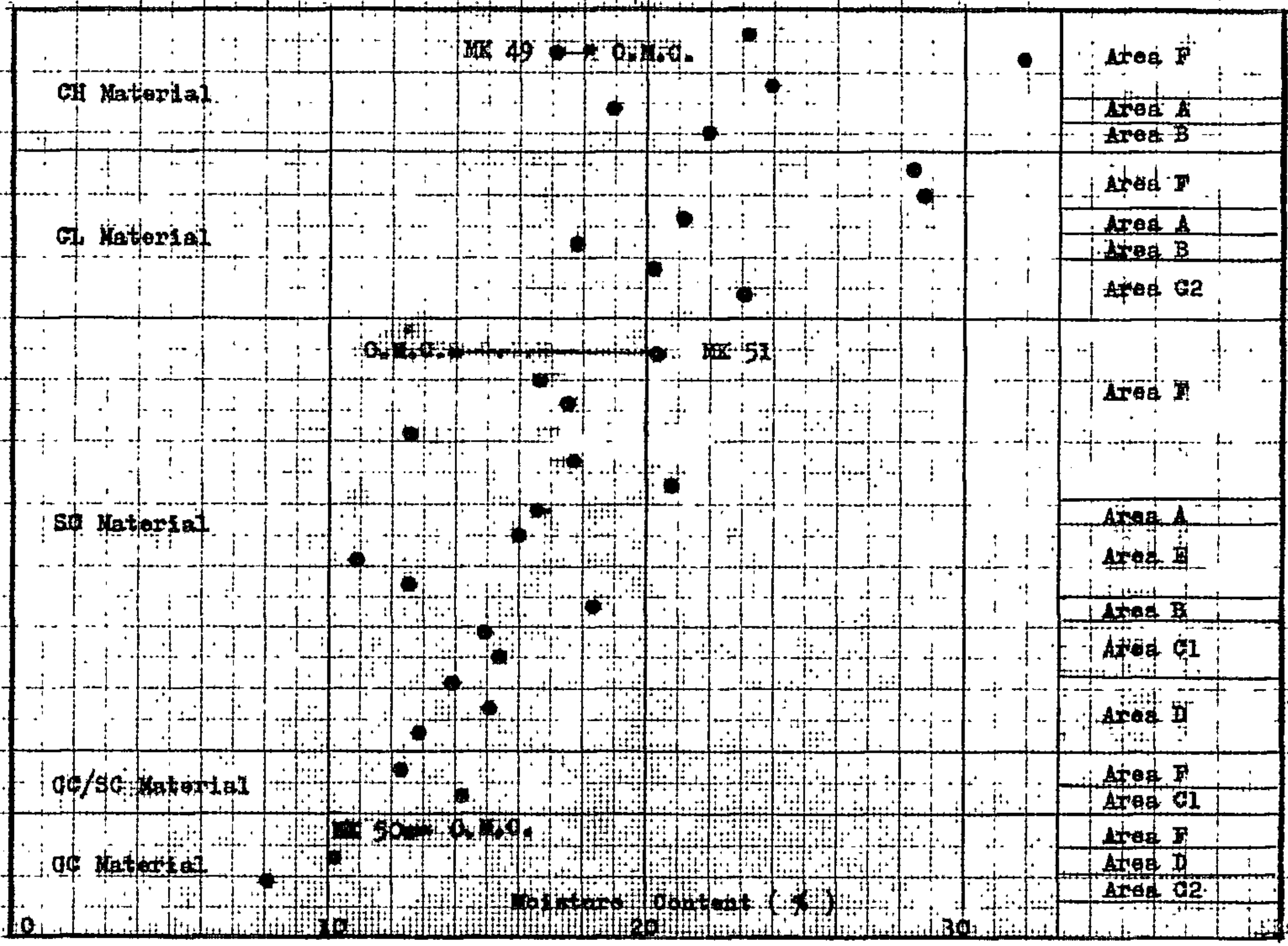
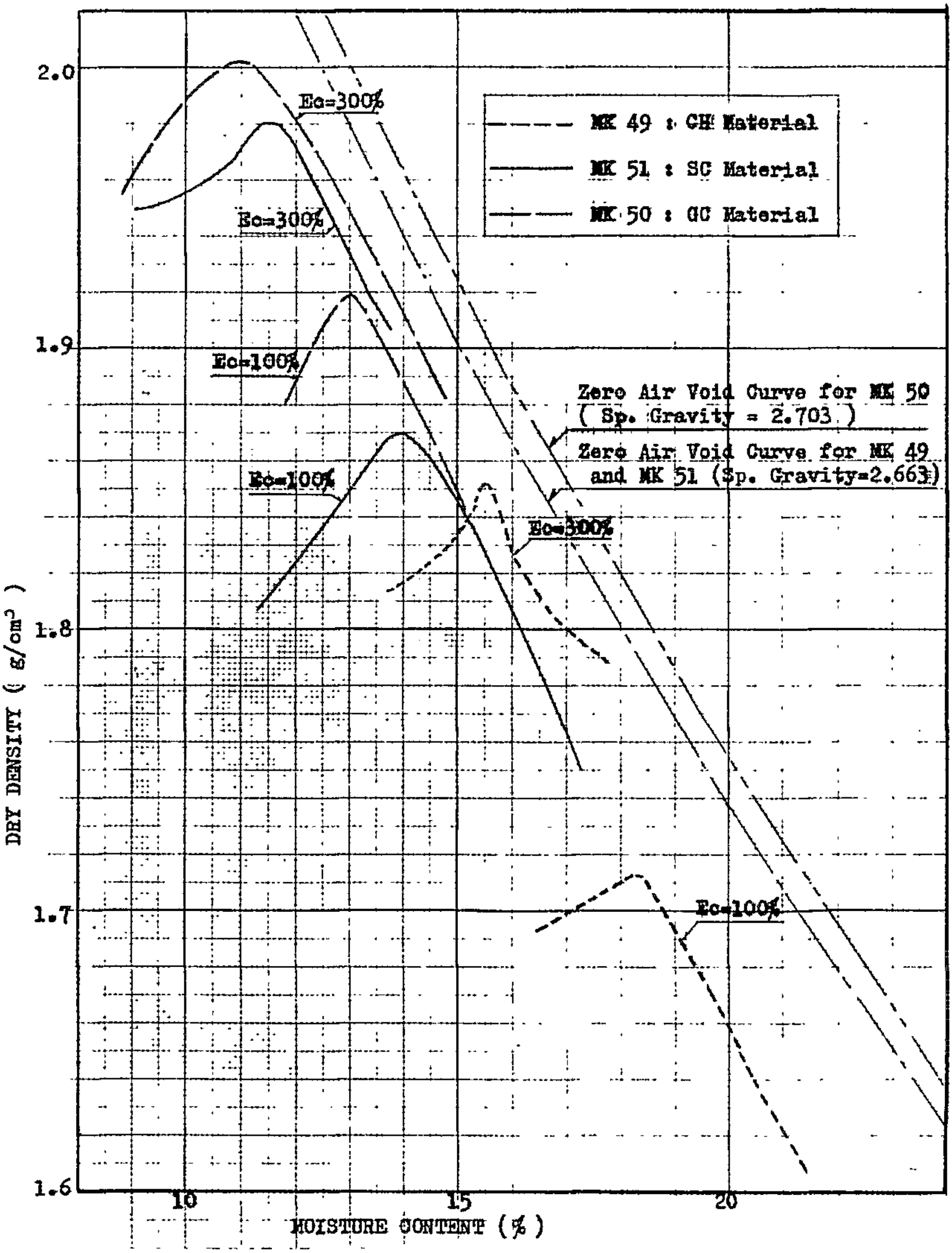


FIG.III3-7 RESULTS OF COMPACTION TESTS: RELATION BETWEEN MOISTURE CONTENT AND DRY DENSITY OF SOIL



$C = 4.0\ t/m^2$, or twice the value in saturated condition, after thorough consideration of the results of previous triaxial compression tests conducted in unsaturated condition. The design values are summarised below (see also Fig. II.3.5 (1)).

Moisture Content ω	= 21 %
Specific Gravity of Soil Particles	= 2.66
Dry Density γd	= $1.61\ t/m^3$
Bulk Density γt	= $1.95\ t/m^3$
Cohesion (when Saturated) C'_{sat}	= $2.0\ t/m^2$
Cohesion (Unsaturated) C'	= $4.0\ t/m^2$
Angle of Internal Friction ϕ'	= 17°
Coefficient of Permeability k	= 10^{-7} cm/sec.

3.2.4 Matters of Special Attention

The major part of soil materials selected for impervious material will be SC material. However, CH. CL material will also be mixed in large quantities. Therefore, development of high pore water pressures, which is detrimental to the stability of the dam, could be expected during compaction. However, it is difficult to observe the actual behaviour of pore water pressure in the triaxial compression tests conducted in the present investigation since the pore water pressures are not measured completely.

In order to overcome the possible development of high pore water pressures during construction, it may be necessary in the design, to take suitable measures such as the limiting of the thickness of impervious core in the case of rockfill dam and the installation of Chimney Drains etc., in the case of earthfill dam.

Moreover, prior to the detailed design, it is also necessary to determine the appropriate type of rolling equipment, the number of turns of rolling, the thickness of spreading and the working moisture content etc., by conducting field compaction tests.

Since the impervious material required has to be collected from a comparatively thin layer of soil extending to a wide area, the use of power shovels in excavation can not be considered due to extremely low efficiency. Moreover, when considering the severe irregularities on the surface of base rock, bulldozers are considered more suitable than the scrapers for excavation and collection of soil material. Therefore, a combination of bulldozers with wheel loaders etc., for loading and dump trucks for the transport of material is considered appropriate for this site.

In the proposed borrow areas, the exploitable soil material is covered by a comparatively thick layer of topsoil. Therefore, excavation and removal of a tremendous volume of topsoil becomes inevitable. It is an efficient and economical procedure to refill an already excavated area with disposed topsoil from the other area which is excavated later.

The stagnation of rain water etc., in the borrow area can largely affect the quality of soil material. Since the proposed borrow areas are specially wide, it is necessary to pay special attention on the drainage in borrow areas during construction.

3.3 Filter Material and Fine Aggregates for Concrete

3.3.1 Availability and Exploitable Quantity

With respect to filter material for the fill type dams and fine aggregates for the concrete dam, investigations were carried so far on the riverbed deposits of Amban Ganga.

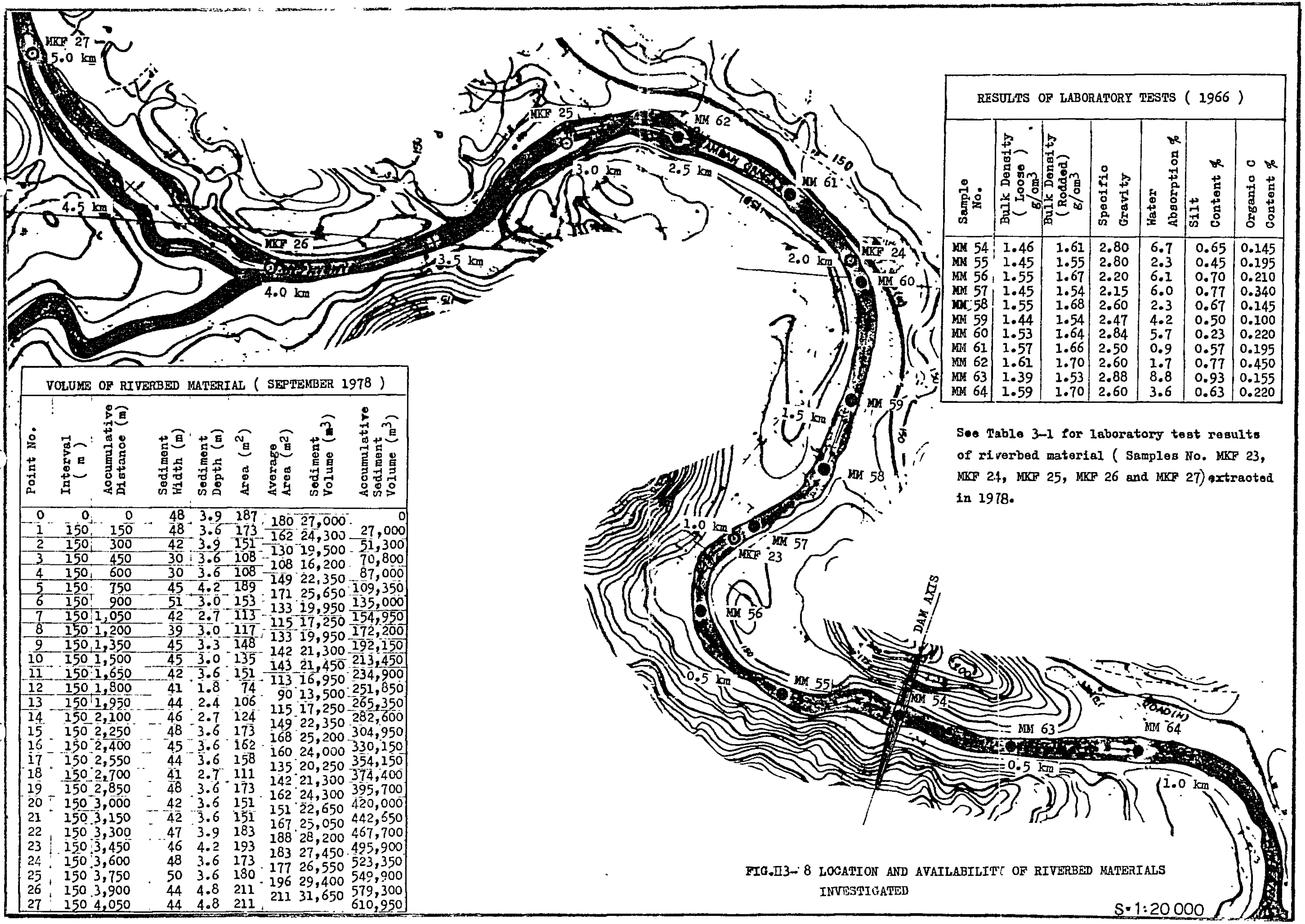
The first investigation of the riverbed deposit was conducted in 1966 along with the investigation of borrow areas for earth material. In this investigation the thickness of sand at the riverbed was measured by penetrating a metal probe into the riverbed deposit. According to this survey conducted in a range of 3 km upstream and 1.3 km downstream, the average thickness of riverbed deposit was about 3 m.

Assuming the average thickness of riverbed deposit at 3 m and the average width of the river at 40 m, about 520,000 m^3 of riverbed deposit could be expected in the 4.3 km stretch of river investigated above.

The second investigation was conducted from July to September 1978 on the riverbed deposit of Amban Ganga in the upstream of dam site. According to the results of this investigation (see Fig. II.3.8), about 100,000 m^3 - 150,000 m^3 of sand is deposited for every kilometer length of the river in the investigated section.

As above, investigations had been conducted twice in the past on the riverbed deposit and the volume of deposit does not differ very much in them. Therefore, in the present investigation, laying emphasis on the physical and mechanical properties of this material, tests for specific gravity, gradation and relative density and moreover, triaxial compression tests (at D_r = 65 %) were conducted.

Riverbed materials are deposited also in the low-lying areas other than the riverbed, for example, in the Borrow Areas C_1 and D. However, the results of reconnaissance and auger borings conducted in these areas show that the content of silt and finer material is relatively high with about 10 % - 30 % and therefore, these materials could not be considered suitable. On the other hand, the riverbed material deposited under the water which is naturally washed and cleaned through the long years could



VOLUME OF RIVERBED MATERIAL (SEPTEMBER 1978)

Point No.	Interval (m)	Accumulative Distance (m)	Sediment Width (m)	Sediment Depth (m)	Area (m^2)	Average Area (m^2)	Sediment Volume (m^3)	Accumulative Sediment Volume (m^3)
0	0	0	48	3.9	187	180	27,000	0
1	150	150	48	3.6	173	162	24,300	27,000
2	150	300	42	3.9	151	130	19,500	51,300
3	150	450	30	3.6	108	108	16,200	70,800
4	150	600	30	3.6	108	149	22,350	87,000
5	150	750	45	4.2	189	171	25,650	109,350
6	150	900	51	3.0	153	133	19,950	135,000
7	150	1,050	42	2.7	113	115	17,250	154,950
8	150	1,200	39	3.0	117	133	19,950	172,200
9	150	1,350	45	3.3	148	142	21,300	192,150
10	150	1,500	45	3.0	135	143	21,450	213,450
11	150	1,650	42	3.6	151	113	16,950	234,900
12	150	1,800	41	1.8	74	90	13,500	251,850
13	150	1,950	44	2.4	106	115	17,250	265,350
14	150	2,100	46	2.7	124	149	22,350	282,600
15	150	2,250	48	3.6	173	168	25,200	304,950
16	150	2,400	45	3.6	162	160	24,000	330,150
17	150	2,550	44	3.6	158	135	20,250	354,150
18	150	2,700	41	2.7	111	142	21,300	374,400
19	150	2,850	48	3.6	173	162	24,300	395,700
20	150	3,000	42	3.6	151	151	22,650	420,000
21	150	3,150	42	3.6	151	167	25,050	442,650
22	150	3,300	47	3.9	183	188	28,200	467,700
23	150	3,450	46	4.2	193	183	27,450	495,900
24	150	3,600	48	3.6	173	177	26,550	523,350
25	150	3,750	50	3.6	180	196	29,400	549,900
26	150	3,900	44	4.8	211	211	31,650	579,300
27	150	4,050	44	4.8	211			610,950

RESULTS OF LABORATORY TESTS (1966)

Sample No.	Bulk Density (Loose) g/cm3	Bulk Density (Rodded) g/cm3	Specific Gravity	Water Absorption %	Silt Content %	Organic C Content %
MM 54	1.46	1.61	2.80	6.7	0.65	0.145
MM 55	1.45	1.55	2.80	2.3	0.45	0.195
MM 56	1.55	1.67	2.20	6.1	0.70	0.210
MM 57	1.45	1.54	2.15	6.0	0.77	0.340
MM 58	1.55	1.68	2.60	2.3	0.67	0.145
MM 59	1.44	1.54	2.47	4.2	0.50	0.100
MM 60	1.53	1.64	2.84	5.7	0.23	0.220
MM 61	1.57	1.66	2.50	0.9	0.57	0.195
MM 62	1.61	1.70	2.60	1.7	0.77	0.450
MM 63	1.39	1.53	2.88	8.8	0.93	0.155
MM 64	1.59	1.70	2.60	3.6	0.63	0.220

See Table 3-1 for laboratory test results of riverbed material (Samples No. MKF 23, MKF 24, MKF 25, MKF 26 and MKF 27) extracted in 1978.

FIG.II3-8 LOCATION AND AVAILABILITY OF RIVERBED MATERIALS INVESTIGATED

be considered the most desirable material.

The sand suitable for filter material in the fill type dams and for fine aggregates in the concrete dam is available in Amban Ganga as river-bed material deposited to an average depth of 3 m. It is reasonable to consider a volume of about 100,000 m^3 per kilometer of river length.

Possibility of alternative fine materials to be obtained by crushing the rocks available in the damsite was examined by laboratory tests, similar to those conducted on river sand, on the samples from the adit in the damsite.

3.3.2 Physical and Mechanical Properties

The results of the tests conducted in 1966 on riverbed deposit of Amban Ganga are shown in Fig. II.3.8, while those of the tests conducted in the present investigation are shown in Table II.3.10.

River sand collected from Amban Ganga is very clean, and as clear from the grain size distribution curves shown in Fig. II.3.9, is a fairly coarse sand with an average Uniformity Coefficient of 2.64. This sand has a Fineness Modulus of 3.40 on the average.

Althogh there is a slight variation in the specific gravity of sand in the previous investigation, this variation is very small in the present investigation. In the dry bases, the average value of specific gravity is 2.55 and in the saturated surface dry basis, this value is 2.62.

Also in the absorption test, the results in the two investigations differ largely. However, in the present investigation, the average absorption is 1.20 %.

From the above results, specially in the present investigation, the riverbed deposit of Amban Ganga is suitable both as a filter material for the fill type dams and as the fine aggregate in the concrete dam.

Further, in order to grasp the mechanical properties of riverbed deposit, triaxial compression tests are being conducted using sand with a relative density of 65 %.

The grain size distribution curve of rock blastings obtained from the adit is shown in Fig. II.3.9 (curve MKF-28). Since the content of silt and finer particles is over 30 %, this material is not considered suitable for the filter material or for the fine aggregate.

3.3.3 Suitability as Filter Material

The river sand of Amban Ganga is the only material available in the close proximity of the damsite and suitable as a filter material for filltype dams and as a fine aggregate for the concrete dam. The

TABLE II.3.10. SUMMARY OF LABORATORY TESTS ON RIVERBED MATERIAL AND ROCK BLASTINGS

Sample No.		MKF 28	MKF 23	MKF 24	MKF 25	MKF 26	MKF 27	Mean
Location of Sampling (Distance from Dam Axis)		Q-I	1 km U/S	2 km U/S	3 km U/S	4 km U/S	5 km U/S	Value
Type of Material		Blastings	Riverbed Material					
Clay (smaller than 2 μ)	%	13	0	0	0	0	0	0
Silt (5μ – 60 μ)	%	17	0	0	0	0	0	0
Sand Fine (60μ–200μ)	%	14	1	2	1	1	1	1.2
Sand Medium (200μ – 600μ)	%	19	8	11	27	17	10	14.6
Sand Coarse (600μ – 2000μ)	%	27	71	67	69	75	63	69.0
Gravel (larger than 2000μ)	%	10	20	20	3	7	25	15.0
Percentage Passing 1/4" mesh		100	100	97	100	99	93	97.8
Persentage Passing 200 mesh		33	0	0	0	0	0	0
Uniformity Coefficient U_c			2.55	3.13	2.32	2.62	2.56	2.64
Specific Gravity Dry Basis			2.58	2.61	2.55	2.60	2.59	2.55
Specific Gravity Saturated Surface Dry Basis			2.62	2.64	2.58	2.63	2.61	2.62
Absorption	%		1.33	1.28	1.33	1.16	0.92	1.20
Fineness Modulus		1.77	3.52	3.58	2.89	3.28	3.73	3.40

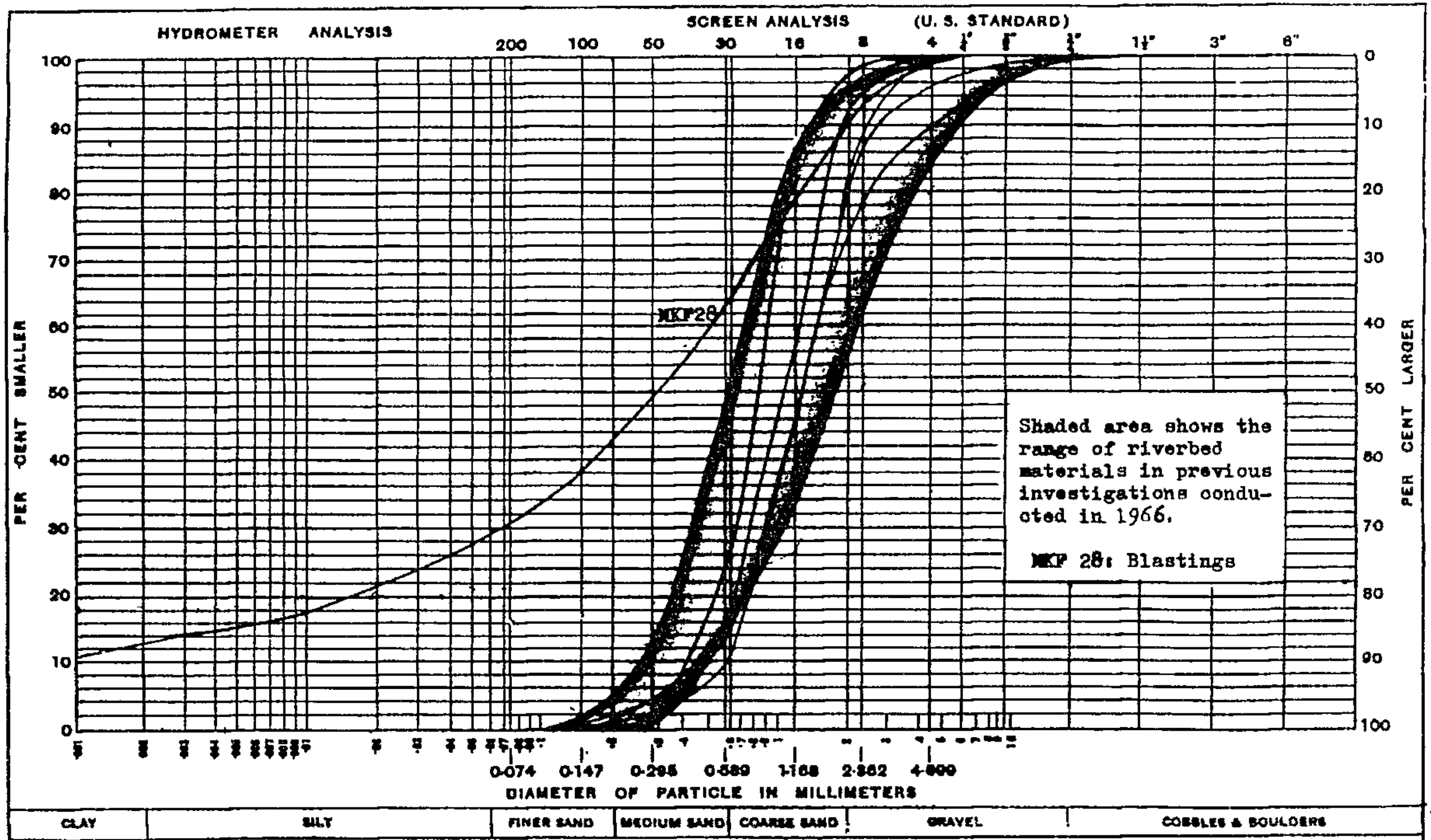


FIG. II.3.9. GRAIN SIZE DISTRIBUTION CURVES OF RIVERBED MATERIALS AND ROCK BLASTINGS tests conducted on rock blastings obtained from an adit in the damsite prove that rock blastings cannot substitute the river sand due to the very high content of silt and finer grains, which exceeds 30 %, in the former.

The river sand is found to be clean and homogeneous throughout the area investigated. Its relationship as a filter material with respect to the impervious material is excellent satisfying the conditions F_{15} $5B_{15}$ and F_{15} $5B_{85}$ (see Fig. II.3.10). Moreover, with practically no particles passing No.200 Standard Sieve, this sand satisfies all the conditions of a filter material, including the condition; F_5 0.0075 mm. The only shortcoming of this river sand is that its grain size distribution curve is not parallel to the grain size distribution curves of impervious material but rather steep. Even this would not be a problem if the width of the filter is taken larger than 3 m.

The design values of the filter material are established as follows based on Table II.3.10.

Moisture content w	= 6 %
Specific Gravity of Soil Particles	= 2.62
Dry Density γd	= 1.80 t/m^3
Bulk Density γt	= 1.91 t/m^3
Cohesion C	= 0
Angle of Internal Friction ϕ	= 30°

Since the results of the tests for the determination of density and the results of triaxial compression tests conducted at 65 % relative density are yet to be obtained, the generally used values are adopted here tentatively. The angle of internal friction of sand is generally in the range of 30° - 35° and the lowest value of 30° is taken here as the design value.

3.3.4 Suitability as a Fine Aggregate for Concrete

The fine aggregates for dam concrete should be clean, excellent in hardness and durability, of suitable particle size and shold be free from harmful amounts of dirt, mud and organic material etc. In this

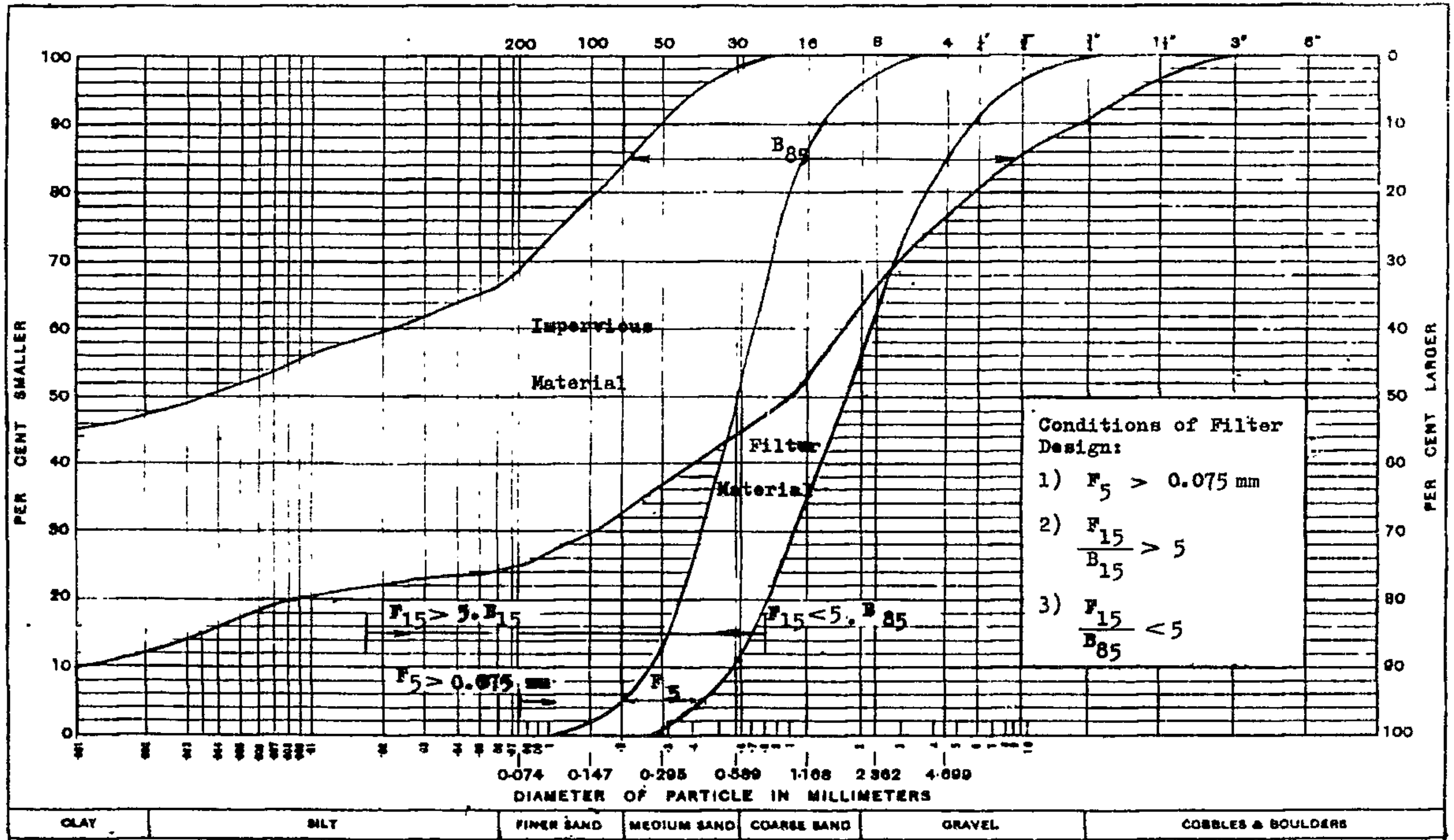


FIG. II.3.10. CONDITIONS FOR THE DESIGN OF FILTER respect, riverbed material of Amban Ganga is very clean and practically does not contain any harmful amounts of organic material etc.

The most appropriate grain size distribution of fine aggregates for dam concrete is said to be within the range shown in Table II.3.11, which is established with long practical experience. Particles finer than 0.15 mm are very important both in reducing the bleeding of concrete and improving the workability. However, the riverbed material tested in this investigation, practically has no particles finer than 0.15 mm and on the other hand is a relatively coarse sand with an average fineness modulus of 3.40.

Therefore, this riverbed material alone could not play the role of fine aggregate satisfactorily. However, it can be used satisfactorily as a fine aggregate for dam concrete by adjusting its grain size distribution using fine sand available in the sands of the river or using the fine material obtained by crushing the rocks available in the damsite.

Next, with regards to the use of quarry rocks for a fine aggregate for dam concrete, the tests conducted in this investigation prove that this material is not desirable for this purpose due to its high content (38 %) of particles finer than 0.15 mm. Moreover, considering the shape of crushed paritcles which has a large influence over the strength of concrete and the large costs necessary for crushing plants etc., river sand is remarkably superior to the rock blastings in many ways.

3.3.5 Matters of Special Attention

In collecting the material, since it is necessary to dredge the riverbed material from a relatively long stretch of the river, the use of pump dredgers are considered desirable rather than drag lines etc., from the view points of movability and efficiency. However, in this case, considerable turbity of river can be expected due to turbulance at the riverbed and it may be necessary to take suitable precautions.

TABLE II.3.11 Comparison of the Standard Range of Grain Size Distribution Recommended for Fine Aggregates in Dam Concrete with the Actual Gradation of River Sand and Rock Blastings

Particle Size (mm)	Recommended Standard Range by Weight	River Sand (Amban Ganga)		Rock Blastings	
		Actual Range by Weight (%)	Remarks	Actual Range by Weight (%)	Remarks
10.0 – 5.0	0 – 8	0 – 10	Satisfactory	1	Satisfactory
5.0 – 2.5	5 – 25	1 – 22	Satisfactory	5	Satisfactory
2.5 – 1.2	10 – 25	10 – 28	Satisfactory	13	Satisfactory
1.2 – 0.6	10 – 30	27 – 38	Realtively high	16	Satisfactory
0.6 – 0.3	15 – 30	9 – 26	Satisfactory	15	Relatively Low
0.3 – 0.15	12 – 20	1 – 12	Relatively Low	12	Relatively Low
0.15 – 0	3 – 10	0 – 1	Relatively Low	38	Excessive

3.4 Rock Material and Coarse Aggregates for Concrete

3.4.1 Available Quantity and the Selection of Quarries

In the investigations conducted in 1965, after reconnaissance of the vicinity of damsite, 4 spots were considered as the possible quarries to collect rock material for the rockfill dam and coarse aggregates for the concrete dam. According to the report on this investigation, Quarry No.1 is located 3.5 km north of the damsite and consists mainly of Crystalline Limestone. Quarry No.2 is located on the left bank of the river about 2.0 km upstream of the dam site. This too, has Crystalline Limestone as the main rock type. Quarry No.3 is a small hill located on the left bank near Elahera Anicut in the downstream and consists mainly of Charnockite. Quarry No.4 is located on the right bank about 6 km downstream and consists of Charnockite.

In the present investigation, reconnaissance of these proposed quarries was made once again and it was found that Quarries No.1 and No.4 are not preferable for long distance of haulage, while Quarries No.2 and No.3 are both small hills and not sufficient for a massive requirement (D. II.17).

In the other hand, the hill with its peak at about E.L. 355 m, proposed by the Japanese Preliminary Survey Team as a prospective quarry, is located on the right bank about 1.2 km upstream of the damsite (see D. II.18).

Geologically, this area consists of gneiss, charnockits, crystalline limestone, calc gneiss, etc., of the Pre-Cambrian Highland Series. All of these rocks are in fresh condition hard and homogeneous with very few cracks, qualifying this site as an excellent quarry for rock materials and coarse aggregates. Results of Boring DM-29 show that rocks above E.L 225 m are gneiss and charnockite while those below this elevation are mainly crystalline limestone and calc gneiss.

The strike of the rocks varies from N-S to N 40°E. Dip is about 10° - 30° to west. Fault structures do not exist in this area.

Quaternary deposit covering these baserocks, is only top soil not exceeding 1 m - 2 m in thickness. Talus deposits are rather rare.

The flat areas close to Amban Ganga are covered with river deposits.

In Boring DM-29, the thickness of weathered zone is about 15 m. This weathered zone is in a condition where relatively fresh blocks remain among decomposed rock. Blocks of fresh gneiss are very hard and suitable as aggregates for concrete.

By selecting the area above E.L.200 m of this hill for quarry, it will be easy to construct a road for the transport of materials to the right bank of the damsite. This proposed quarry, which is refered to as Quarry Q-I, has a haulage diatance of only about 1.5 km. By the adoption of Bench Cut Method, it is possible to obtain sufficient cut face. This proposed quarry meets in every way requirement of a massive production of material. Sufficient material is available here only by cutting a small part of this hill (see Fig. II.3.11).

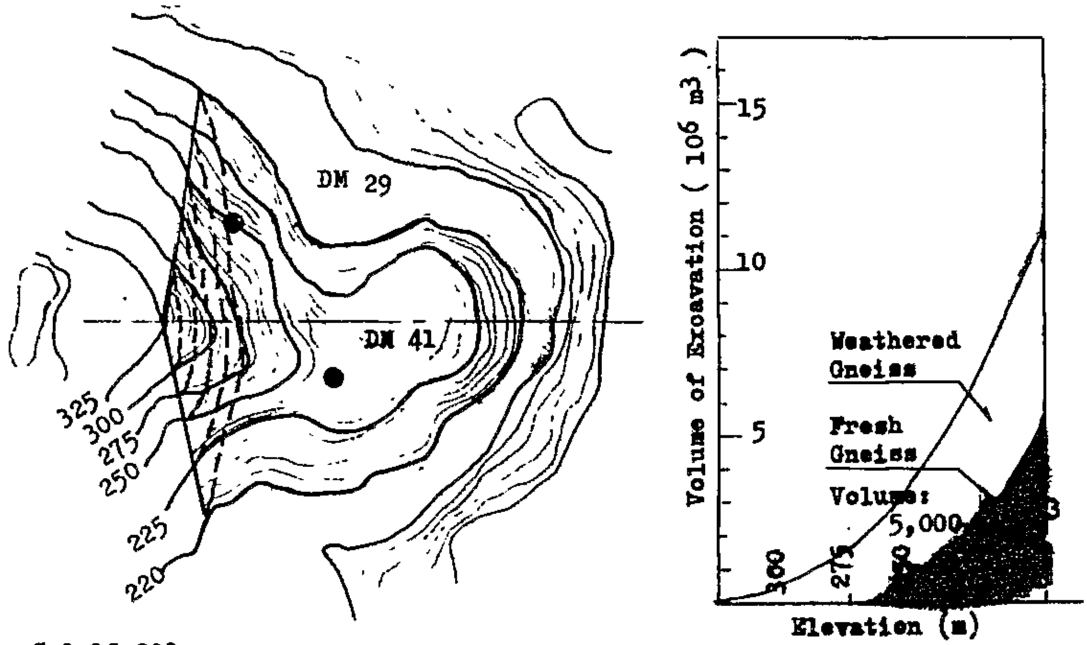
With regards to the rock material for the rockfill dam, Moragahakanda Hill which makes the left abutment for the second sub dam is considered suitable for a quarry as proposed earlier by the Japanese Preliminary Survey Team. This area hereinafter refered to as Quarry Q-II (see D. II. 18) is geologically very much similar to Quarry Q-I. In Boring DM-39, rocks above E.L. 280 are seen to be gneiss and charnockite while those below this elevation are calc gneiss, crystalline limestone etc. Both drillings DM-37 and DM-40 encountered crystalline limestone or calc gneiss. As in the case of Quarry Q-I, all the fresh rocks are hard and homogeneous with very few cracks.

The strike of the rocks is almost in the N-S direction and the dip ranges from 15° to the horizontal.

Quaternary deposit distributed over the baserock is only topsoil of thickness not more than 1 m - 2 m, while very thin layers of talus deposit are observed rarely.

Thickness of the weathered zone is about 4 m in DM-37, 9 m in DM-39 and 2 m in DM-40. The thickness in DM-39 is deemed common on the slope, whereas thin weathered zone as is seen in DM-37 and DM40 is exceptionally characteristic for the terrace which had undergone intensive erosion in the past.

FIG. II.3.11 AVAILABILITY OF ROCK MATERIALS (QUARRY I)



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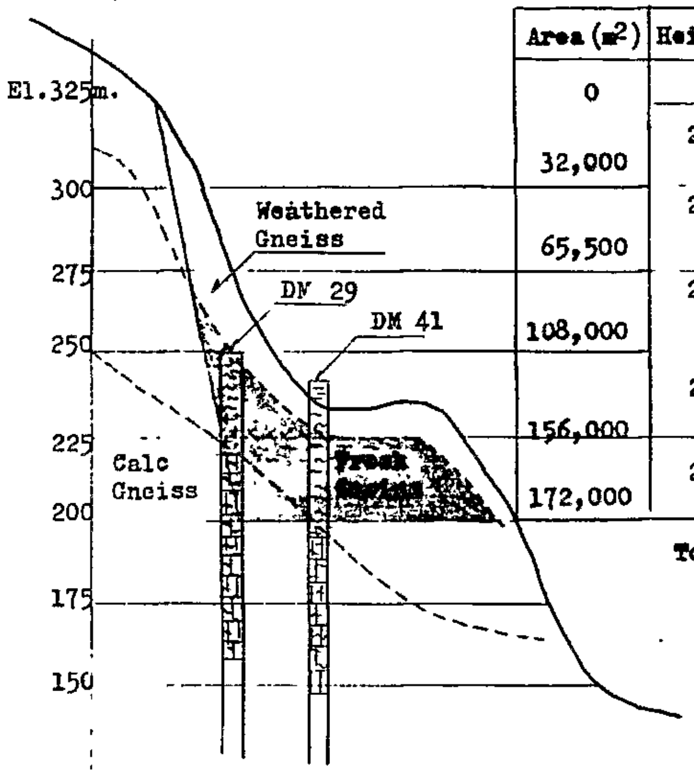


Area (m^2)	Height (m)	Volume (m^3)	
0			
	25	400,000	
32,000			400,000
	25	1,219,000	
65,500			1,619,000
	25	2,169,000	
108,000			3,788,000
	25	3,300,000	
156,000			7,088,000
	25	4,100,000	
172,000			11,188,000

Total Volume of Excavation

S=1:10,000

Weathered condition is very much similar to that in Quarry Q-1, with relatively fresh blocks contained in decomposed rock.

Considering the eastern side of this Moragahakanda Hill becomes the abutment to the second sub dam, the quarry should be located on a relatively steep slope above E.L. 200 m on the southeast face of the hill, for advantages as follows:-

* By selecting the quarry at an elevation above the highest water level in the reservoir, future problems of leakage through exposed rock could be avoided.

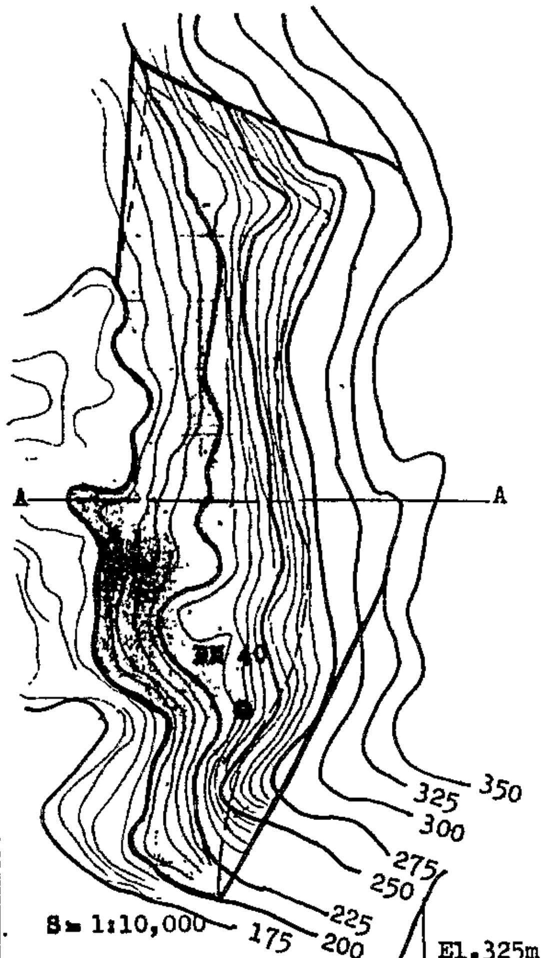
* The soil covering is thin.

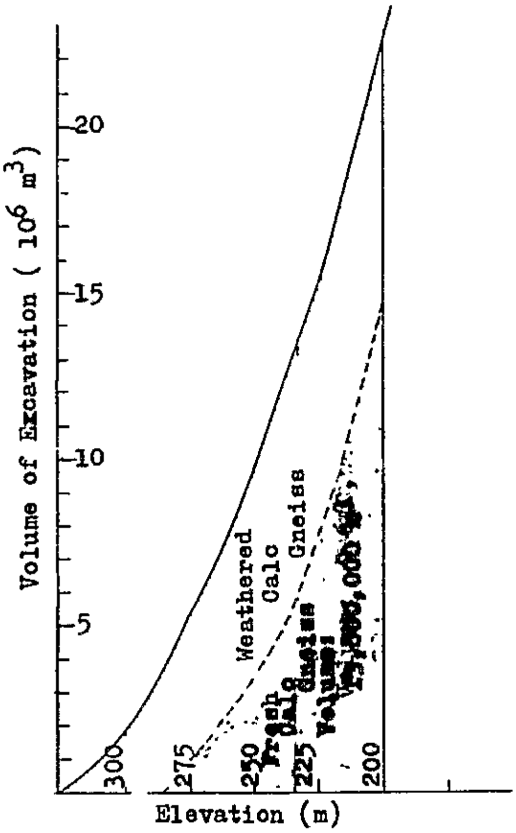
* To make it possible to have cut faces as long as possible.

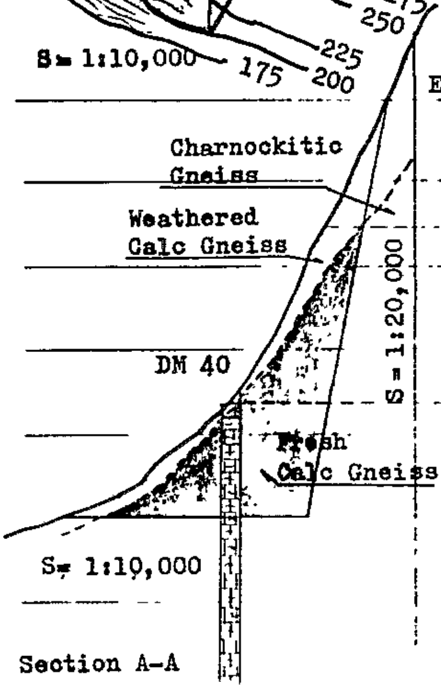
* To bring down the average gradient of the road for transport of materials to about 5 %.

As a result, the average distance of haulage from the Quarry Q - II to the damsite is about 1.5 km. Considering the scale of this hill and the quality of material available here, there is no problem with respect to the quantity of exploitable rock material (see Fig. II.3.12).

FIG. II.3.12. AVAILABILITY OF ROCK MATERIALS (QUARRY II)







El.	Area (m^2)	Height (m)	Volume (m^3)
El.325m	0		
		25	1,738,000
300	139,000		1,738,000
		25	3,594,000
275	148,500		5,332,000
		25	4,319,000
250	197,000		9,651,000
		25	5,663,000
225	256,000		15,314,000
		25	7,525,000
200	346,000		22,839,000
175			

Total Volume of Excavation

3.4.2 Physical and Mechanical Properties

Quarries Q-I and Q-II consist of various rock types such as gneiss, limestone, calc gneiss, charnockite etc., either in fresh condition or in weathered condition. Several samples picked up from drill cores in various degrees of weathering were tested for the physical and mechanical properties such as specific gravity, absorption and compressive strength. The results of these tests are summarized in Table II.3.12.

In this table, samples denoted with DM-29 represent Quarry Q-I, while those with DM-37 represent Quarry Q-II. The remaining samples are obtained from the drillings made along the dam axis.

It is clear from this table that fresh gneiss has a specific gravity in the range of 2.91 to a rarely high value of 3.35, and a mean value of 3.04. Specific gravity of weathered gneiss is about 2.82 while that of calc gneiss is in the range of 2.83 - 2.91. Fresh limestone shows values in the range of 2.88 - 2.92.

Except for weathered gneiss which shows a relatively high degree of absorption in the range of 0.37 % - 0.57 %, all the rock types show values generally less than 0.25 %. The average absorption for the fresh rocks of all types is 0.17 %.

The compressive strength of fresh gneiss is realatively high with values varying from 1,111 kg/cm^2 to 1,832 kg/cm^2 and with an average value of 1,542 kg/cm^2. Calc gneiss shows a compressive strength in a wide range of 661 kg/cm^2 - 1,124 kg/cm^2. Although only two samples were tested, Fresh limestone has a compressive strength in the range of 668 kg/cm^2 = 842 kg/cm^2. It was impossible to determine the strength of weathered gneiss because of cracks in the boring core specimens.

As clear from the forgoing, the rocks available in Quarries Q-I and Q-II have a compressive strength in a wide range of about 650 kg/cm^2 - 1,800 kg/cm^2.

Furthermore, tests were also conducted with blasted rock samples obtained from outcrops in the vicinity of Quarries Q-I and Q-II. The results of these tests for the various properties such as absorption,

TABLE II.3.12. LABORATORY TEST RESULTS OF ROCK SAMPLES FROM BORING CORE

SAMPLE No.	LOCATION OF EXTRACTION		ROCK TYPE	SPECIFIC GRAVITY		ABSORPTION	COMPRESSIVE STRENGTH
	SITE	DEPTH (M)		S.S.D	DRY	(%)	(Kg/cm²)
DM 29-83	Quarry I	14.5	Weathered	2.817	2.807	0.374	- *
DM 29-85	"	14.5	Gneiss	2.832	2.816	0.570	- *
DM 29-127	"	19.0	Fresh Gneiss	-	-	-	1832
DM 29-128	"	19.2	"	2.914	2.912	0.064	1492
DM 29-135	"	20.8	"	-	-	-	1542
DM 29-139	"	20.9	"	2.997	2.986	0.377	1200
DM 29-155	"	23.3	"	3.164	3.162	0.080	1813
DM 29-162	"	24.5	"	2.803	2.797	0.202	1536
DM 29-162	"	24.5	"	3.353	3.349	0.134	1536
DM 29-176	"	26.1	"	-	-	-	1818
DM 29-177	"	26.2	"	-	-	-	1111
DM 29-18[illegible]	"	28.8	Calc Gneiss	2.834	2.827	0.251	1124
DM 29-220	"	37.7	"	2.847	2.842	0.185	661
DM 29-254	"	45.3	Fresh Limestone	2.880	2.874	0.233	668
DM 37-16	Quarry II	2.6	Calc Gneiss	2.914	2.913	0.038	773
DM 37-37	"	6.8	Fresh Limestone	2.922	2.919	0.107	842
DM 6-2	Dam Axis	11.7	Fresh Gneiss	3.055	3.054	0.037	1996
DM 7-18	"	11.5	"	3.063	3.061	0.021	1847
DM 16-77	"	15.7	"	2.917	2.916	0.045	1268
DM 16-86	"	18.2	"	2.927	2.926	0.043	1792
DM 19-28	"	13.1	Crystalline Limestone	2.896	2.891	0.149	473
DM 20-23	"	7.0	Gneiss	3.180	3.106	0.052	1889
DM 21-25	"	15.8	Calc Gneiss	2.915	2.911	0.163	1132

Note: * Unable to determine the compressive strength due to cracks in the rock samples.

TABLE II.3.13. SUMMARY OF THE TEST RESULTS OF QUARRY MATERIALS - (ROCK BLASTINGS)

Quarry No.			I					II					II				
Laboratory No.			MNQA-1					MNQB-1					MNQB-2				
Rock Classification			Basic Charnokite					Weathered Limestone					Weathered Limestone				
Abrasion Test	After 100 rev		7.40 %					21.43%					22.53%				
	After 500 rev		36.07 %					67.80%					69.15%				
Aggregate Size	Sieve Size Passing	Retained	Soundness % Loss	Bulk Density (t/m³)	Absorption %	Specific Gravity SSD	Specific Gravity DRY	Soundness % Loss	Bulk Density (t/m³)	Absorption %	Specific Gravity SSD	Specific Gravity DRY	Soundness % Loss	Bulk Density (t/m³)	Absorption %	Specific Gravity SSD	Specific Gravity DRY
Coarse Aggregates	3"	1 1/2"	0.45	1.584	0.284	3.004	3.069	1.33	1.469	0.247	2.900	2.899	1.83	1.505	0.239	2.919	2.912
	1 1/2"	3/4"	1.12	1.607	0.378	2.995	3.058	8.97	1.531	0.356	2.930	2.920	6.99	1.536	0.530	2.890	2.870
	3/4"	3/8"	2.56	1.531	0.102	3.052	3.049	3.70	1.502	0.20	2.820	2.765	11.24	1.565	0.620	2.907	2.890
	3/8"	US-4	4.70	1.439	0.315	3.043	3.034	15.80	1.568	0.51	2.911	2.896	13.90	1.567	0.504	2.918	2.903
Fine Aggregates	US-4	US-8	3.2					6.5					14.9				
	US-8	US-16	6.5					7.2					11.0				
	US-16	US-30	4.5					4.5					6.3				
	US-30	US-50	4.3					6.2					6.7				
	US-4	US-200		1.823	1.70	3.106	3.053		1.717	0.49	2.944	2.929		1.693	2.04	2.810	2.760

Remarks:

1) Los Angles Abrasion Test was conducted as per Designation 21 of U.S.B.R. Concrete Manual using Grading A.

2) Soundness Test was conducted as per Designation 19 of U.S.B.R. Concrete Manual by the Sodium Sulphate Method.

abrasion, soundness, density and specific gravity are presented in Table II.3.13. The rock types used in these tests are basic charnockite in the case of Quarry Q-I and limestone in the case of Quarry Q-II. These rock material obtained from outcrops are generally weathered during the long period of their exposure to the atmosphere.

The specific gravity of charnockite in Quarry Q-I is about 3.02 and that of limestone in Quarry Q-II is about 2.91.

In the soundness test by the Sodium Sulphate Method as per Designation 19 of U.S.B.R. Concrete Manual, the percentage loss is less than 4.7 % in the case of charnockite, but as large as 15.8 % for the particles passing 3/8" sieve and retained in US-4 sieve in the case of weathered limestone. However, the average percentage loss of all coarse aggregates passing 3" sieve and retained in US-4 sieve is only 2.2 % in the case of charnockite and 7.9 % in the case of weathered limestone.

Abrasion of charnockite is 7.4 % after 100 revolutions and 36.1 % after 500 revolutions as against the corresponding values of 22.0 % and 68.4 % of weathered limestone.

The average absorption of coarse aggregates is 0.27 % for charnockite and 0.40 % for weathered limestone.

3.4.3 Suitability as Rock Material

As mentioned earlier in 3.4.1, Quarry Q-II is meant for rock material for the rockfill dam. The laboratory test of the rock samples gives compression strength in the range of 650 kg/cm^2 - 1,800 kg/cm^2. The percentage loss in soundness test gradually decreases with the increase in size for particles above 5 mm. Taking the above into account, this material can be satisfactory for rock material for the rockfill type dam.

The design values of rock material are tentatively established as follows;

Moisture Content w = 2 %
Specific Gravity G_s = 2.70
Dry Density γ_d = 1.80 t/m^3

Bulk Density γ_t = 1.84 t/m^3

Angle of Internal Friction ϕ = 40°

(assumed conservatively)

Similar quality can be expected for calcareous rocks in the sub-damsite No.1. In case that diversion channel is excavated through this site, the excavated material can be utilized for rock fill material.

3.4.4 Suitability as Coarse Aggregates for Concrete

Quarry Q-I is proposed as the quarry for carse aggregates for dam concrete. Results of the tests (see Table II.3.13) show that rocks obtained from this quarry sufficiently satisfy the following conditions for coarse aggregates as specified in the Concrete Manual;

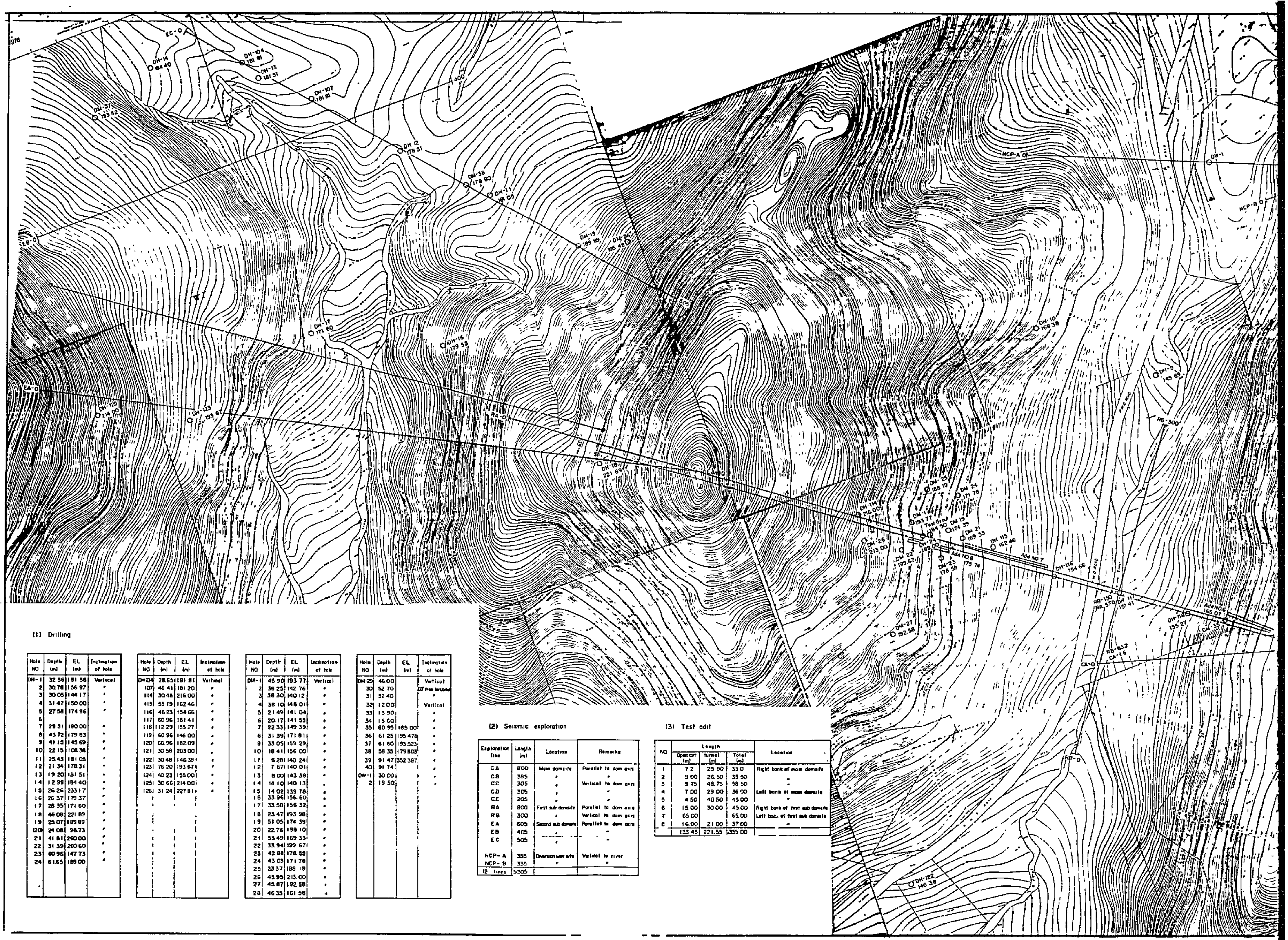
Average absorption	= 0.22 % - 1.0%
Soundness (% loss)	= 2.2 % - 10 %
Abrasion after 100 rev.	= 7.4 % - 10 %
Abrasion after 500 rev.	= 36.1 % - 40 %
Specific gravity	= 3.02 - 2.60

By selecting rocks of charnockite and gneiss in Quarry Q-I above E.L. 200, sufficient quantity of material suitable as coarse aggregates for the concrete dam could be obtained.

3.4.5 Matters of Special Attention

The Large Scale Direct Shear Tests for which the preparations are being made at the field should be conducted without fail prior to the detailed design of the dams. The results of these tests should be taken into account in determining the design values.

At the stage of detailed design, it may be required to consider the necessity of excavating adits and conducting blasting tests in order to confirm the thickness of weathered zone and the variation of rock types in Quarries Q-I and Q-II.



(1) Drilling

Hole NO	Depth (m)	EL (m)	Inclination of hole
DH-1	32.36	181.36	Vertical
2	30.78	156.97	"
3	30.05	144.17	"
4	31.47	150.00	"
5	27.58	174.96	"
6			
7	29.31	190.00	"
8	45.72	179.83	"
9	41.15	145.69	"
10	22.15	108.38	"
11	25.43	181.05	"
12	21.34	178.31	"
13	19.20	181.51	"
14	12.99	184.40	"
15	26.26	233.17	"
16	26.37	179.37	"
17	28.35	171.60	"
18	46.08	221.89	"
19	25.07	189.89	"
20	24.08	98.73	"
21	41.81	260.00	"
22	31.39	260.60	"
23	60.96	147.73	"
24	61.65	189.00	"

Hole NO	Depth (m)	EL (m)	Inclination of hole
DH104	28.65	181.81	Vertical
107	46.41	181.20	"
114	30.48	216.00	"
115	55.19	162.46	"
116	46.23	154.66	"
117	60.96	151.41	"
118	112.29	155.27	"
119	60.96	146.00	"
120	60.96	182.09	"
121	30.58	203.00	"
122	30.48	146.38	"
123	76.20	193.67	"
124	40.23	155.00	"
125	30.66	214.00	"
126	31.24	227.81	"

Hole NO	Depth (m)	EL (m)	Inclination of hole
DM-1	45.90	193.77	Vertical
2	36.25	142.76	"
3	38.30	140.12	"
4	38.10	148.01	"
5	21.49	141.04	"
6	20.17	141.55	"
7	22.33	149.39	"
8	31.39	171.81	"
9	33.05	159.29	"
10	18.41	156.00	"
11	8.28	140.24	"
12	7.67	140.01	"
13	8.00	143.38	"
14	14.10	140.13	"
15	14.02	139.78	"
16	33.96	156.60	"
17	33.58	156.32	"
18	23.47	193.98	"
19	51.05	174.39	"
20	22.76	198.10	"
21	53.49	169.33	"
22	33.94	199.67	"
23	42.88	178.55	"
24	43.03	171.78	"
25	23.37	188.19	"
26	45.95	213.00	"
27	45.87	192.58	"
28	46.35	161.58	"

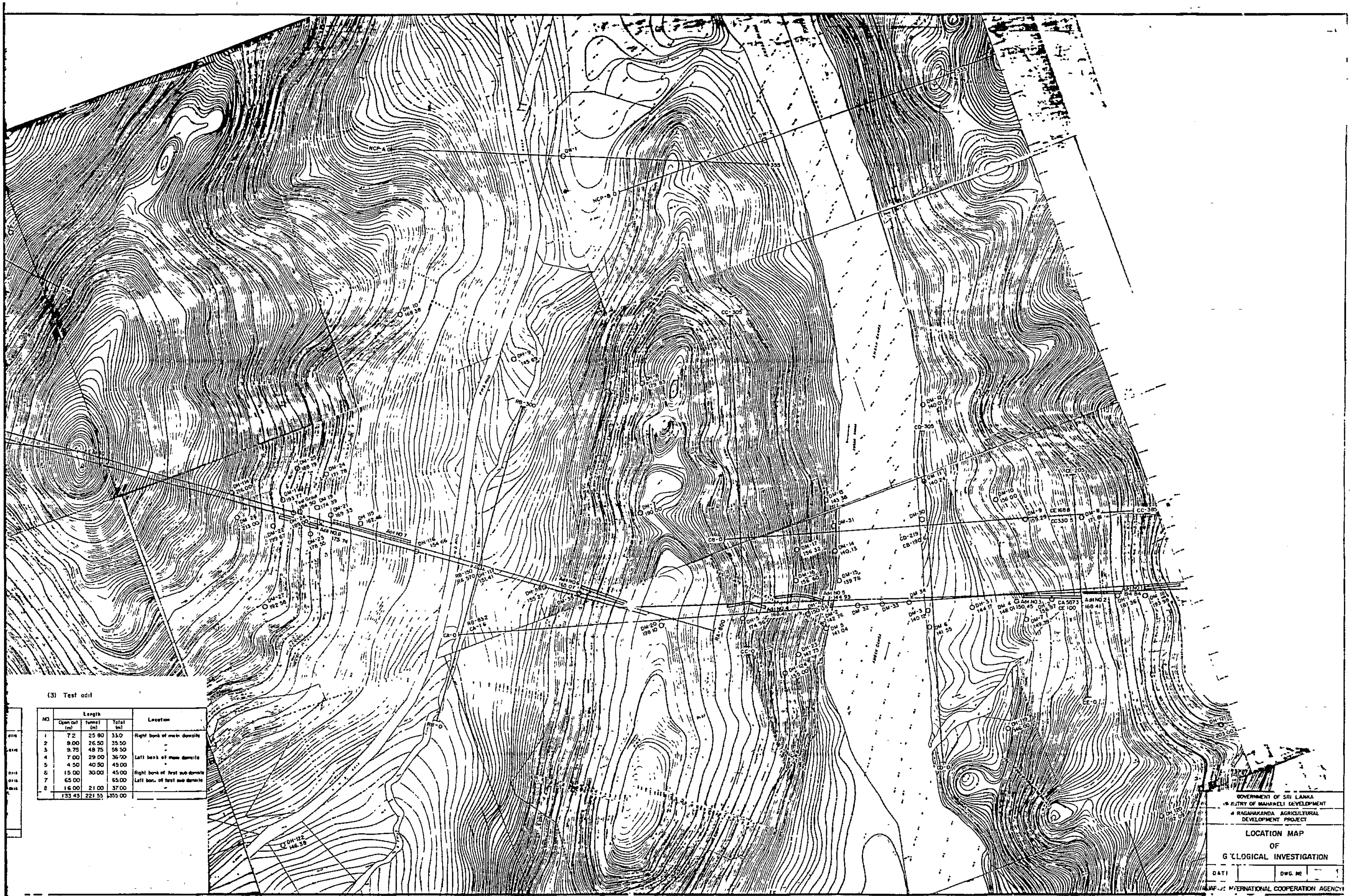
Hole NO	Depth (m)	EL (m)	Inclination of hole
DM-29	46.00		Vertical
30	52.70		60° from horizontal
31	52.40		"
32	12.00		Vertical
33	13.90		"
34	15.60		"
35	60.95	165.00	"
36	61.25	195.478	"
37	61.60	193.523	"
38	58.35	179.803	"
39	91.47	352.387	"
40	91.74		"
DW-1	30.00		"
2	19.50		"

(2) Seismic exploration

Exploration line	Length (m)	Location	Remarks
CA	800	Main damsite	Parallel to dam axis
CB	385	"	"
CC	305	"	Vertical to dam axis
CD	305	"	"
CE	205	"	"
RA	800	First sub damsite	Parallel to dam axis
RB	300	"	Vertical to dam axis
EA	605	Second sub damsite	Parallel to dam axis
EB	405	"	"
EC	505	"	"
NCP-A	355	Diversion weir site	Vertical to river
NCP-B	335	"	"
12 lines	5305		

(3) Test adit

NO	Length			Location
	Open cut (m)	tunnel (m)	Total (m)	
1	7.2	25.80	33.0	Right bank of main damsite
2	9.00	26.50	35.50	"
3	9.75	48.75	58.50	"
4	7.00	29.00	36.00	Left bank of main damsite
5	4.50	40.50	45.00	"
6	15.00	30.00	45.00	Right bank of first sub damsite
7	65.00		65.00	Left bank of first sub damsite
8	16.00	21.00	37.00	"
	133.45	221.55	355.00	



(3) Test adit

NO.	Length			Location
	Open cut (m)	tunnel (m)	Total (m)	
1	7.2	25.80	33.0	Right bank of main damsite
2	9.00	26.50	35.50	"
3	9.75	48.75	58.50	"
4	7.00	29.00	36.20	Left bank of main damsite
5	4.50	40.50	45.00	"
6	15.00	30.00	45.00	Right bank of first sub damsite
7	65.00		65.00	Left bank of first sub damsite
8	16.00	21.00	37.00	"
	133.45	221.55	355.00	

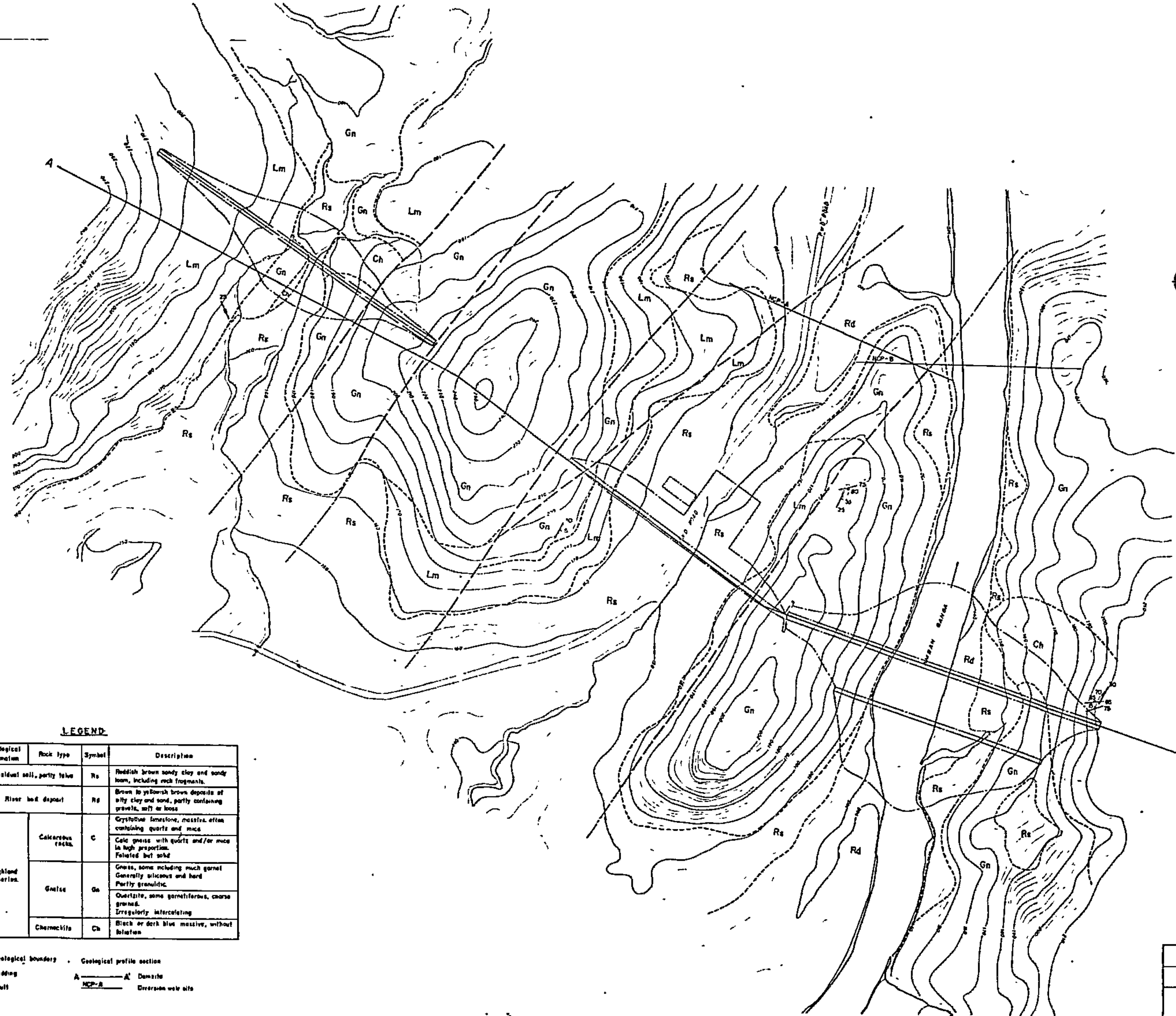
GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

RAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

LOCATION MAP
OF
GEOLOGICAL INVESTIGATION

DATE		DWG. №	

JAPAN INTERNATIONAL COOPERATION AGENCY



LEGEND

Geological age	Geological formation	Rock type	Symbol	Description
Quaternary	Residual soil, partly talus		Rs	Reddish brown sandy clay and sandy loam, including rock fragments.
	River bed deposit		Rd	Brown to yellowish brown deposits of silty clay and sand, partly containing gravels, soft or loose
Pre-Cambrian.	Highland series.	Calcareous rocks.	C	Crystalline limestone, massive, often containing quartz and mica
				Calc gneiss with quartz and/or mica in high proportion. Foliated but solid
		Gneiss	Gn	Gneiss, some including much garnet Generally siliceous and hard Partly granulitic.
				Quartzite, some garnetiferous, coarse grained. Irregularly intercalating
		Charnockite	Ch	Black or dark blue massive, without foliation

Geological boundary

Bedding

Fault

Geological profile section

A —— A' Damsite

NCP-A —— Diversion weir site

Scale

0 100m

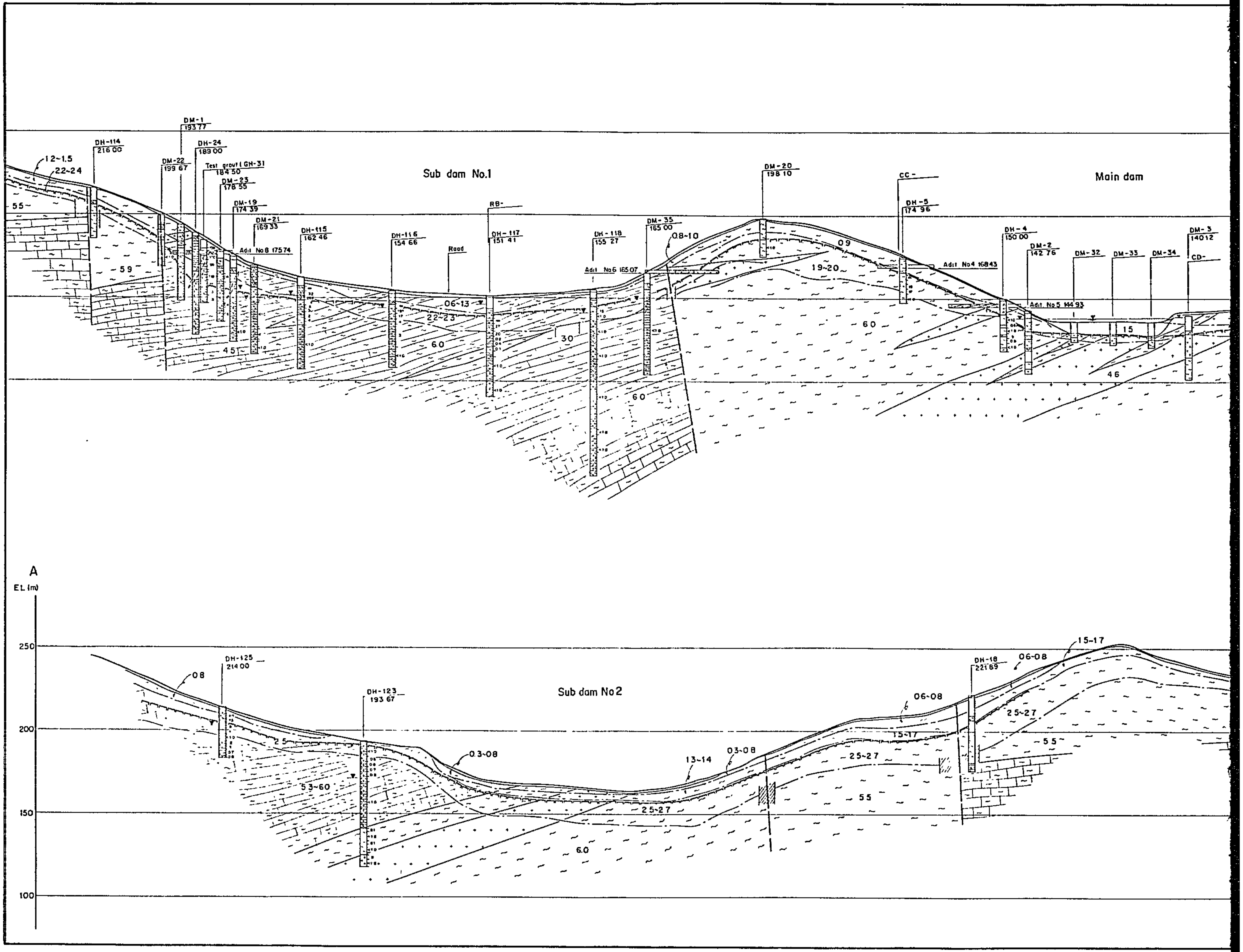
GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

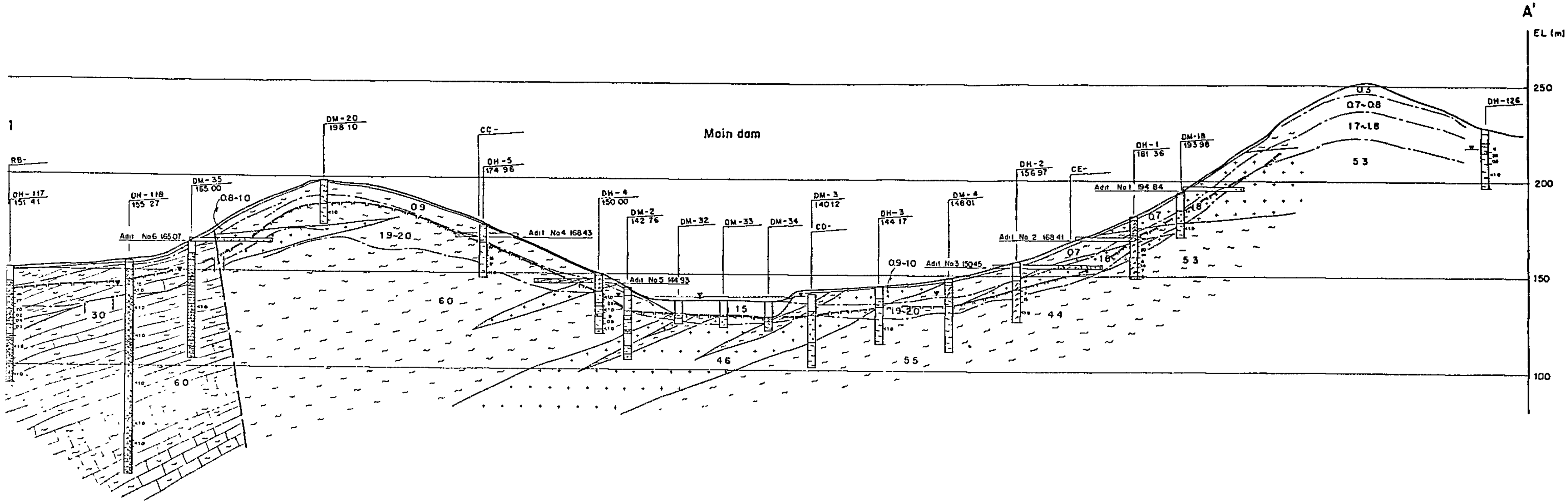
GEOLOGICAL MAP OF DAMSITE

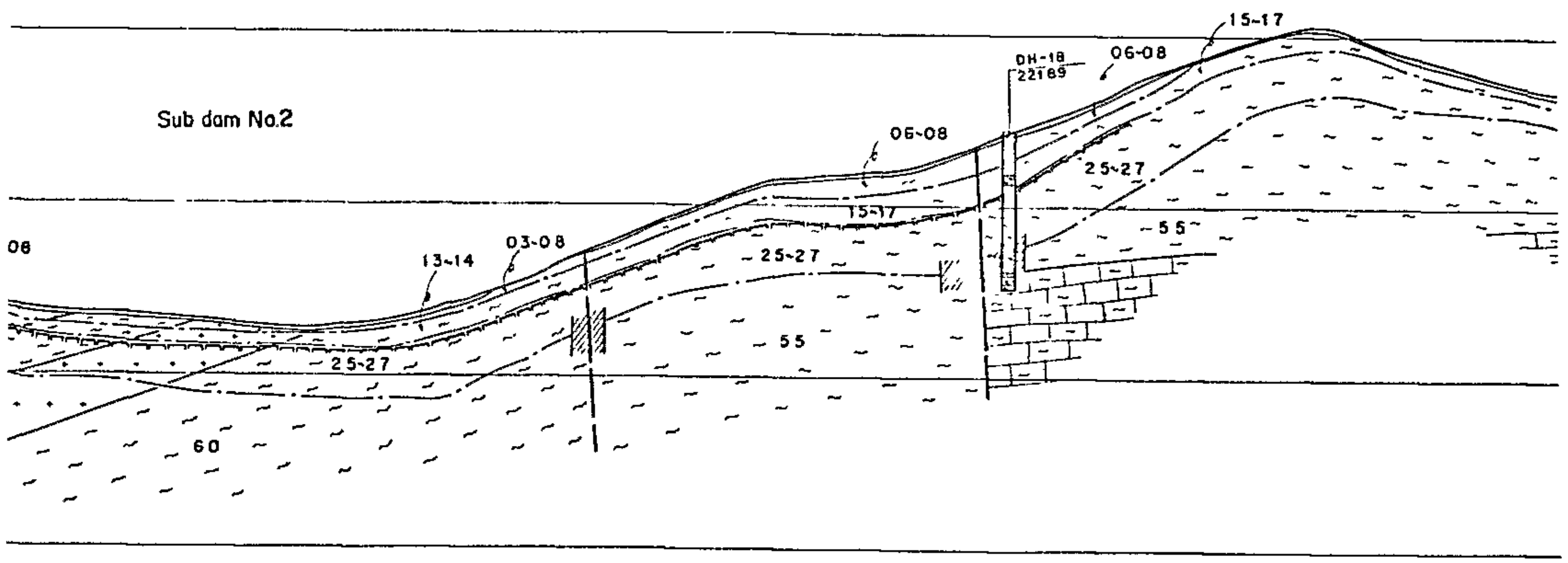
DATE | DWG № II.2

JAPAN INTERNATIONAL COOPERATION AGENCY



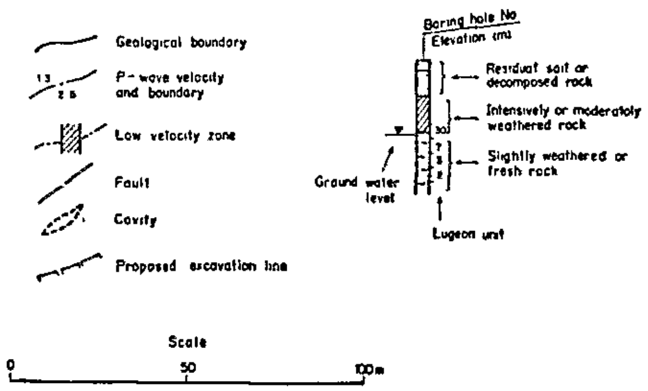
Sub dam No.1
Main dam
DH-114 216.00
DM-1 193.77
DM-22 199.67
DM-24 189.00
Test grout (GH-31) 184.50
DM-23 178.55
DM-19 174.39
DM-21 169.33
Adit No8 175.74
DH-115 162.46
DH-116 154.66
Road
RB-
DH-117 151.41
DH-118 155.27
Adit No6 165.07
DM-35 165.00
DM-20 198.10
CC-
DH-5 174.96
Adit No4 168.43
DH-4 150.00
DM-2 142.76
Adit No5 144.93
DM-32
DM-33
DM-34
DM-3 140.12
CD-
1.2~1.5
2.2~2.4
5.5~
5.9
4.5
0.6~1.3
2.2~2.3
6.0
3.0
6.0
0.8~1.0
0.9
1.9~2.0
6.0
1.5
4.6
A
EL (m)
250
200
150
100
Sub dam No2
DH-125 214.00
DH-123 193.67
DH-18 221.89
0.8
2.5
5.3~6.0
0.3~0.8
1.3~1.4
0.3~0.8
2.5~2.7
6.0
2.5~2.7
5.5
0.6~0.8
1.5~1.7
0.6~0.8
1.5~1.7
2.5~2.7
5.5





LEGEND

Geological age	Geological formation	Rock type	Symbol	Description
Quaternary	Residual soil, partly talus			Reddish brown sandy clay and sandy loam, including rock fragments
	River bed deposit			Brown to yellowish brown deposits of silty clay and sand, partly containing gravels, soft or loose
Pre-Cambrian	Highland series	Crystalline limestone		Composed of calcite, often containing quartz and mica, massive and solid
		Calc gneiss		Composed of calcite, with quartz and/or mica in high proportion Foliated but solid
		Gneiss		Generally siliceous and hard Some including much garnet Partly granulitic
		Charnockite		Black or dark blue, massive and solid, without foliation
		Quartzite		Composed of quartz, some including garnet Irregularly intercalating Generally hard and cracky



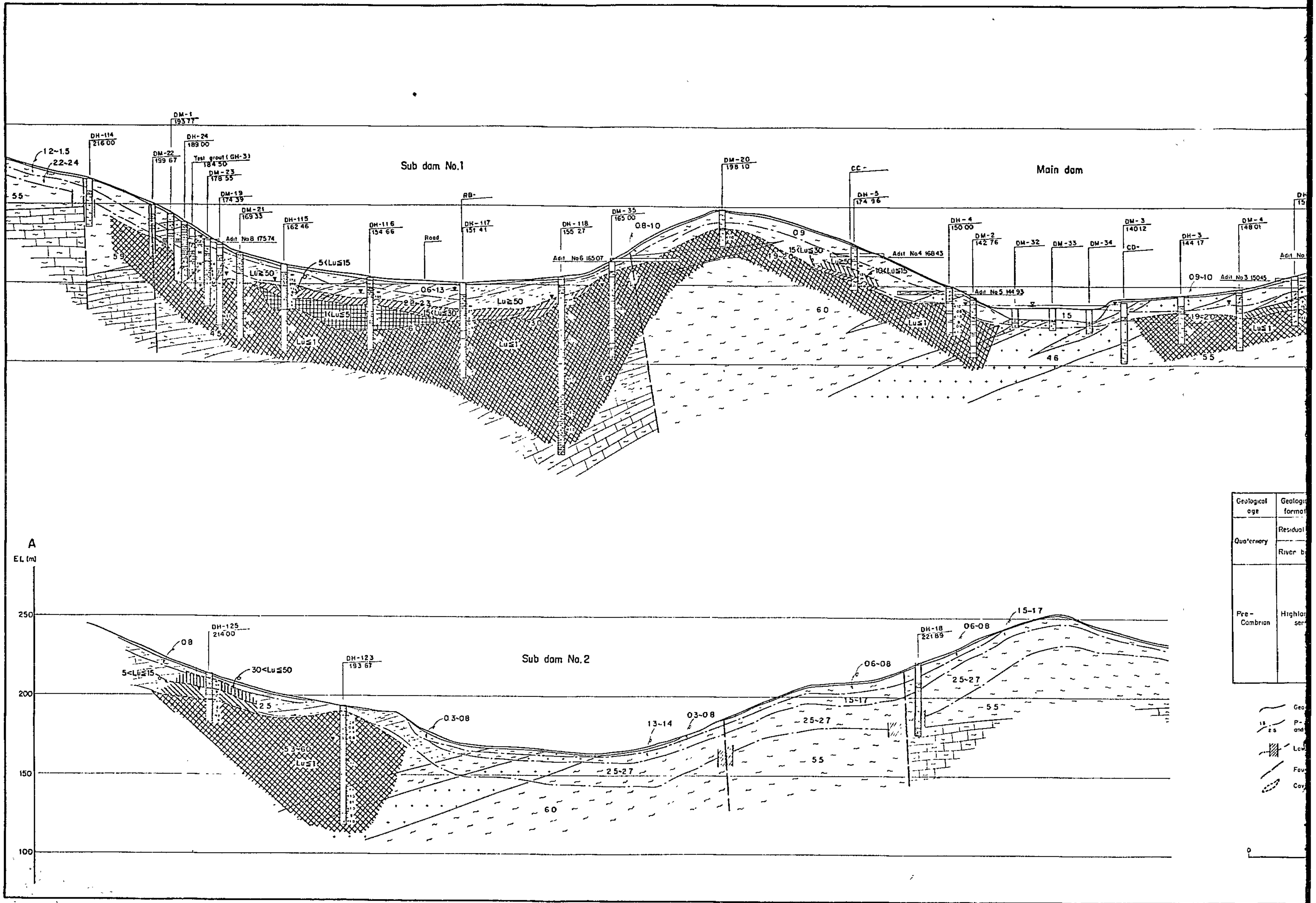
GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

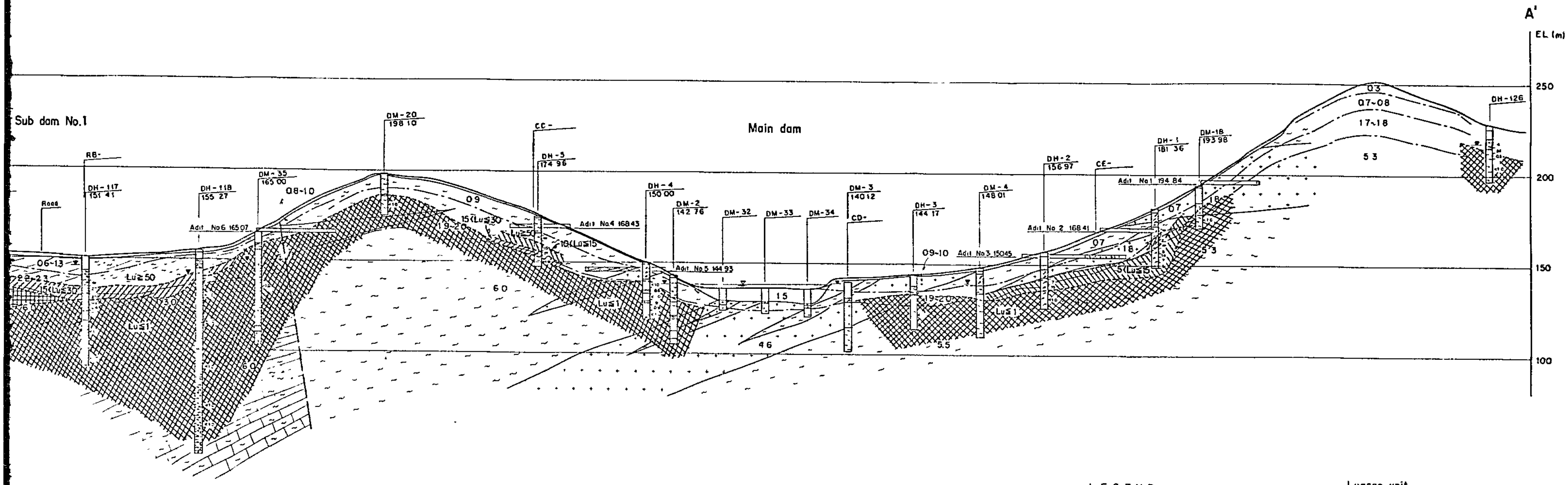
GEOLOGICAL PROFILE OF DAMSITE

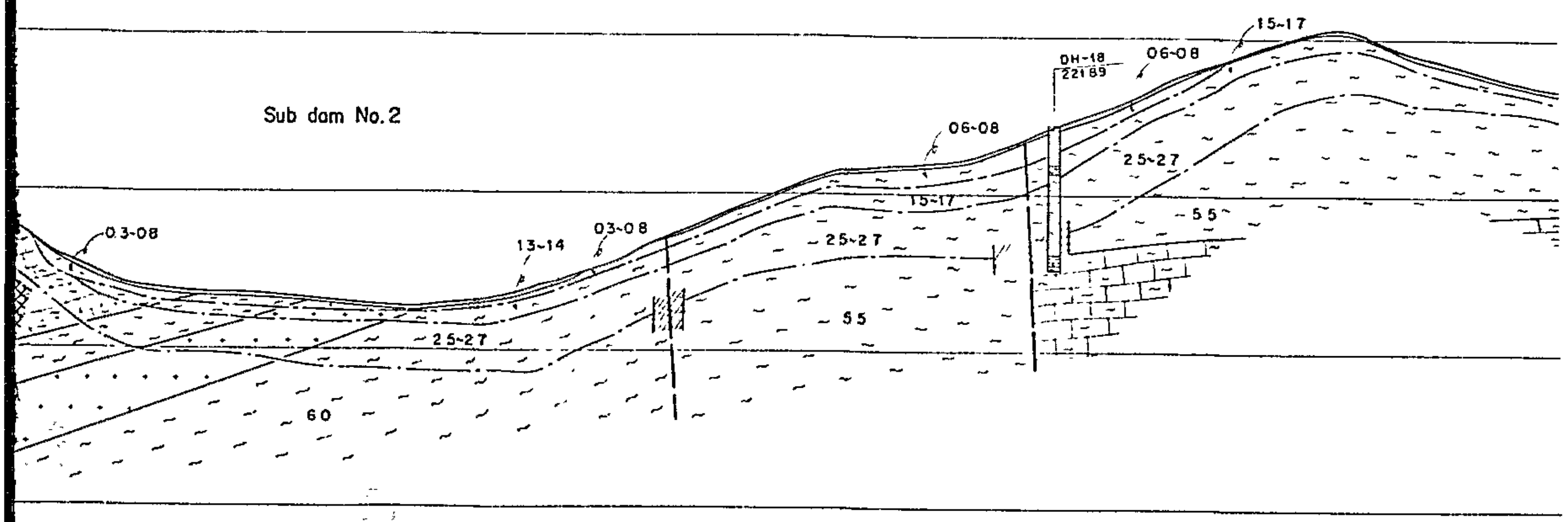
DATE		DWG. No	II. 3

JAPAN INTERNATIONAL COOPERATION AGENCY



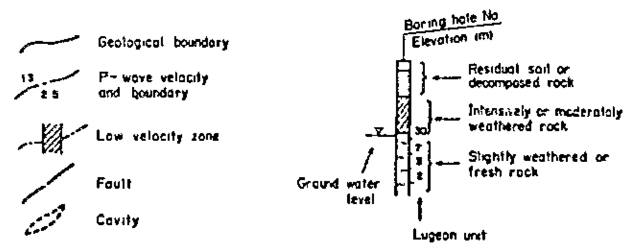
Sub dam No.1
Main dam
DH-114 216.00
DM-1 193.77
DM-22 199.67
DH-24 189.00
Test grout (GH-3) 184.50
DM-23 178.55
DM-19 174.39
DM-21 169.33
DH-115 162.46
DH-116 154.66
Road
RB-
DH-117 151.41
DH-118 155.27
DM-35 165.00
DM-20 198.10
CC-
DH-5 174.96
DH-4 150.00
DM-2 142.76
DM-32
DM-33
DM-34
DM-3 140.12
CD-
DH-3 144.17
DM-4 148.01
Adit No.8 175.74
Adit No.6 165.07
Adit No.4 168.43
Adit No.5 144.93
Adit No.3 150.45
Lu≧50
5<Lu≦15
1<Lu≦5
15<Lu≦30
10<Lu≦15
Lu≦1
Sub dam No.2
DH-125 214.00
DH-123 193.67
DH-18 221.89
30<Lu≦50
A
EL (m)
250
200
150
100
Geological age
Quaternary
Pre-Cambrian
Residual
River b
Highlan





LEGEND

Geological age	Geological formation	Rock type	Symbol	Description
Quaternary	Residual soil , partly talus			Reddish brown sandy clay and sandy loam , including rock fragments
	River bed deposit			Brown to yellowish brown deposits of silty clay and sand , partly containing gravels , soft or loose
Pre - Cambrian	Highland series	Crystalline limestone		Composed of calcite , often containing quartz and mica , massive and solid
		Calc gneiss		Composed of calcite , with quartz and/or mica in high proportion Foliated but solid
		Gneiss		Generally siliceous and hard Some including much garnet Partly granulitic
		Charnockite		Black or dark blue , massive and solid without foliation
		Quartzite		Composed of quartz , some including garnet Irregularly intercalating Generally hard and cracky



Scale
0 50 100m

Lugeon unit.

- 50 < Lu
- 30 < Lu ≦ 50
- 15 < Lu ≦ 30
- 5 < Lu ≦ 15
- 1 < Lu ≦ 5
- Lu ≦ 1

GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

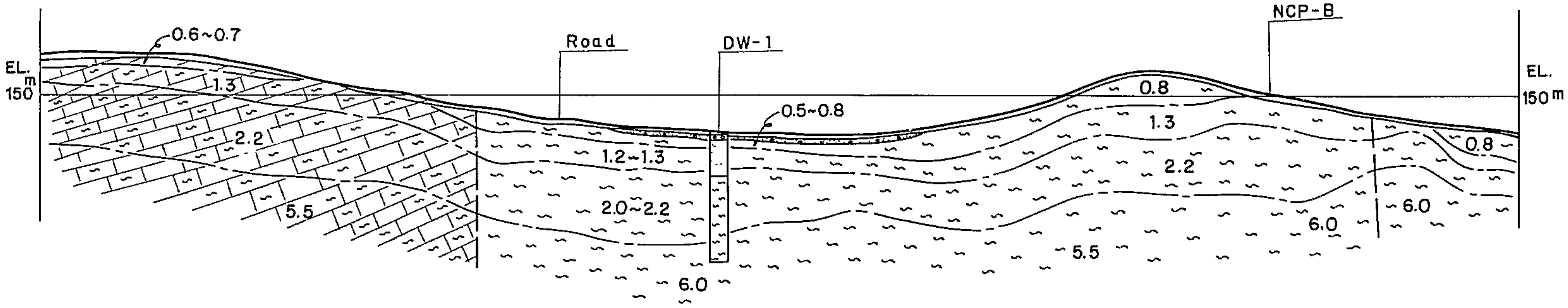
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

LUGEON MAP OF DAMSITE

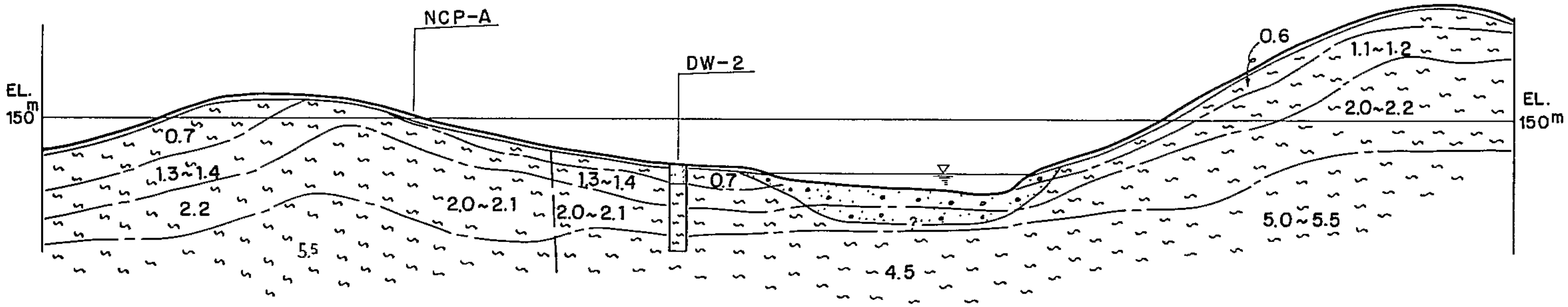
DATE		DWG. №	II . 4

JAPAN INTERNATIONAL COOPERATION AGENCY

NCP-A



NCP-B



LEGEND

Geological boundary

1.3 / 2.0 P-wave velocity and boundary.

Fault

Scale 0 — 50 m

Quaternary: Residual soil, Partly talus. / River bed deposit

Pre-cambrian: Gneiss, charnockite and granulite. / Calc gneiss and crystalline limestone

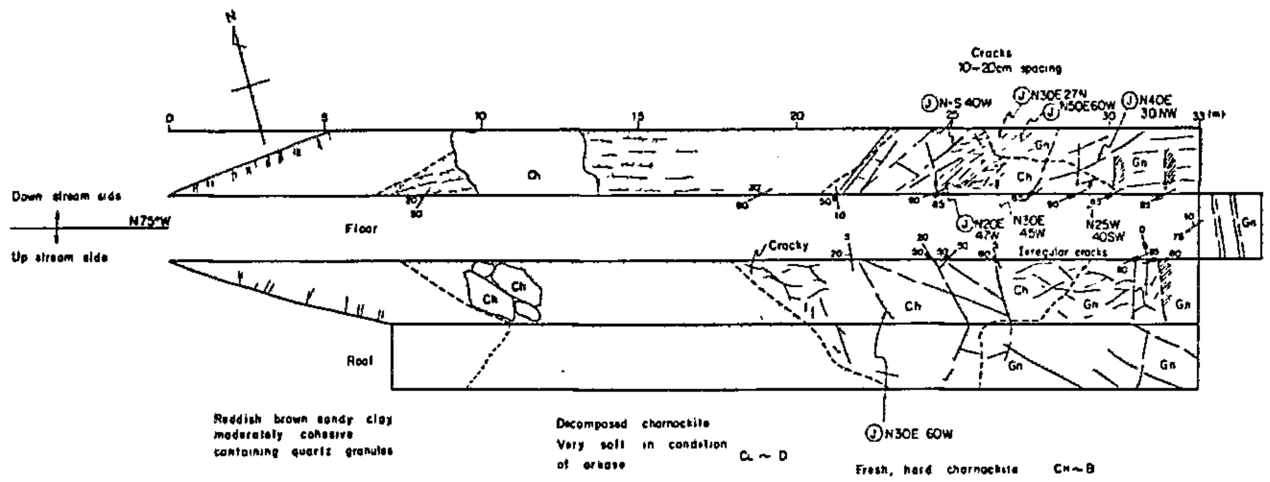
GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

GEOLOGICAL PROFILE OF DIVERSION WEIR SITE

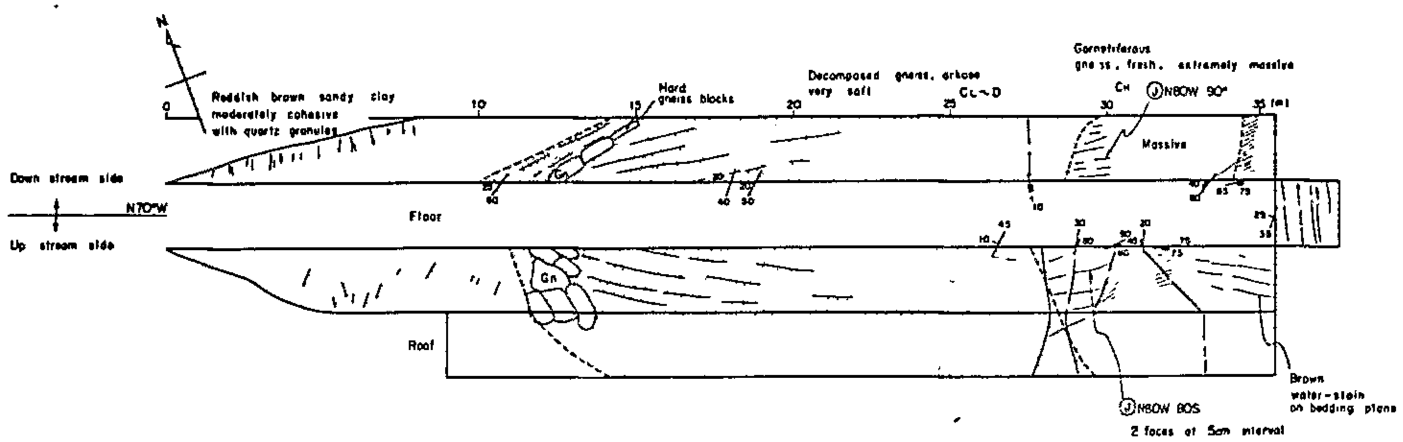
DATE		DW.G No	II . 5

JAPAN INTERNATIONAL COOPERATION AGENCY

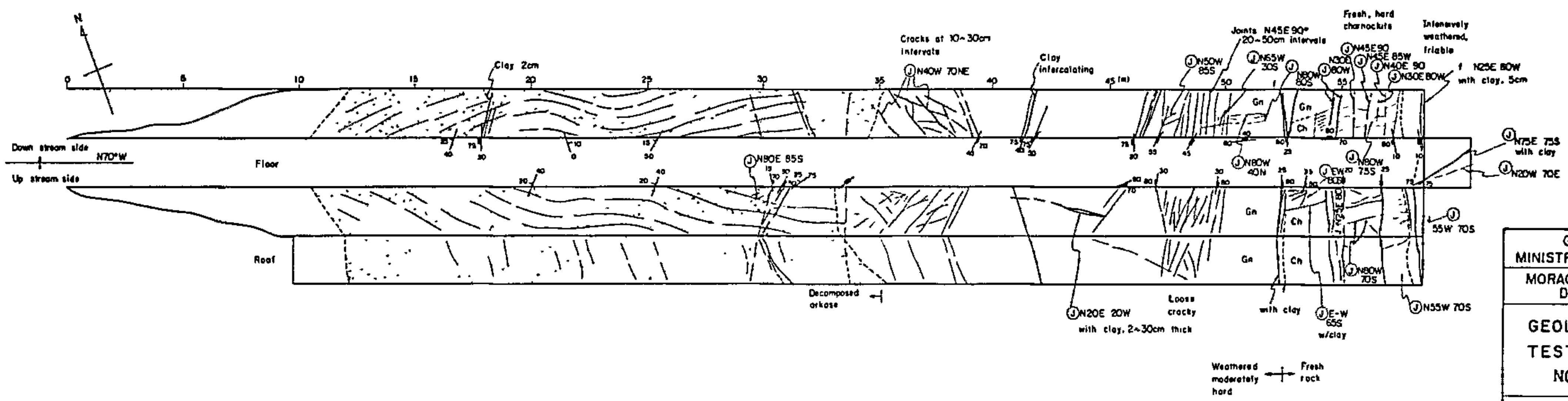
MAIN DAMSITE (RIGHT BANK)



ADIT NO. 1
Length = 33.00m
EL (floor) = 194.84m



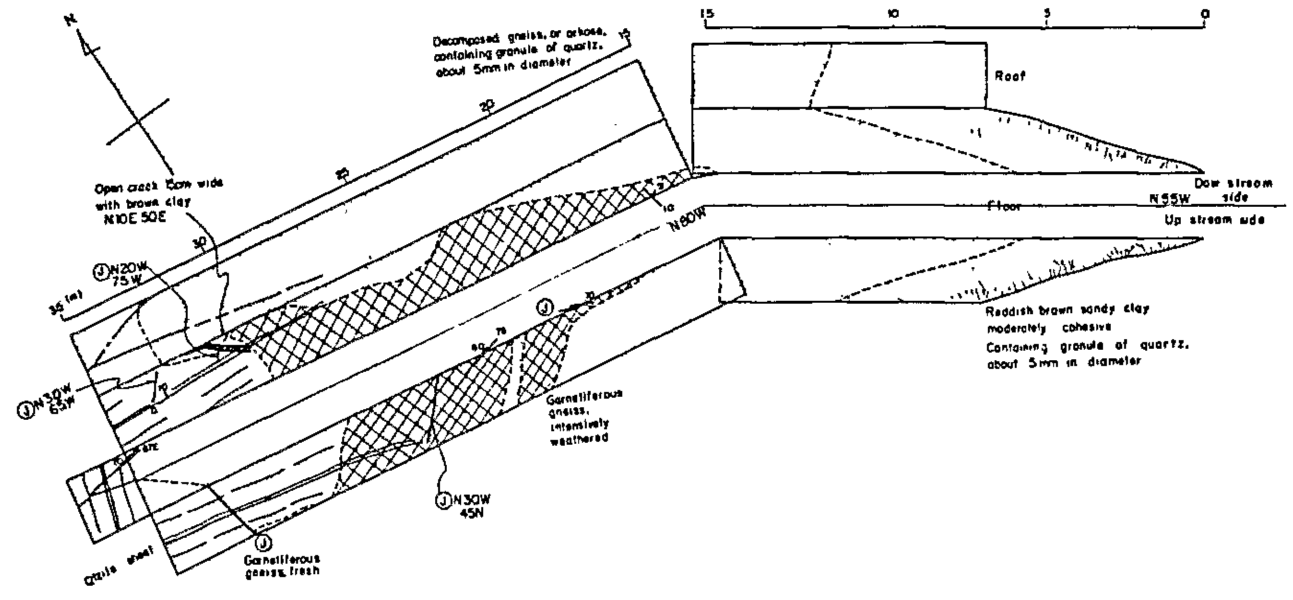
ADIT NO.2
Length = 35.50m
EL (floor) = 168.91m



ADIT NO.3
Length = 58.50 m
EL (floor) = 150.45 m

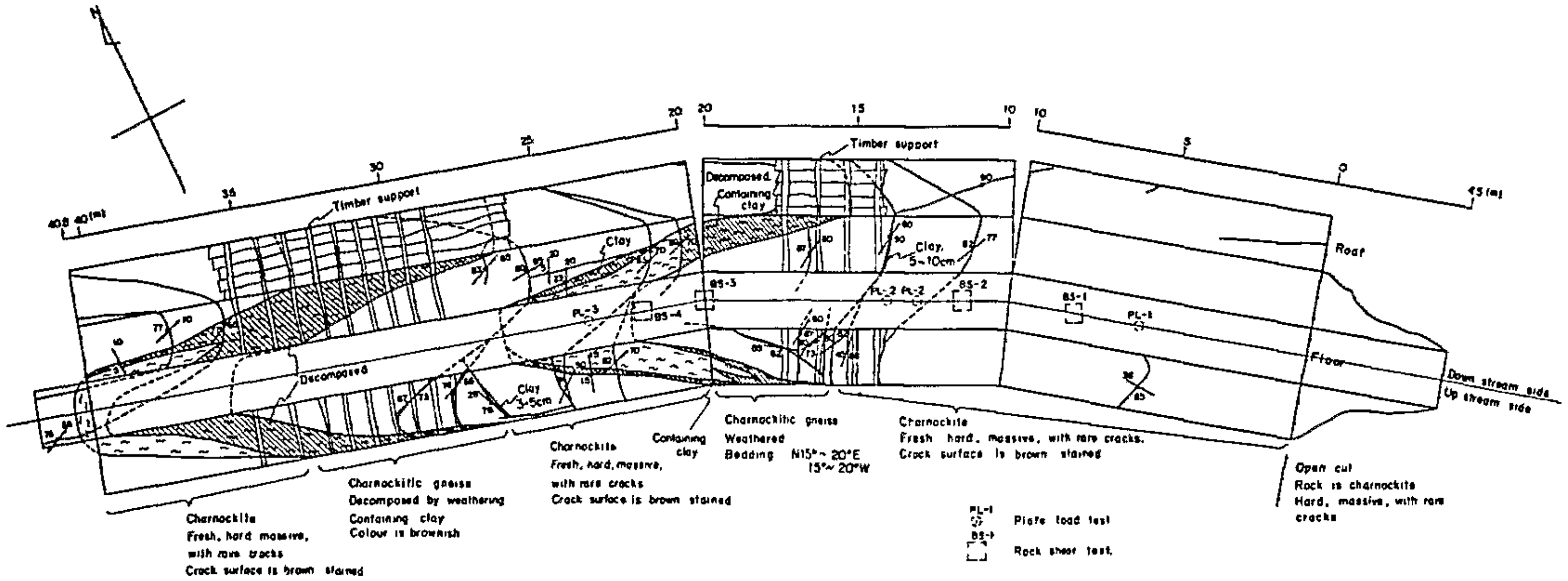
GOVERNMENT OF SRI LANKA MINISTRY OF MAHAWELI DEVELOPMENT
MORAGAHAKANDA DEVELOPMENT AGRICULTURAL PROJECT
GEOLOGICAL RECORD OF TEST ADIT. NO.1 NO.2 NO.3
DATE   DWG № II.6
JAPAN INTERNATIONAL COOPERATION AGENCY

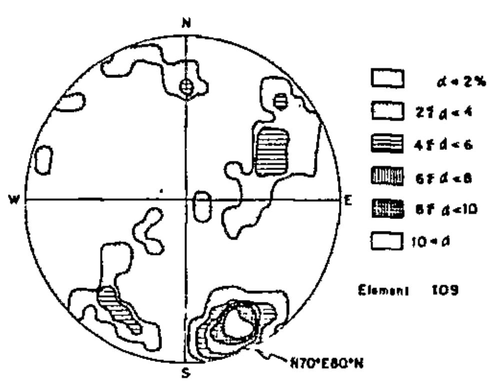
MAIN DAMSITE (LEFT BANK)



ADIT NO.4
Length = 35.00 m
EL (floor) = 168.43 m

ADIT NO.5
Length = 45.00 m
EL (floor) = 144 93 m





GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

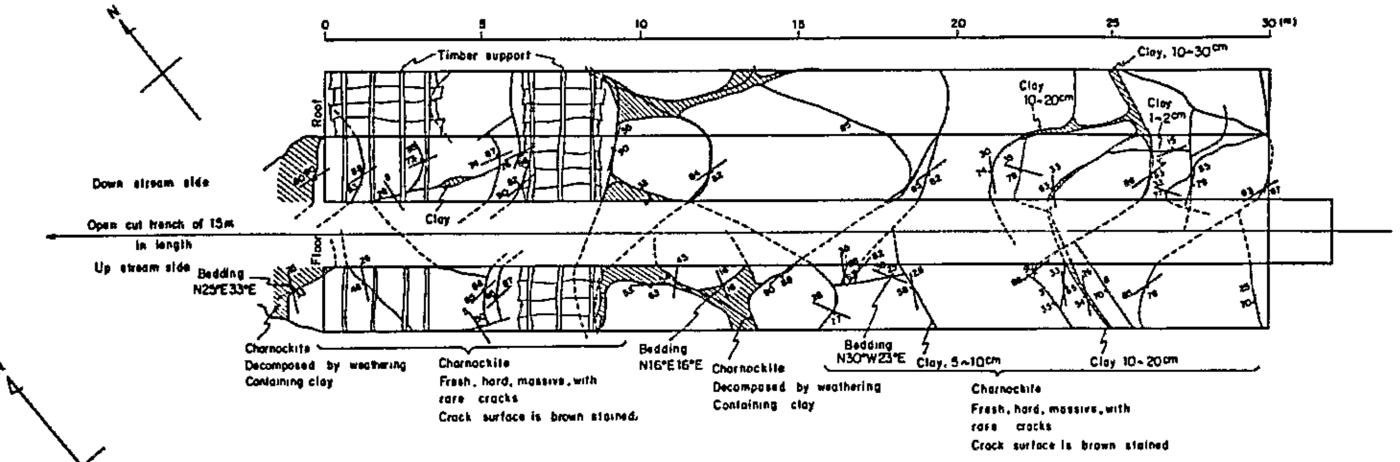
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

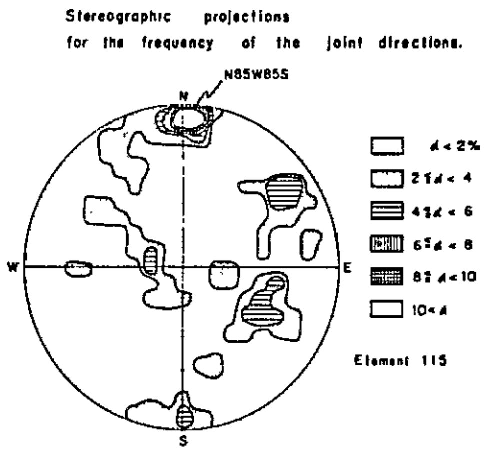
GEOLOGICAL RECORD OF TEST ADIT.
NO.4 NO.5

DATE		DWG No	II.7

JAPAN INTERNATIONAL COOPERATION AGENCY

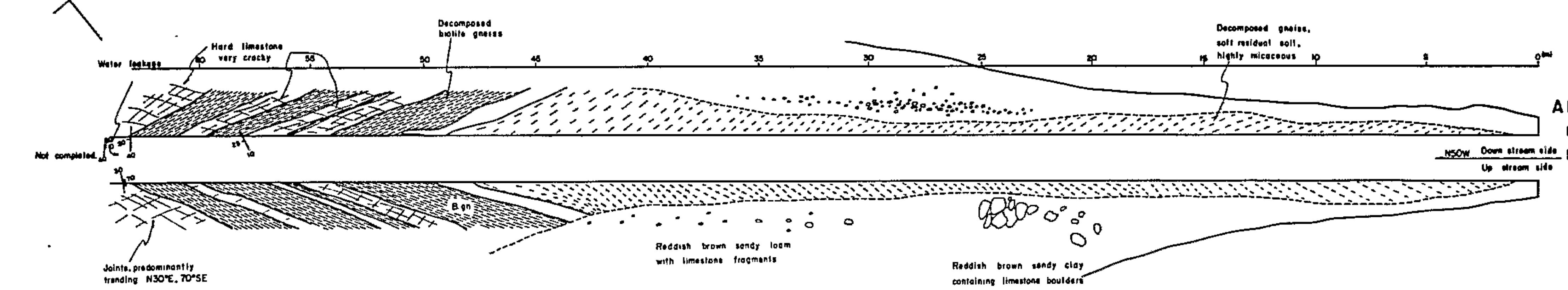
FIRST SUB – DAMSITE





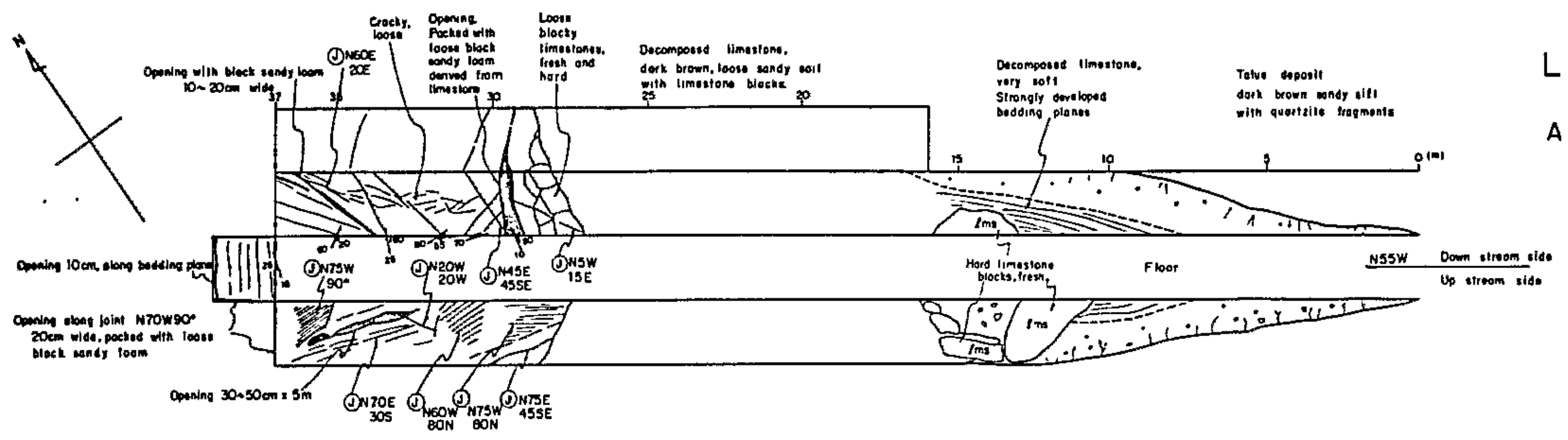
RIGHT BANK

ADIT NO.6
Length = 45.00m
EL(floor) = 165.07m



LEFT BANK

ADIT NO.7
Length =
EL(floor) =

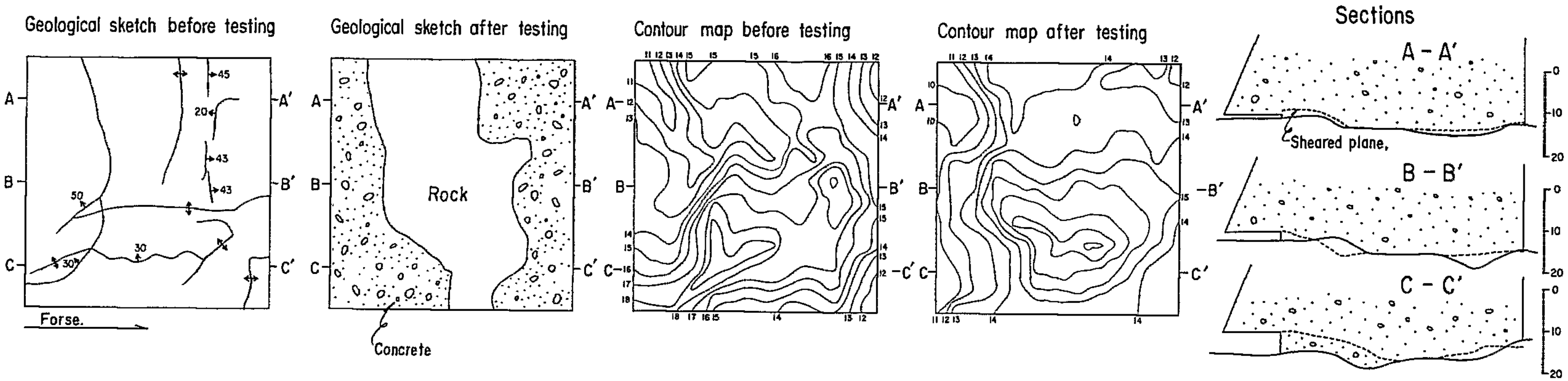


LEFT BANK

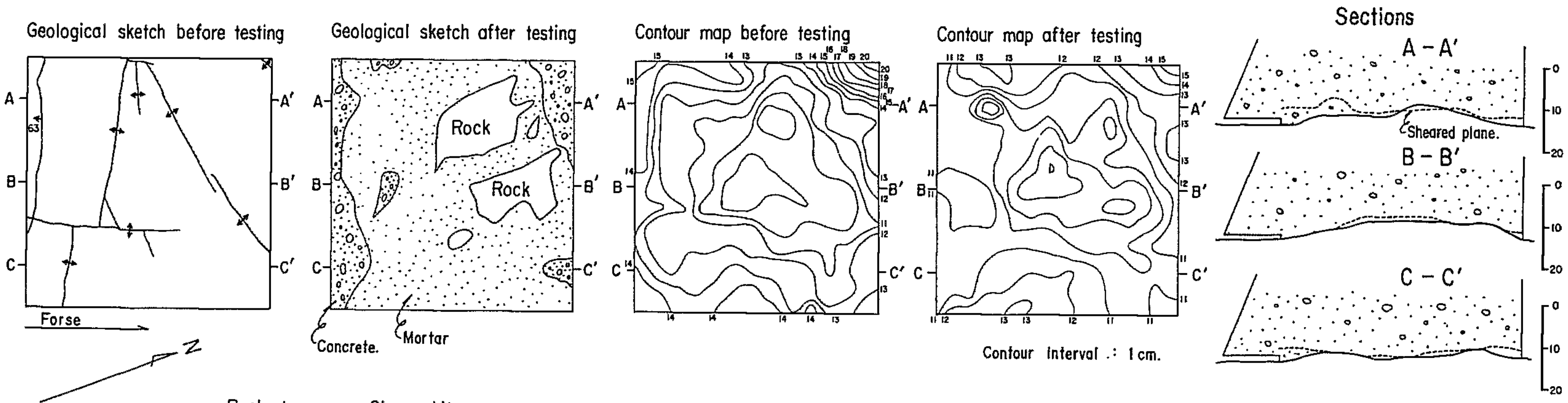
ADIT NO.8
Length = 37.00m
EL(floor) = 175.74m

GOVERNMENT OF SRI LANKA MINISTRY OF MAHAWELI DEVELOPMENT			
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT			
GEOLOGICAL RECORD OF TEST ADIT. NO.6 NO.7 NO.8			
DATE		DWG No	II.8
JAPAN INTERNATIONAL COOPERATION AGENCY			

BS-1.



BS-2



Rock type : Charnockite.

Note : Fresh, solid and massive, with tight cracks.

Scale.

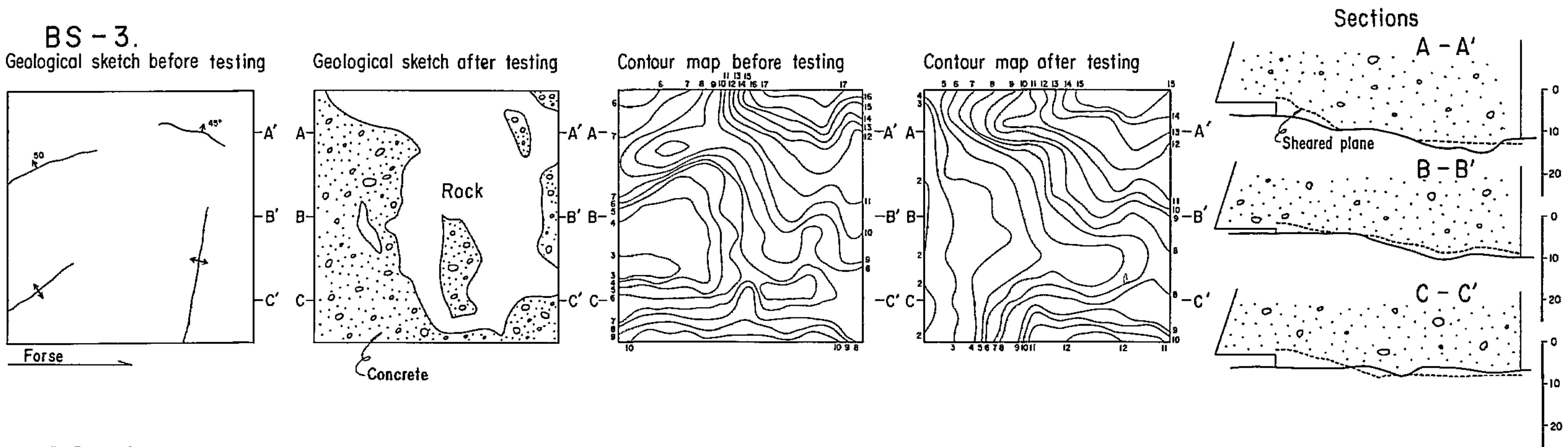
GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

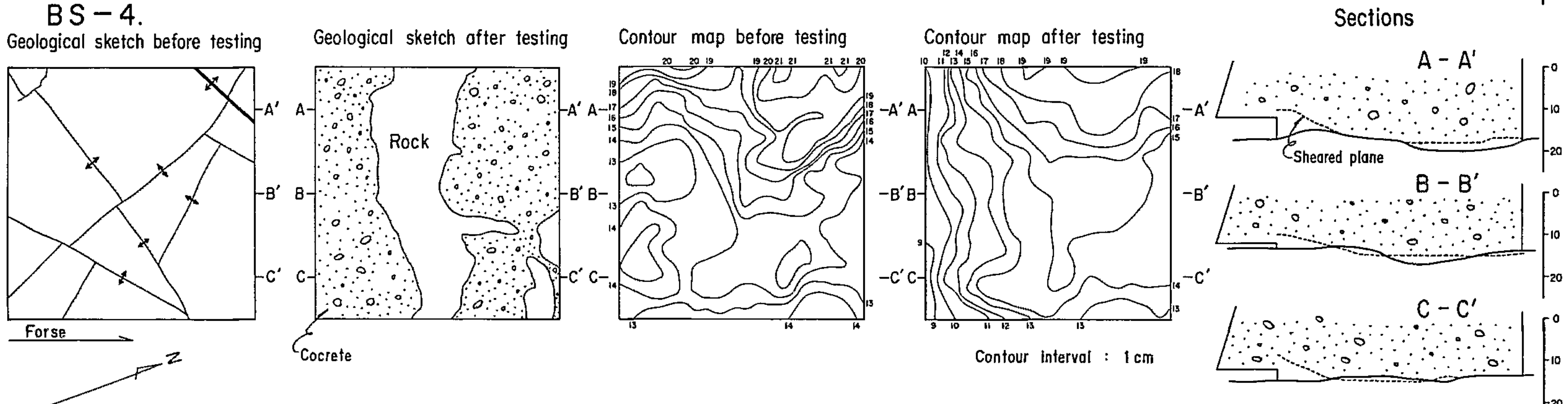
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

ROCK SHEAR TEST
GEOLOGICAL CONDITION OF TEST PLANES. BS-1. BS-2.

DATE | D.W.G No II.9

JAPAN INTERNATIONAL COOPERATION AGENCY





Rock type : Charnockite

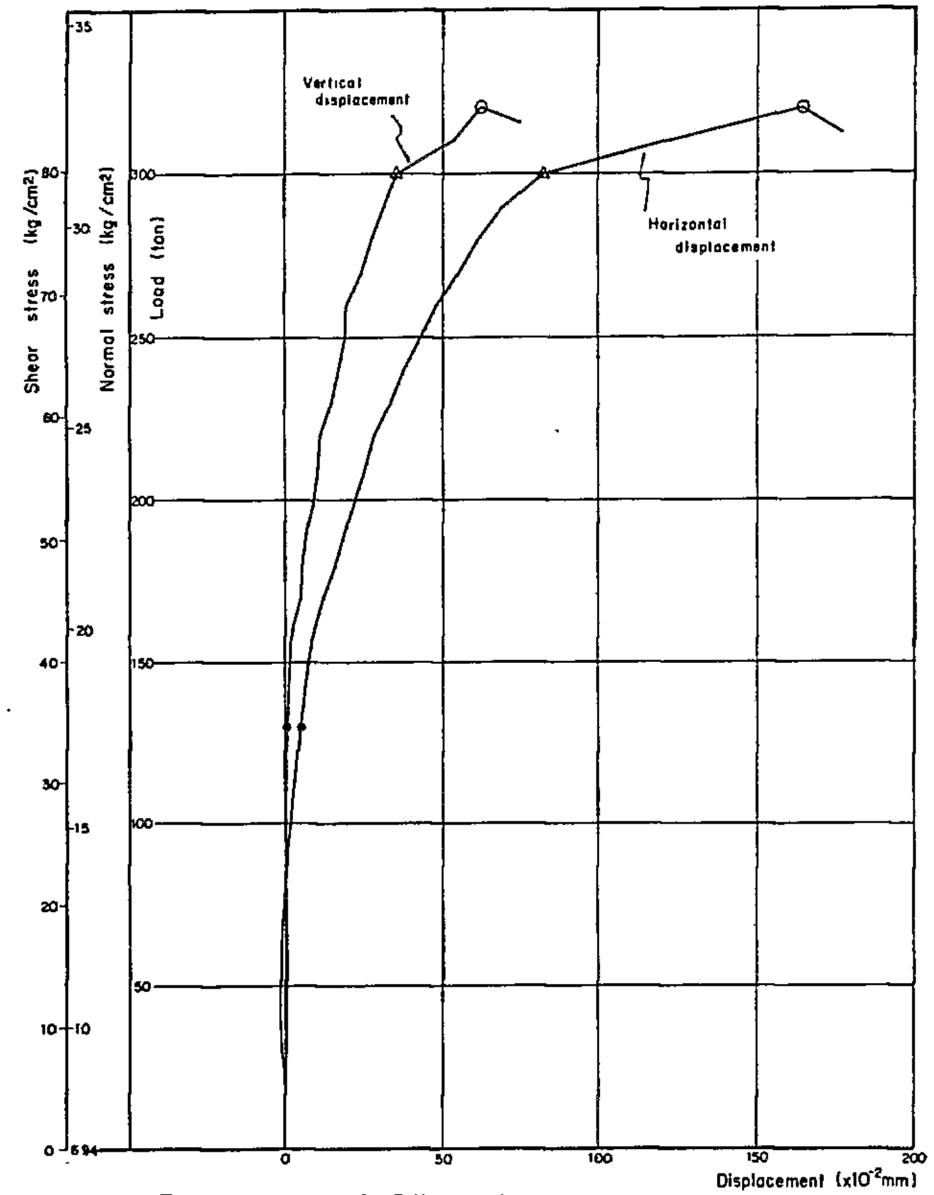
Note : Fresh. solid and massive, with tight cracks

Scale.

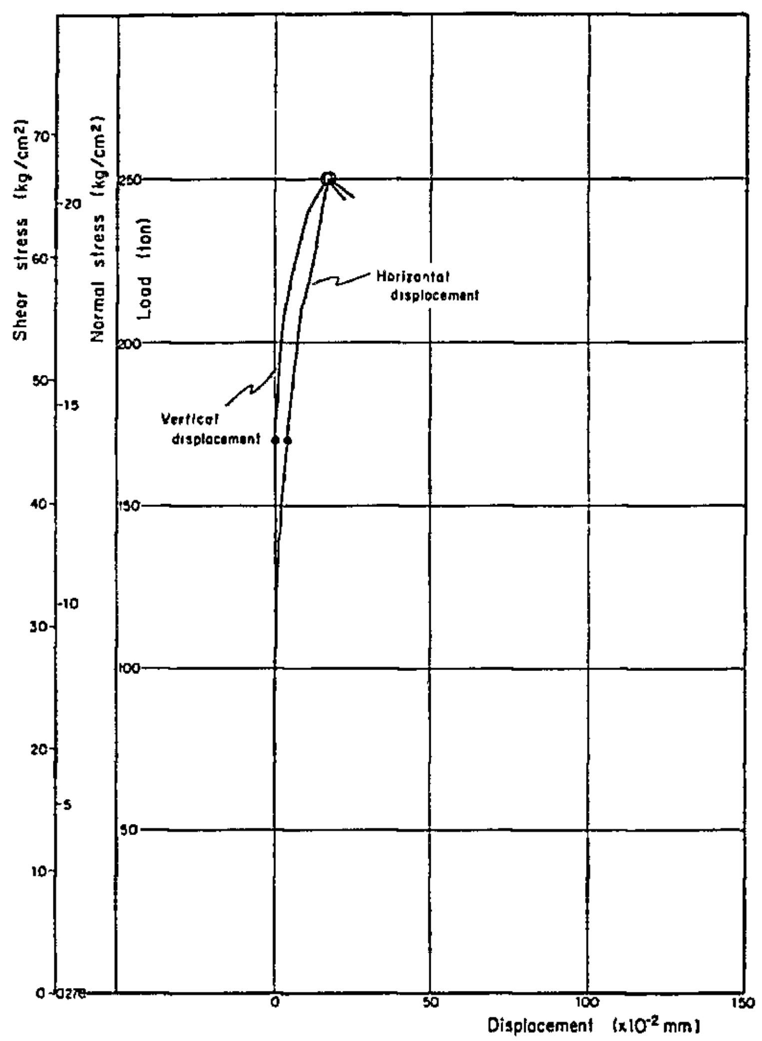
0 50 cm

GOVERNMENT OF SRI LANKA MINISTRY OF MAHAWELI DEVELOPMENT
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT
ROCK SHEAR TEST GEOLOGICAL CONDITION OF TEST PLANES. BS-3. BS-4.
DATE | DWG No II.10
JAPAN INTERNATIONAL COOPERATION AGENCY

BS-1 1st LOADING N=25ton θ=17°

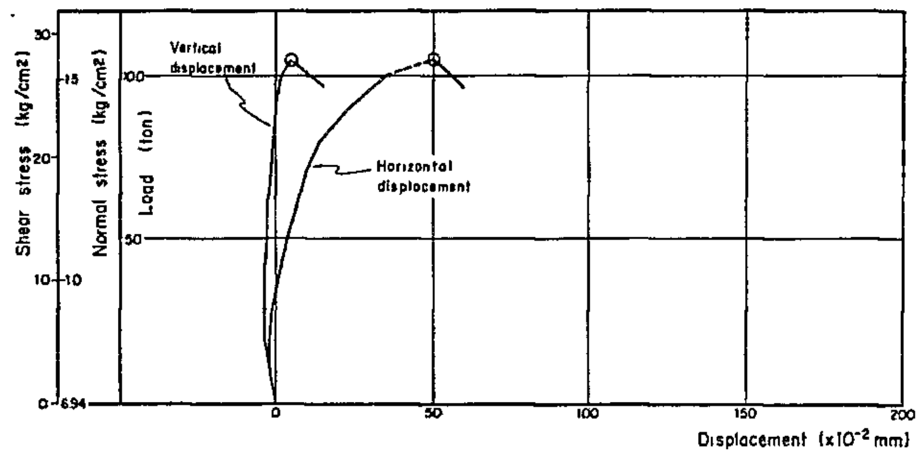


BS-2 1st LOADING N=1ton θ=17°

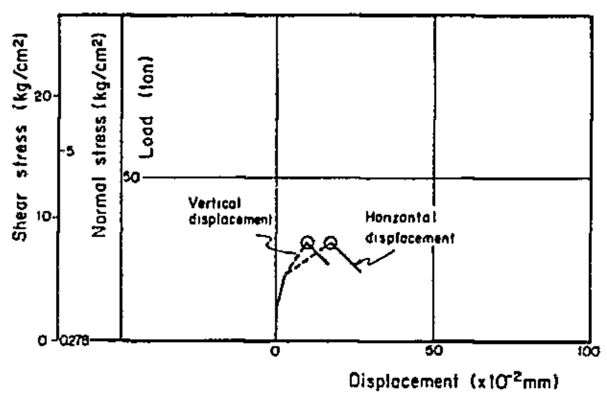


O Failured point
Δ Principal yield point
● Upheaval point

BS-1 2nd LOADING N=25ton θ=17°



BS-2 2nd LOADING N=1ton θ=17°



GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

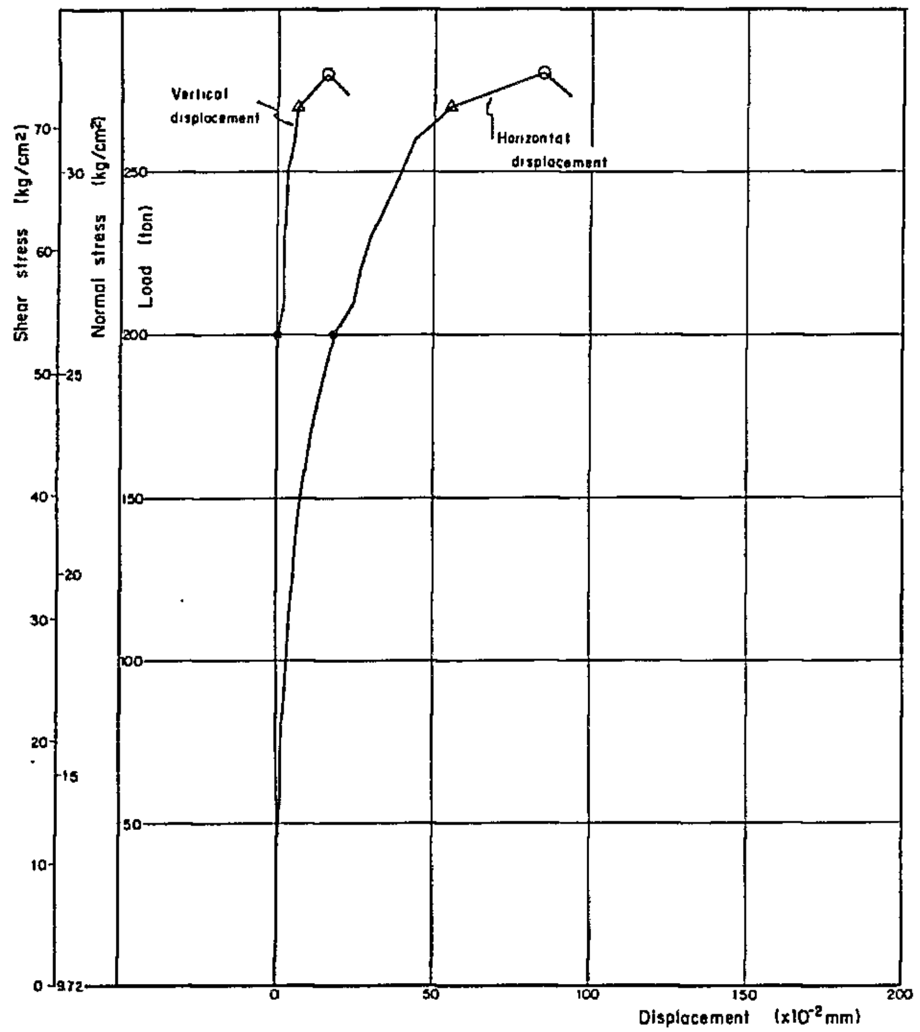
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

ROCK SHEAR TEST
LOAD DISPLACEMENT CURVES
BS-1 BS-2

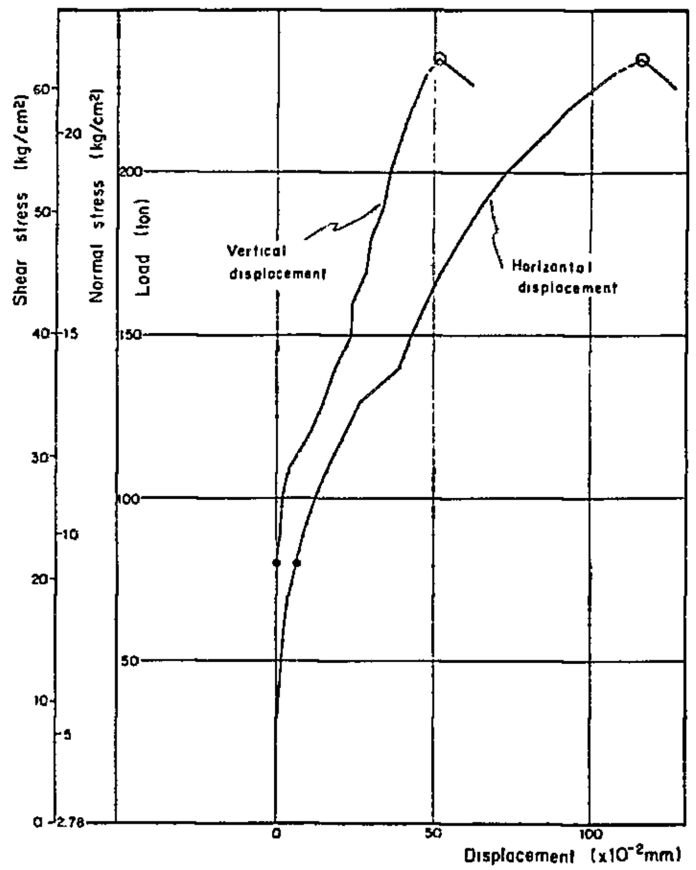
DATE		D.W.G No	II.11

JAPAN INTERNATIONAL COOPERATION AGENCY

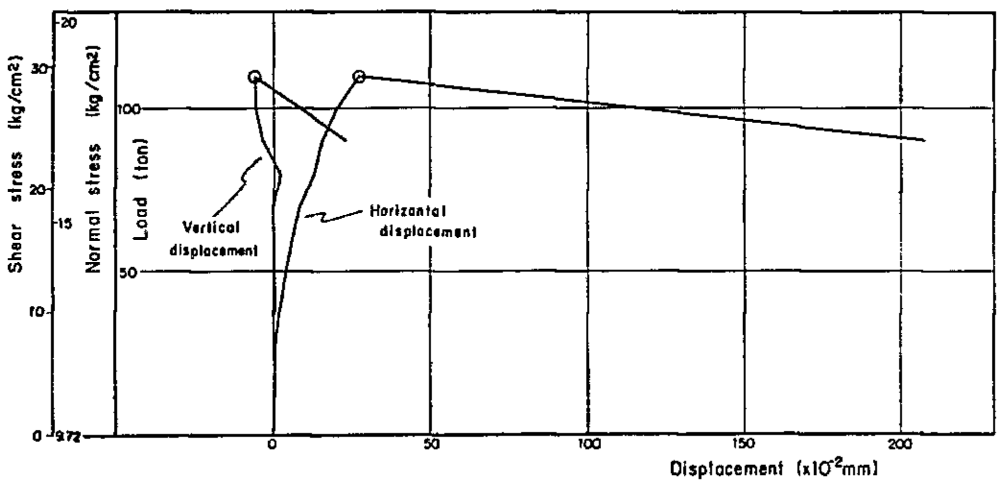
BS-3 1st LOADING N=35 ton θ=17°



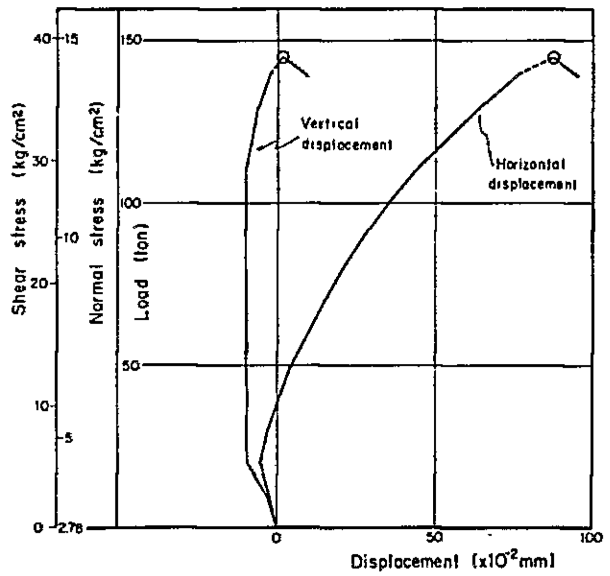
BS-4 1st LOADING N=10 ton θ=17°



BS-3 2nd LOADING N=35 ton θ=17°



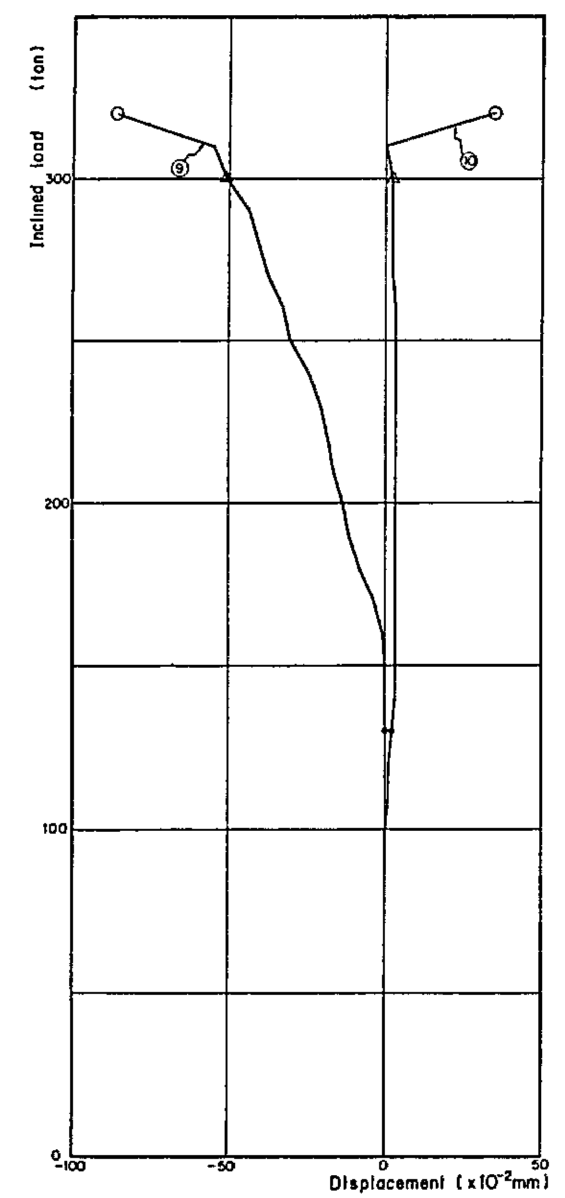
BS-4 2nd LOADING N=10 ton θ=17°



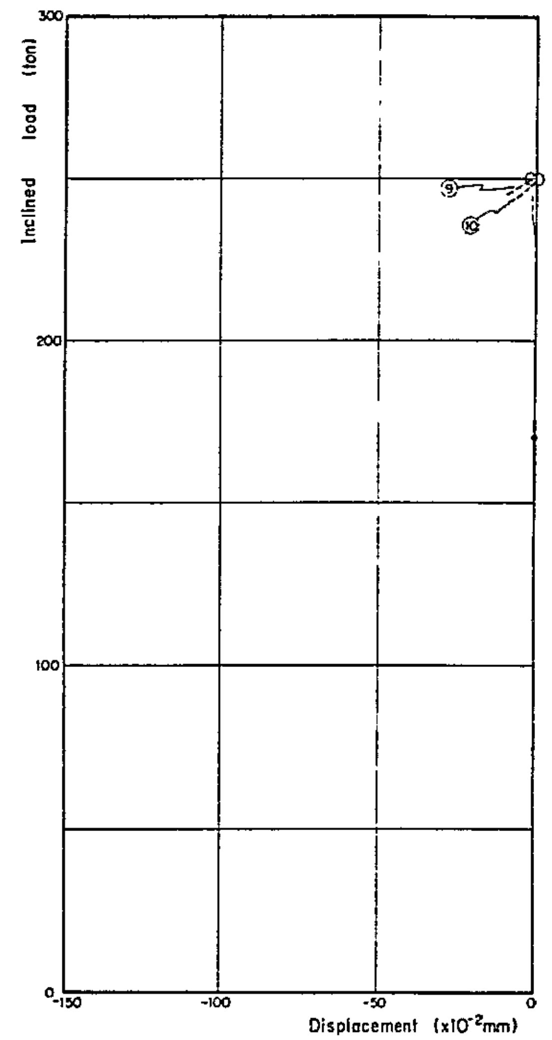
○ Failured point
△ Principal yield point
● Upheaval point

GOVERNMENT OF SRI LANKA MINISTRY OF MAHAWELI DEVELOPMENT			
MORAGAHAKANDA AGRICULTURAL. DEVELOPMENT PROJECT			
ROCK SHEAR TEST LOAD DISPLACEMENT CURVES BS-3 BS-4			
DATE		DWG No	II.12
JAPAN INTERNATINAL COOPERATION AGENCY			

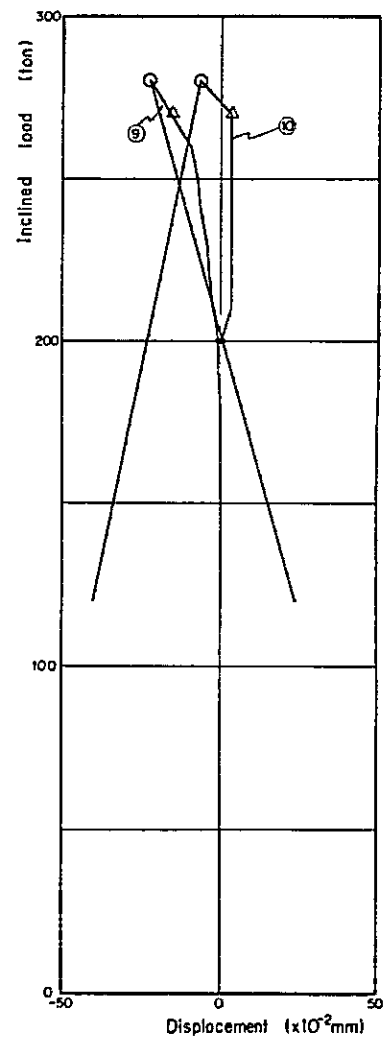
BS-1



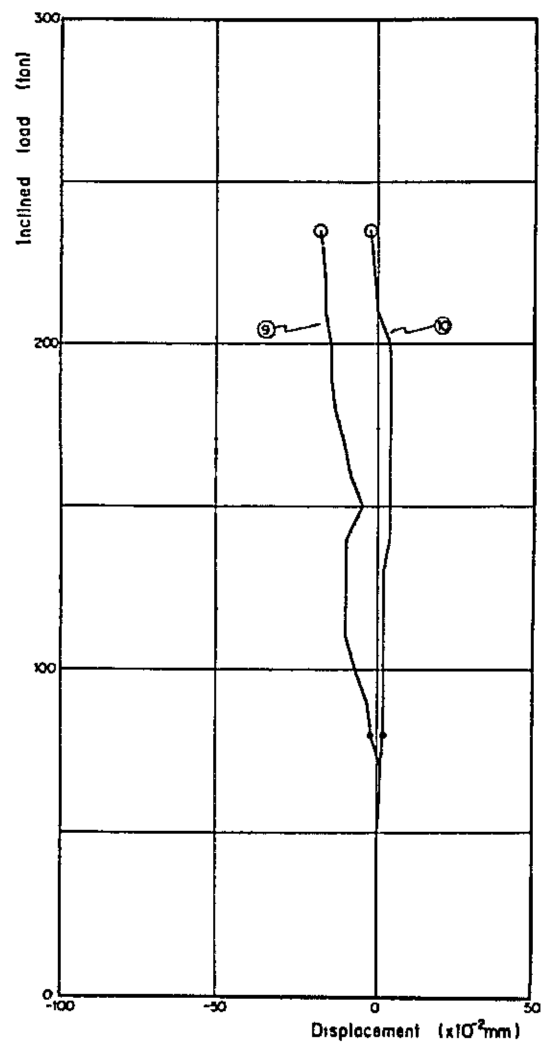
BS-2



BS-3

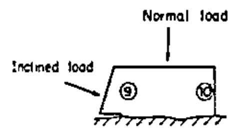


BS-4

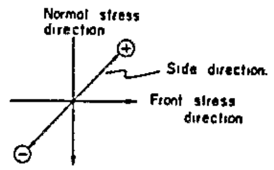


○ Failured point
△ Principal yield point
• Upheaval point

Index to gauge location



Index to direction



GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

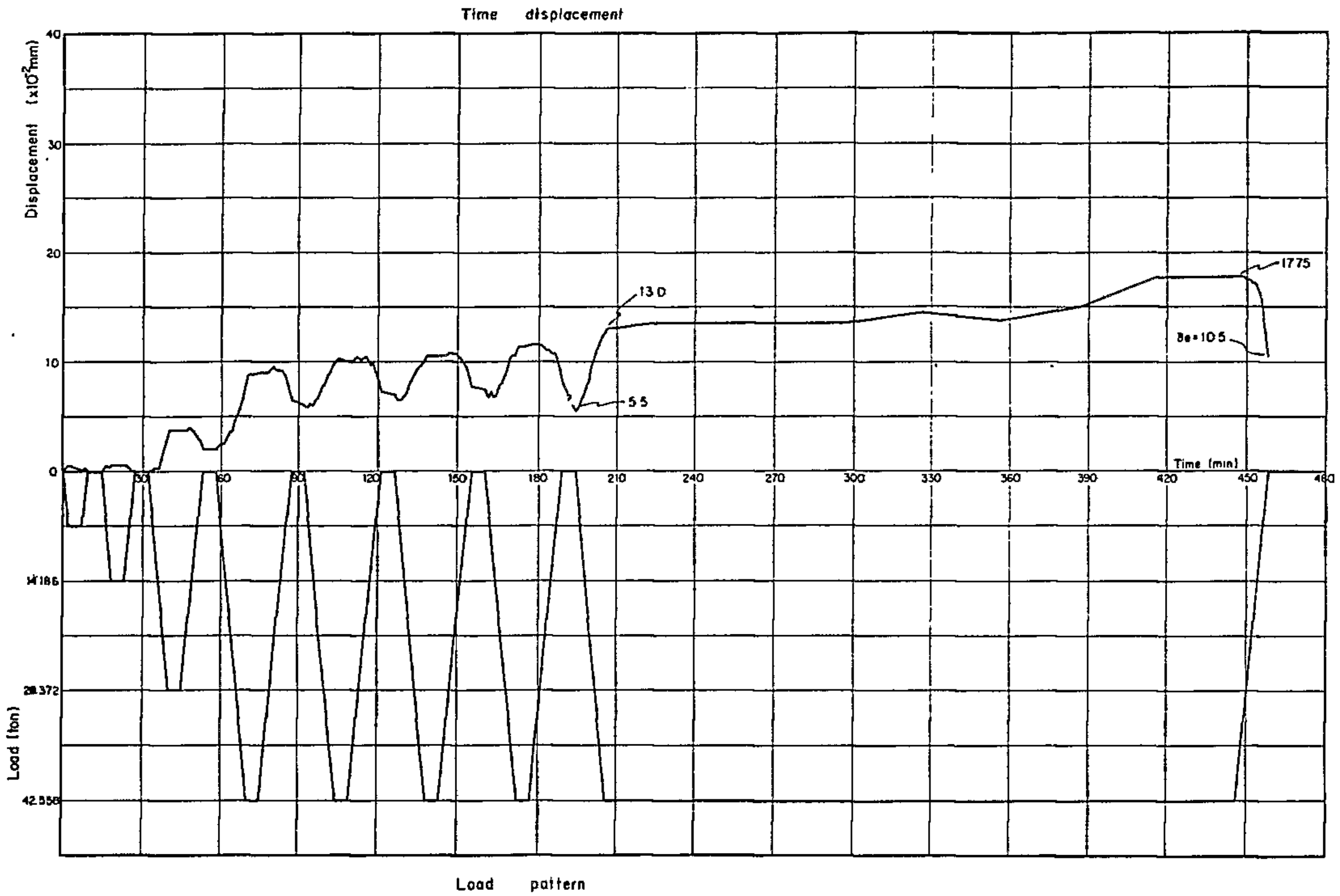
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

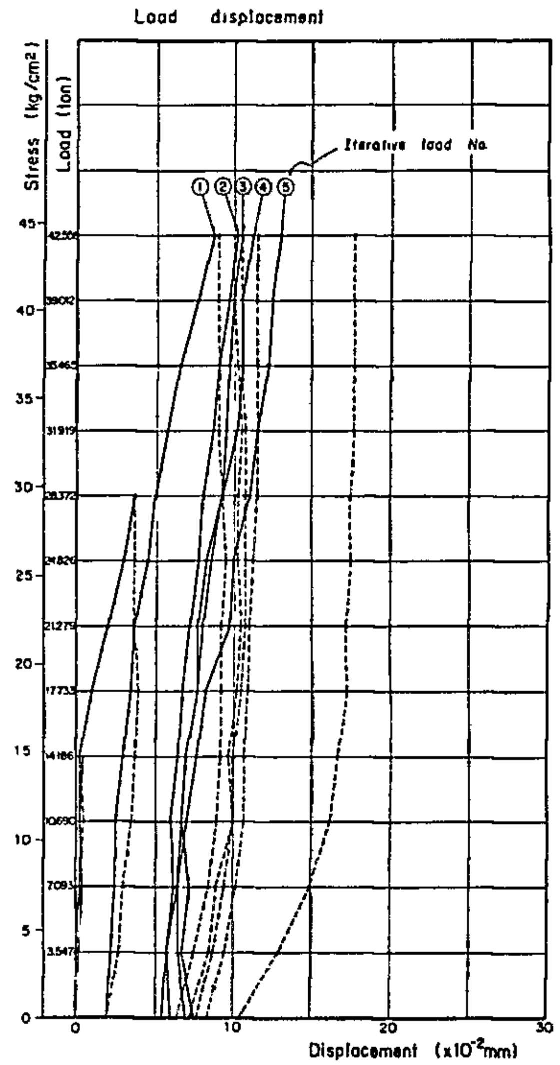
ROCK SHEAR TEST
DISPLACEMENT OF SIDE GAUGE

DATE		DWG No	II.13

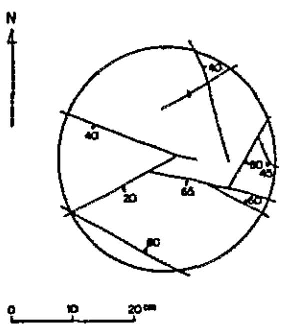
JAPAN INTERNATIONAL COOPERATION AGENCY

PL-2 ø=35cm (962.1cm²)





Geological sketch of loading plane



Rock type Charnockite

Note : Fresh, solid and massive, with tight cracks

Test result

Iterative loading No. on 60 ton	Tangental elasticity (Et) kg/cm²	Secantial elasticity (Es) kg/cm²	Modulus of deformation (D) kg/cm²
1	103,760	172,934	
2	172,934	274,660	
3	311,281	333,516	
4	194,550	311,281	
5	194,550	155,641	
Average	195,415	249,606	86,074

GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

PLATE LOAD TEST
PL – 2

DATE | DWG No. II.14

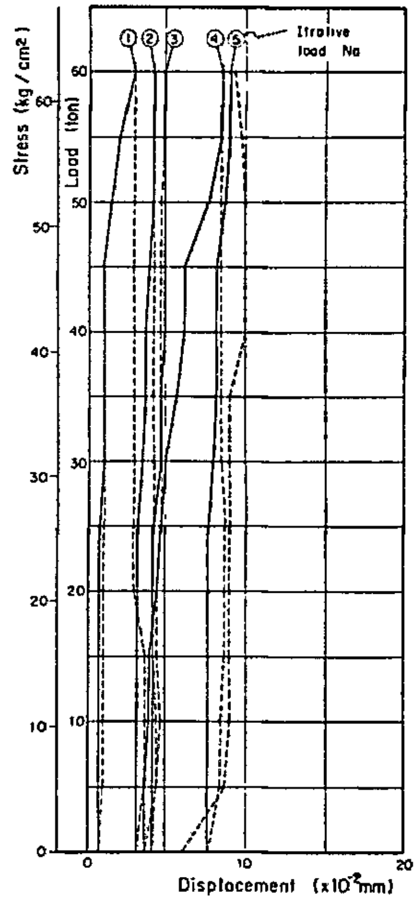
JAPAN INTERNATIONAL COOPERATION AGENCY

PL - 2'

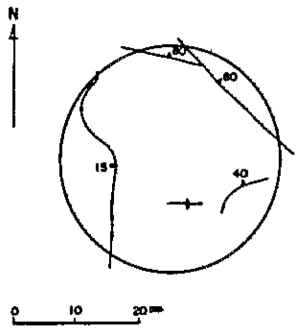
Time displacement

Load pattern

Load displacement



Geological sketch of loading plane



Rock type Charnockite

Note : Fresh, solid and massive, with tight cracks

Test result

Iterative loading No. on 60 ton	Tangential elasticity (Et) kg/cm²	Secantial elasticity (Es) kg/cm²	Modulus of deformation (D) kg/cm²
1	—	731,429	
2	—	1,695,714	
3	—	2,194,286	
4	—	346,466	
5	—	1,316,571	
Average	—	1,246,893	—

GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

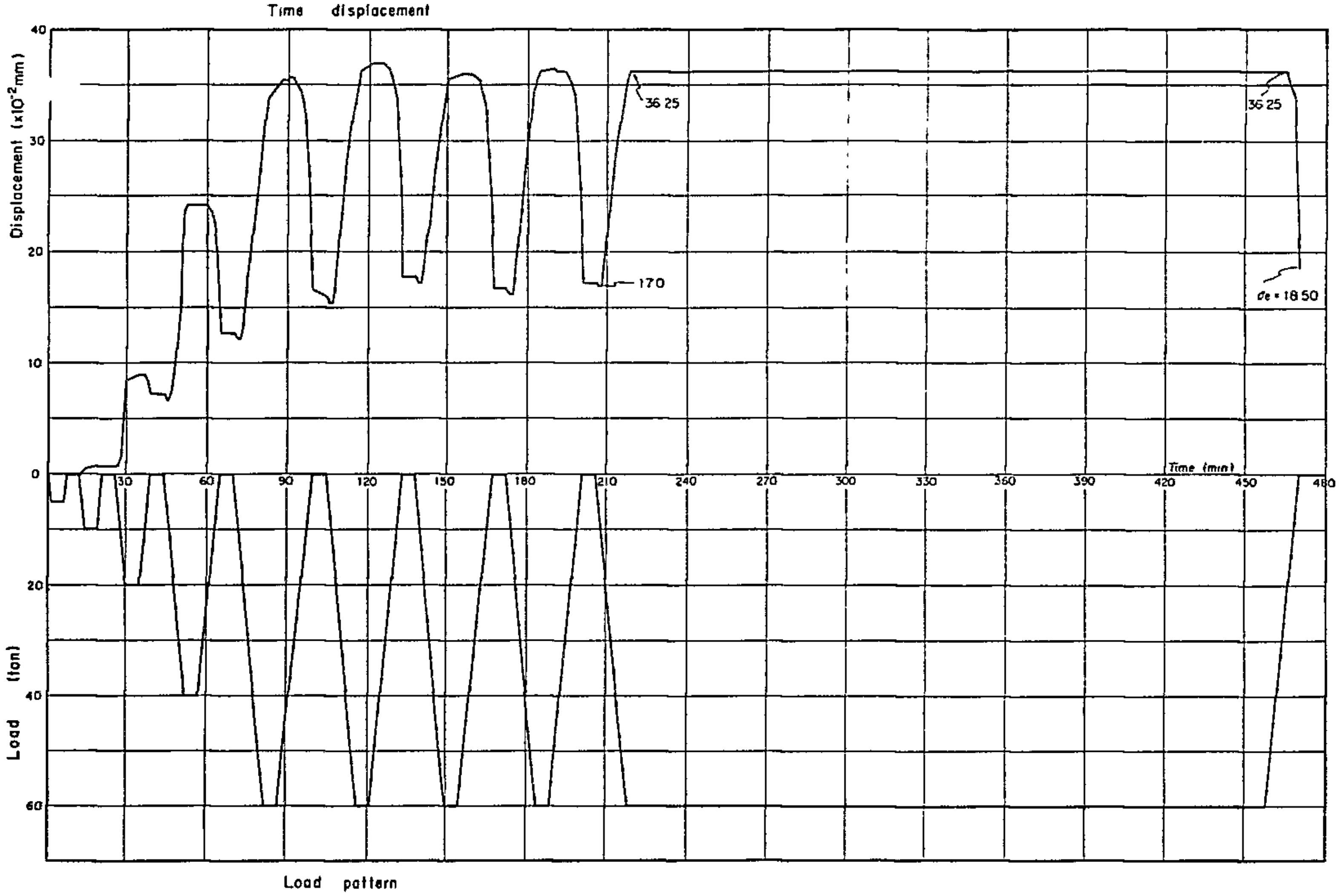
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

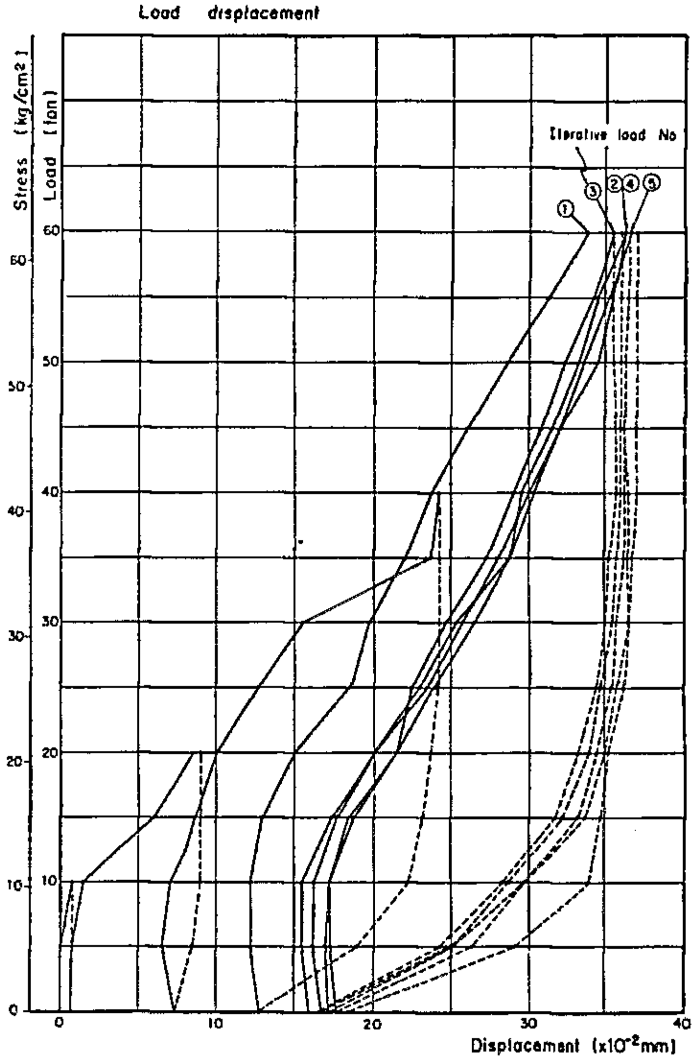
PLATE LOAD TEST
PL - 2'

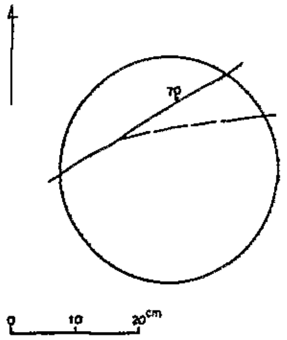
DATE		DWG №	II.15

JAPAN INTERNATIONAL COOPERATION AGENCY

PL - 3   ø = 35 cm   A = 962.11cm²







Rock type Charnockite

Note Fresh, solid and massive, with tight cracks

Test result

Iterative loading No on 60 ton	Tangential elasticity (E+) kg/cm²	Secantial elasticity (Es) kg/cm²	Modulus of deformation (D) kg/cm²
1	—	78,367	
2	86,617	81,270	
3	86,617	92,716	
4	96,807	89,396	
5	91,429	85,492	
Average	90,368	84,448	51,801

GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

PLATE LOAD TEST
PL - 3

DATE		DWG No	II.16

JAPAN INTERNATIONAL COOPERATION AGENCY

D.II.17 LOCATION OF PREVIOUS GEOLOGICAL SURVEY AT MORAGAHAKANDA DAMSITE

D.II.18. LOCATION OF RECENT GEOLOGICAL SURVEY AT MORAGAHAKANDA DAMSITE

LEGEND

BA Borrow Areas
Q Quarry Area
DM Rock Boring
AH Auger Holes
TP Test Pits
BP Blasting Points

■	TP 1 - 37 DOWNSTREAM	Conducted by ID in July 1978.
◧	TP 1 - 4 DOWNSTREAM	Conducted by ID in 1978/79 under supervision of JICA Team.
●	AH 1 - 26 DOWNSTREAM	Conducted by ID in 1978/79 under supervision of JICA Team.
◉	AH 1 - 3 UPSTREAM and DOWNSTREAM	Conducted by ID in 1978/79 under supervision of JICA Team for comparison with previous results in each Borrow Area.

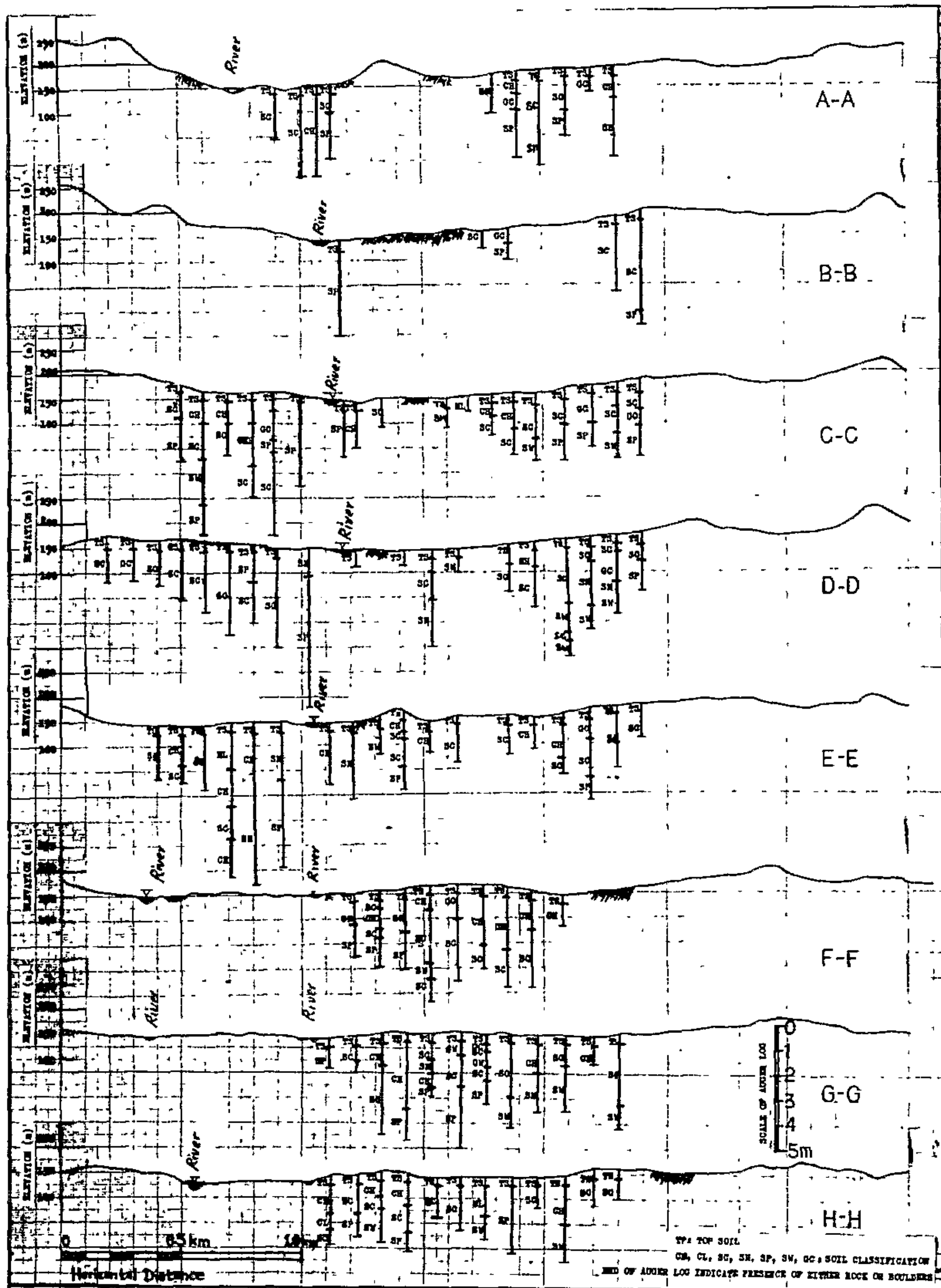
GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

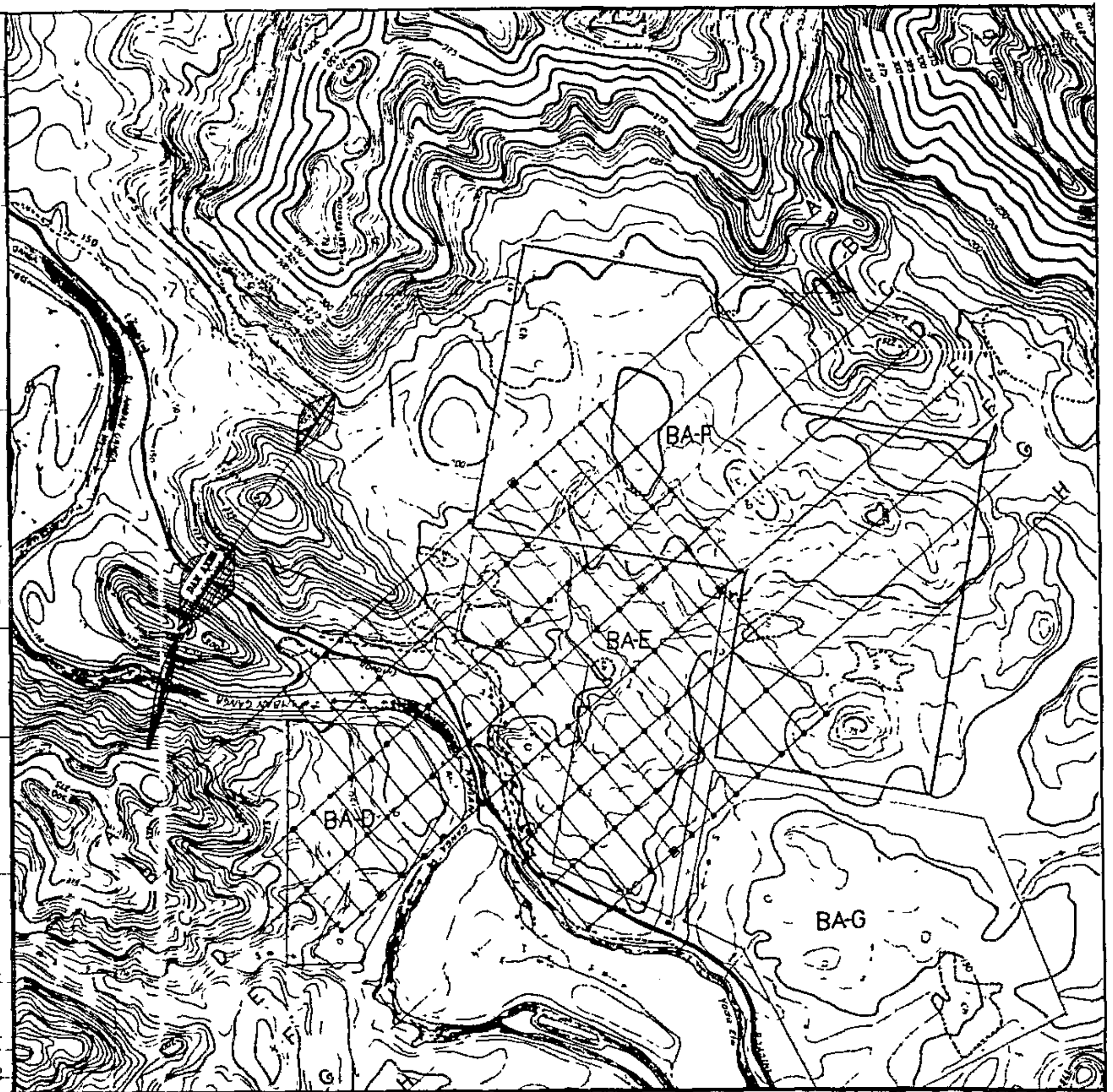
LOCATION OF RECENT GEOLOGICAL SURVEY AT MORAGAHAKANDA DAMSITE

DATE		DWG No	D.II.18

JAPAN INTERNATIONAL COOPERATION AGENCY



D.II.19. TYPICAL GEOLOGICAL PROFILE OF DOWNSTREAM BORROW AREAS



LEGEND

OUTCROPS

BA BORROW AREA

VOLUME OF EARTH MATERIAL AVAILABLE IN BORROW AREAS E, F.

SOIL TYPE	VOLUME (m^3)
TS	471,000
CH	630,000
GC	123,000
SC	1,544,000
SP	651,000
Total	3,419,000

Note: The volume estimated here is the minimum volume available in Borrow Area E and part of Borrow Area F, where soil profile is confirmed with auger holes or test pits. Therefore, the total volume available in the whole borrow area is considered to be much larger than these figures.

GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

GEOLOGICAL PROFILE OF DOWNSTREAM BORROW AREAS

DATE | DWG. No D.II.19

JAPAN INTERNATIONAL COOPERATION AGENCY