FIGURES

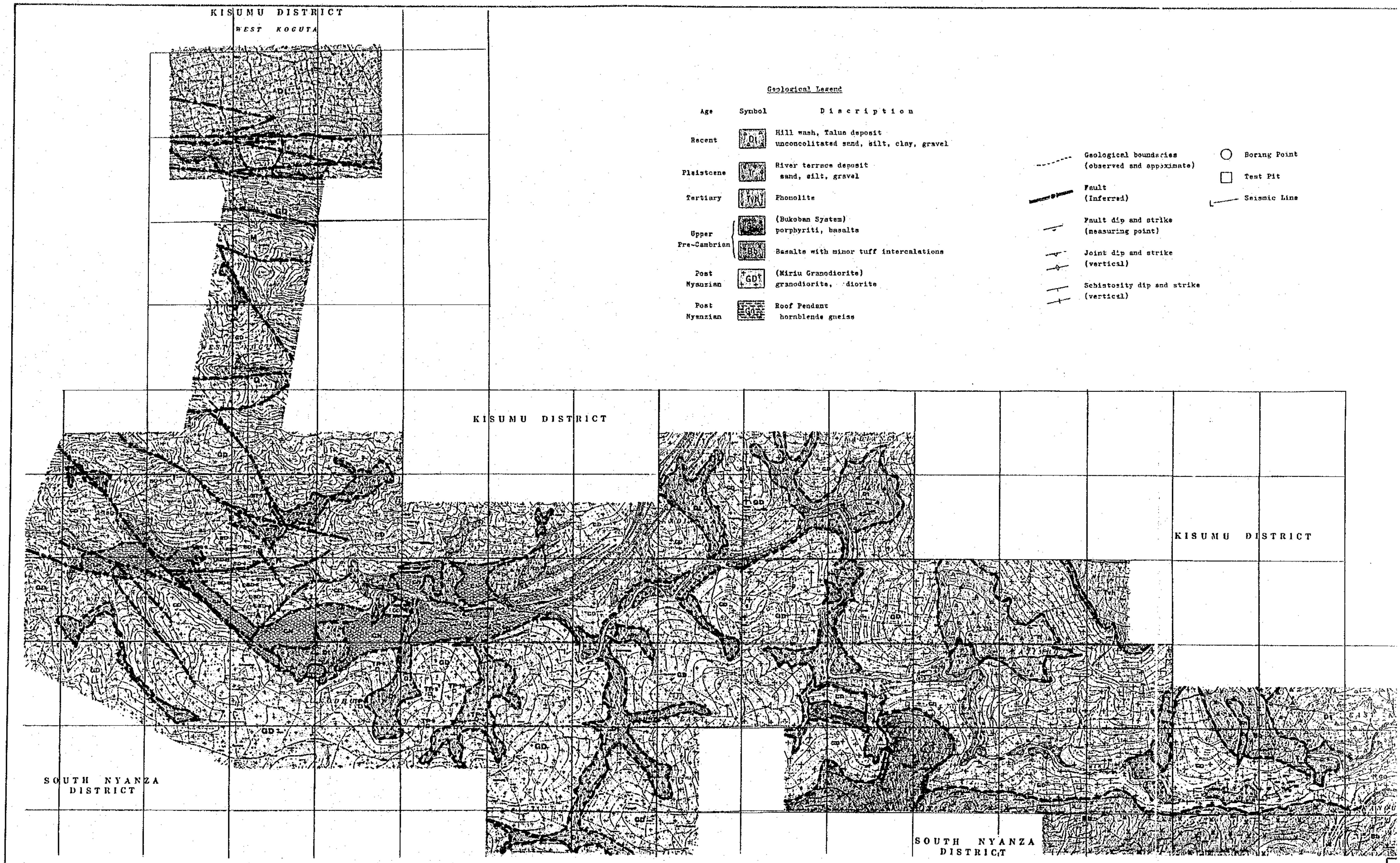


Figure 2.1 Geological Map for the Sondu/Miriu Reservoir

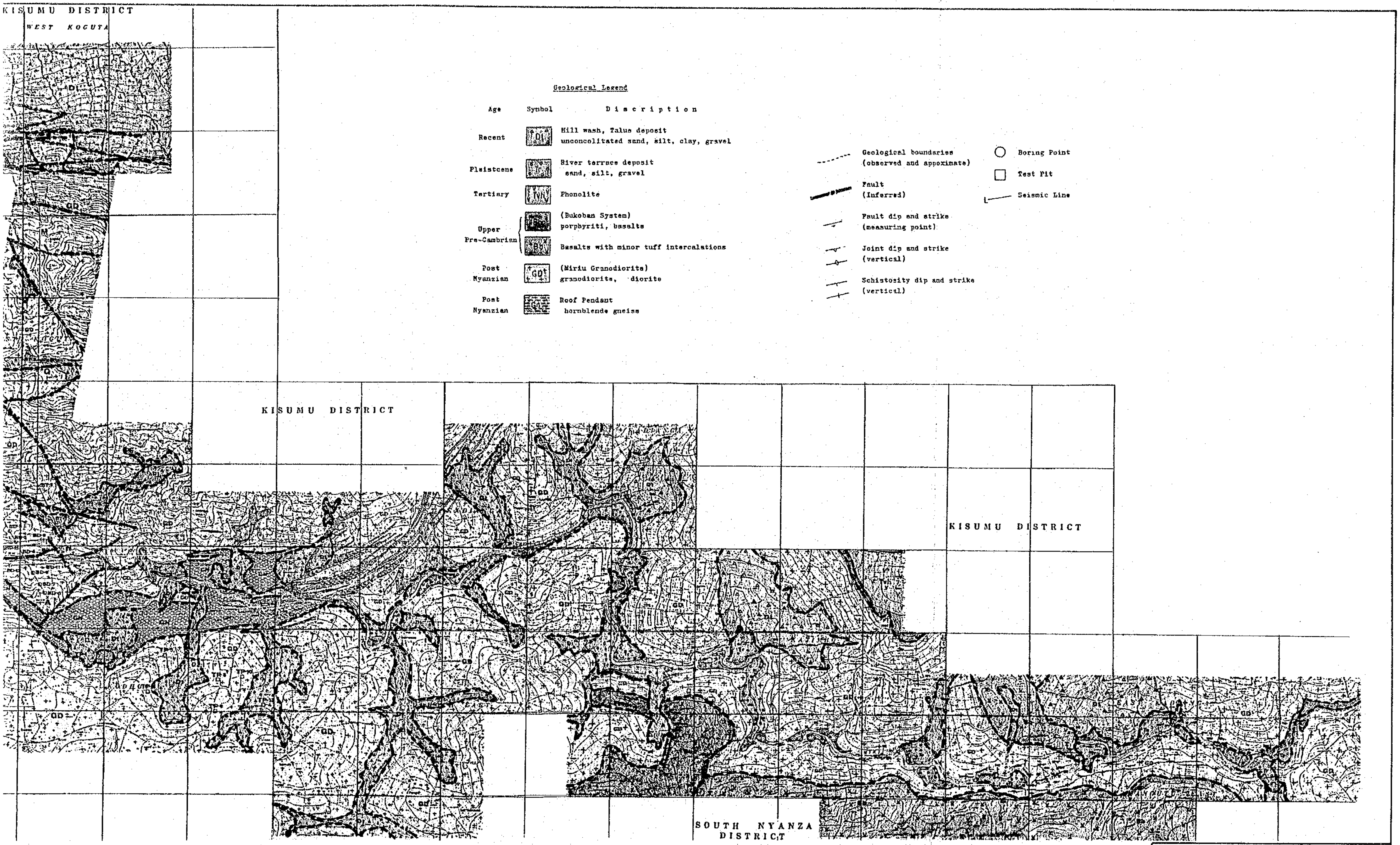


Figure 2.1 Geological Map for the Sondu/Miriu Reservoir

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

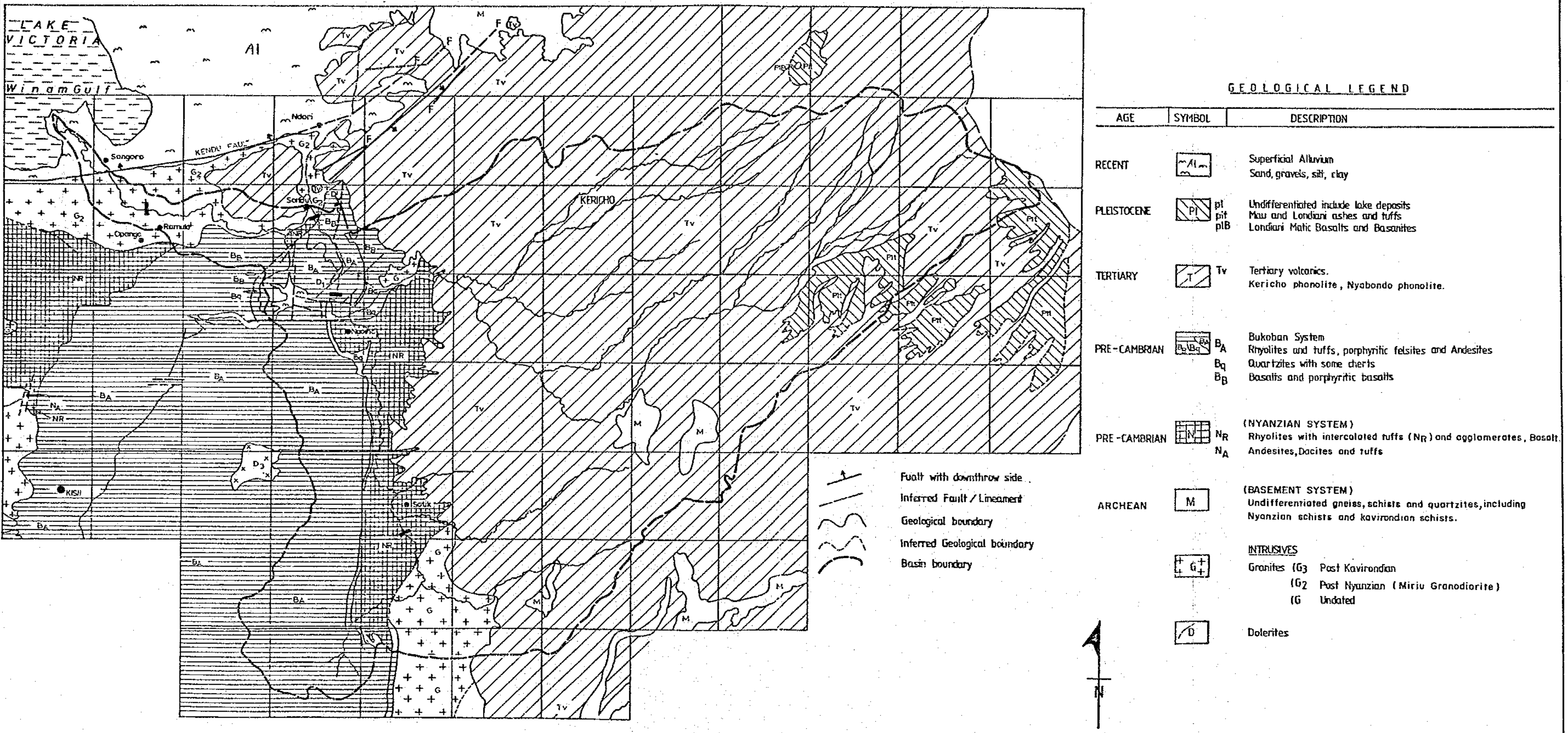


Figure 2.2
General Geology of the
Project Catchment Area

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

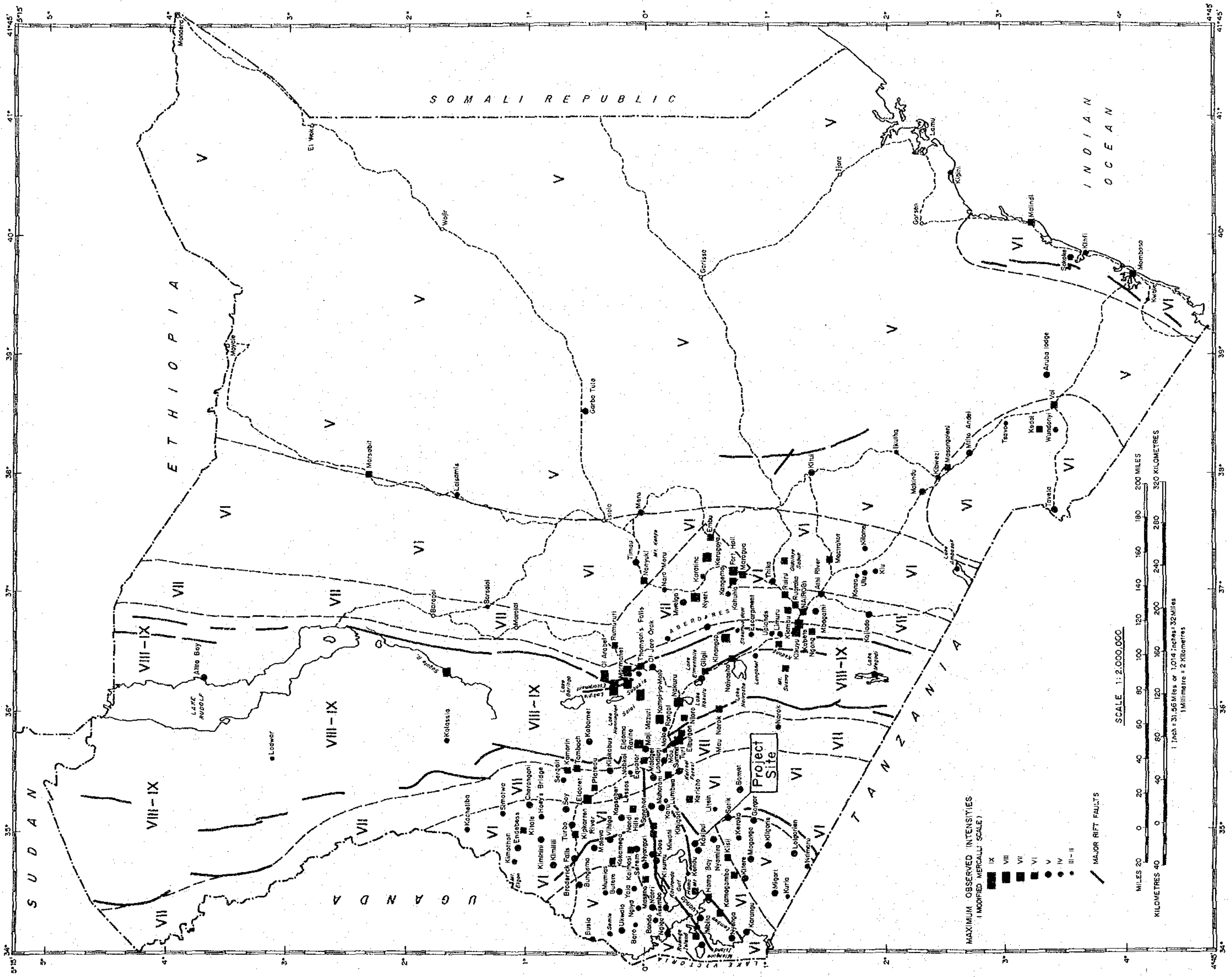


Figure 3.1
Seismic Zoning Map of Kenya
Showing Maximum Observed
Intensity (1892 - 1969)

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

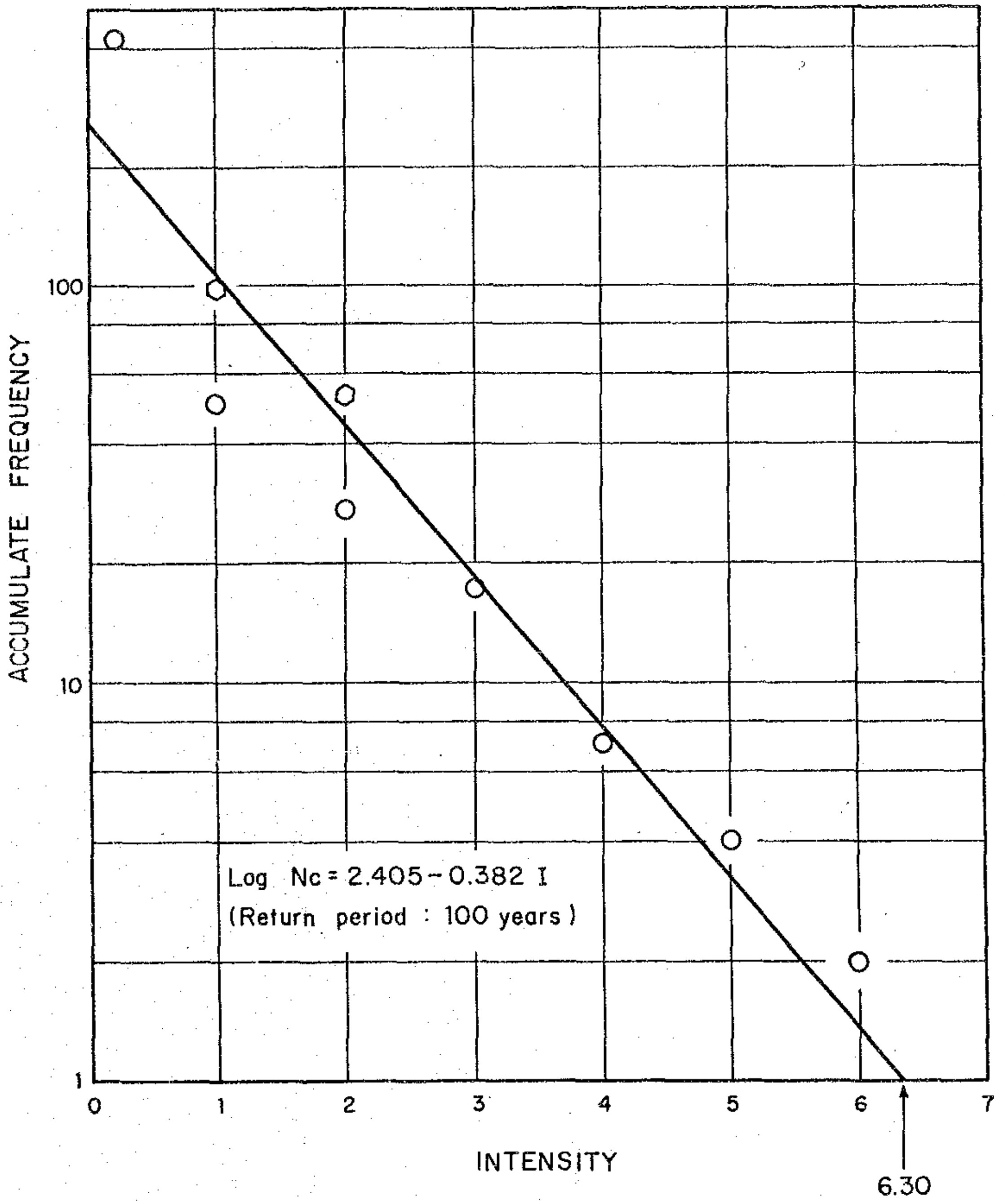


Figure 3.2
Relationship between Accumulated Frequency and Intensity of the Earthquake

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

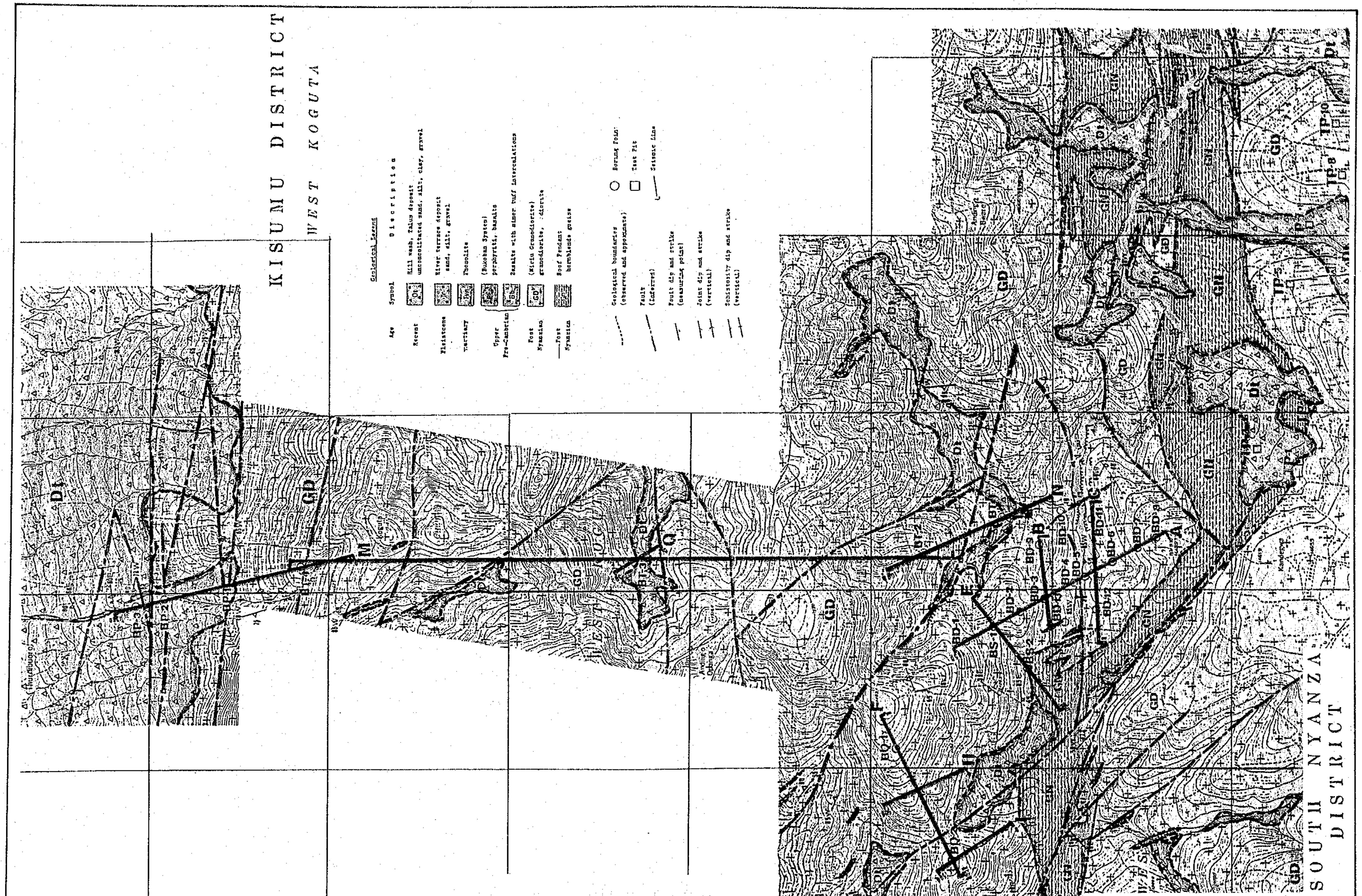
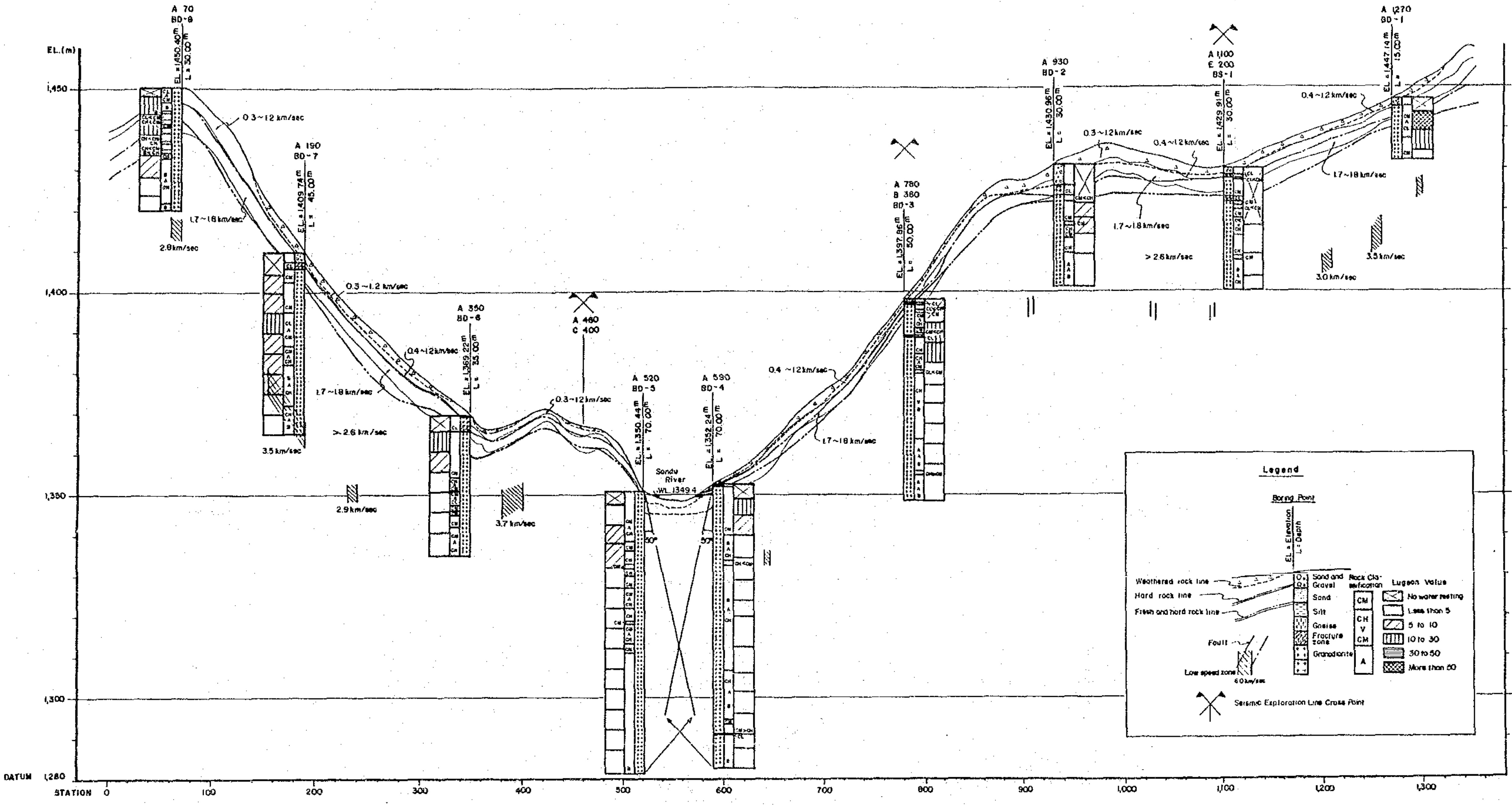
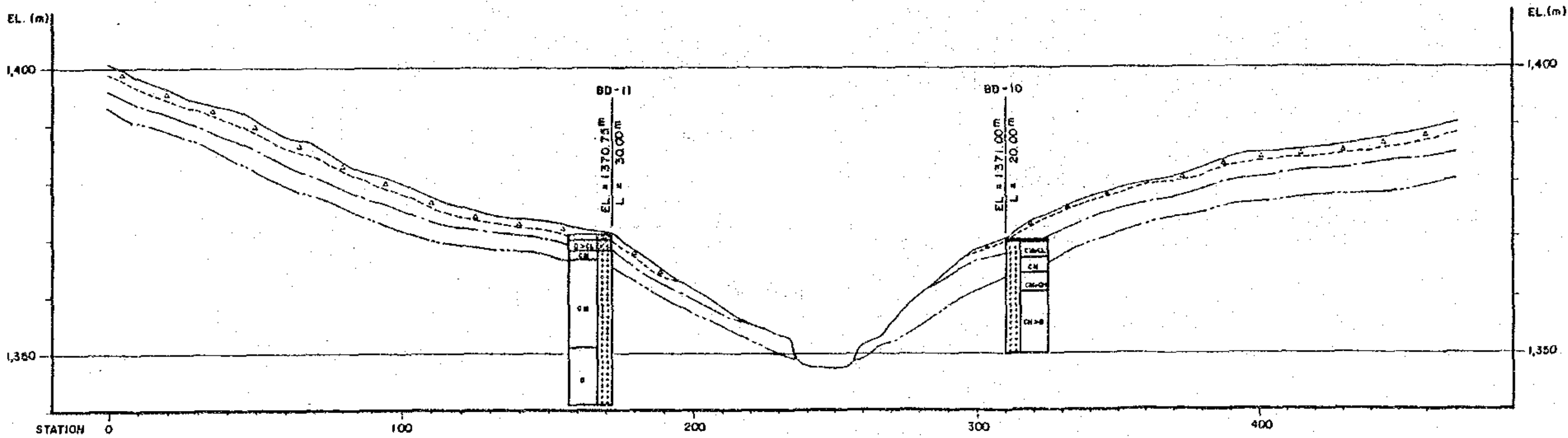


Figure 4.1 Geological Map of the Damsite and Associated Works Site

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY



A-Line Geological Section for the Lower Storage Damsite

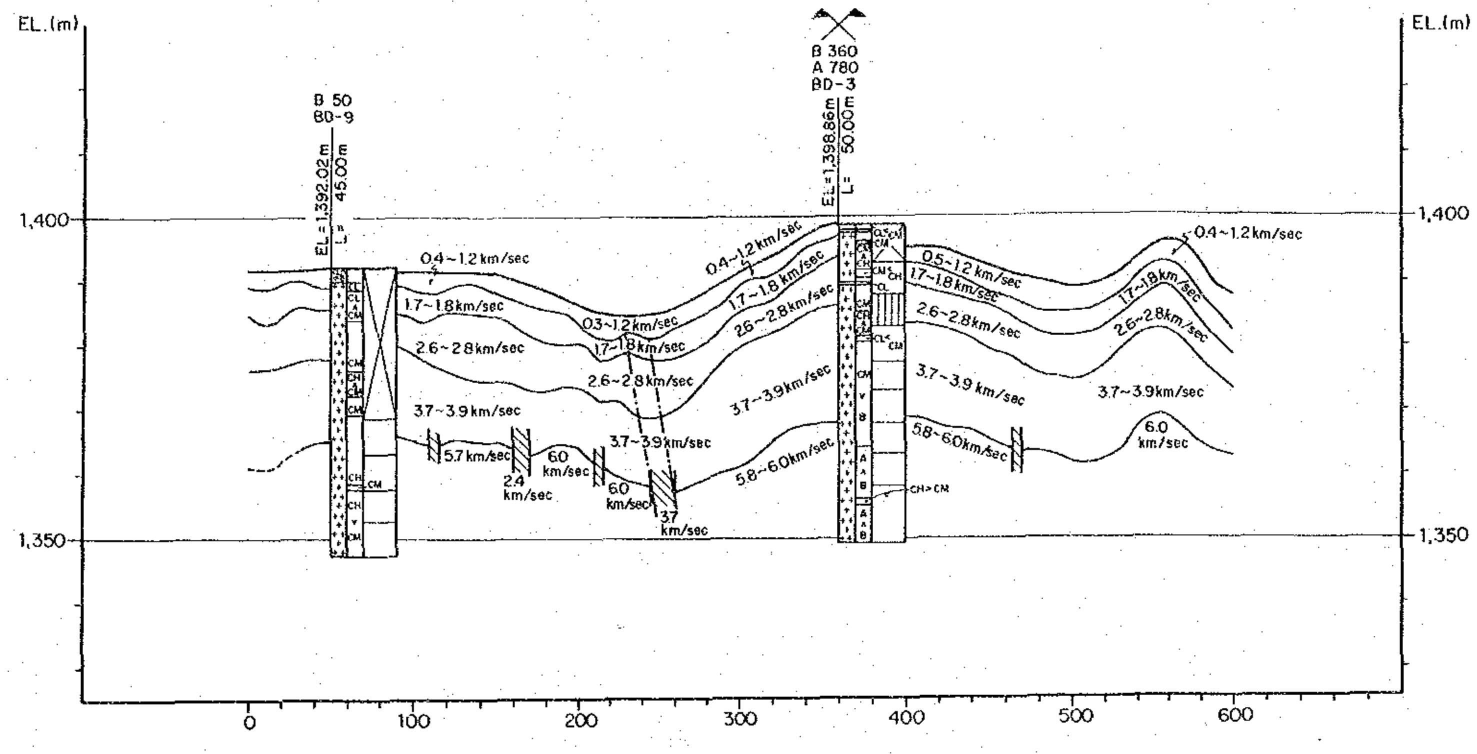


Geological Section for the Upper Intake Damsite

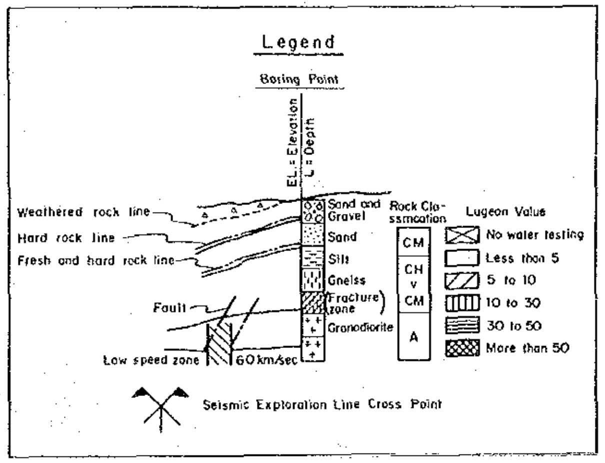
Figure 4.2

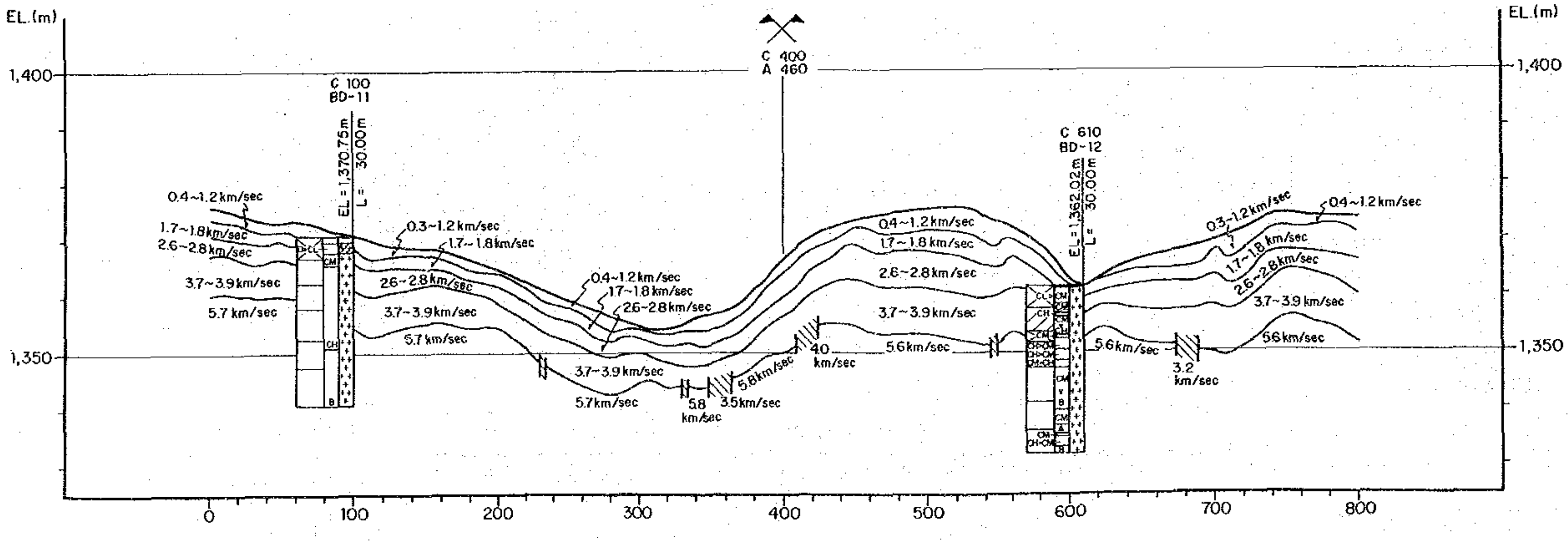
Geological Sections(1/6)

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY



Geological Section for B-Line

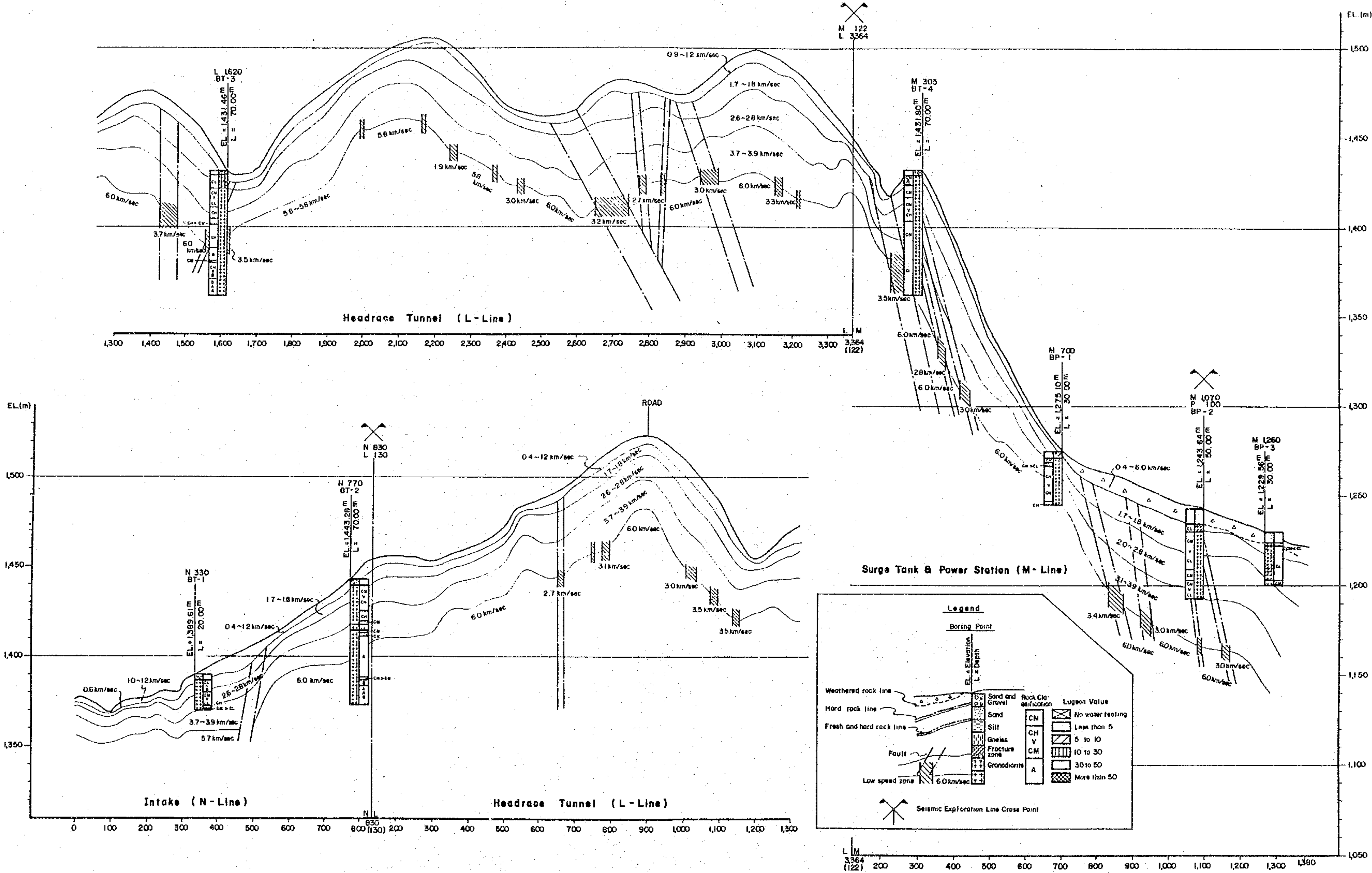




Geological Section for C-Line

Figure 4.2
Geological Sections (2/6)

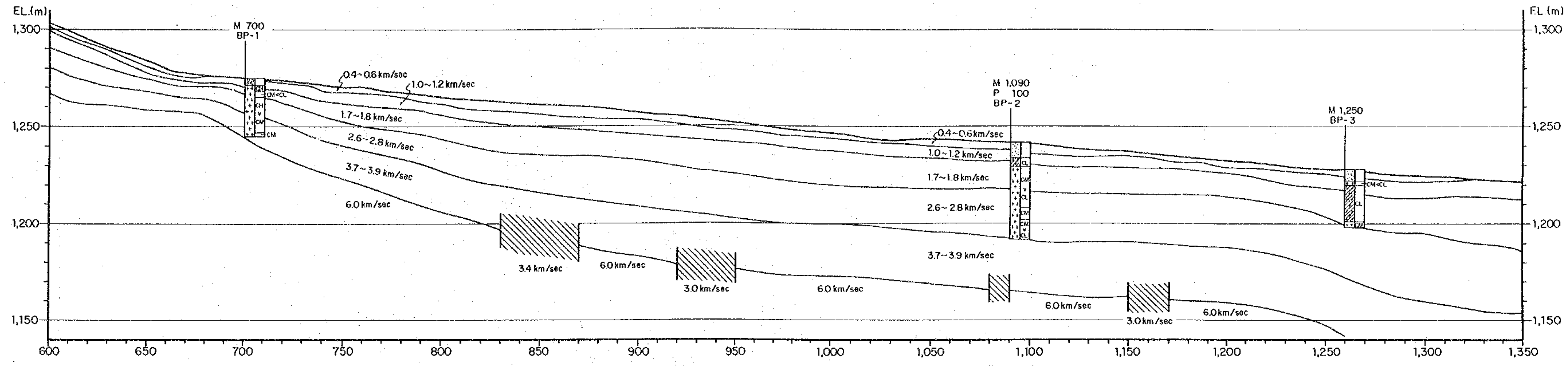
REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY



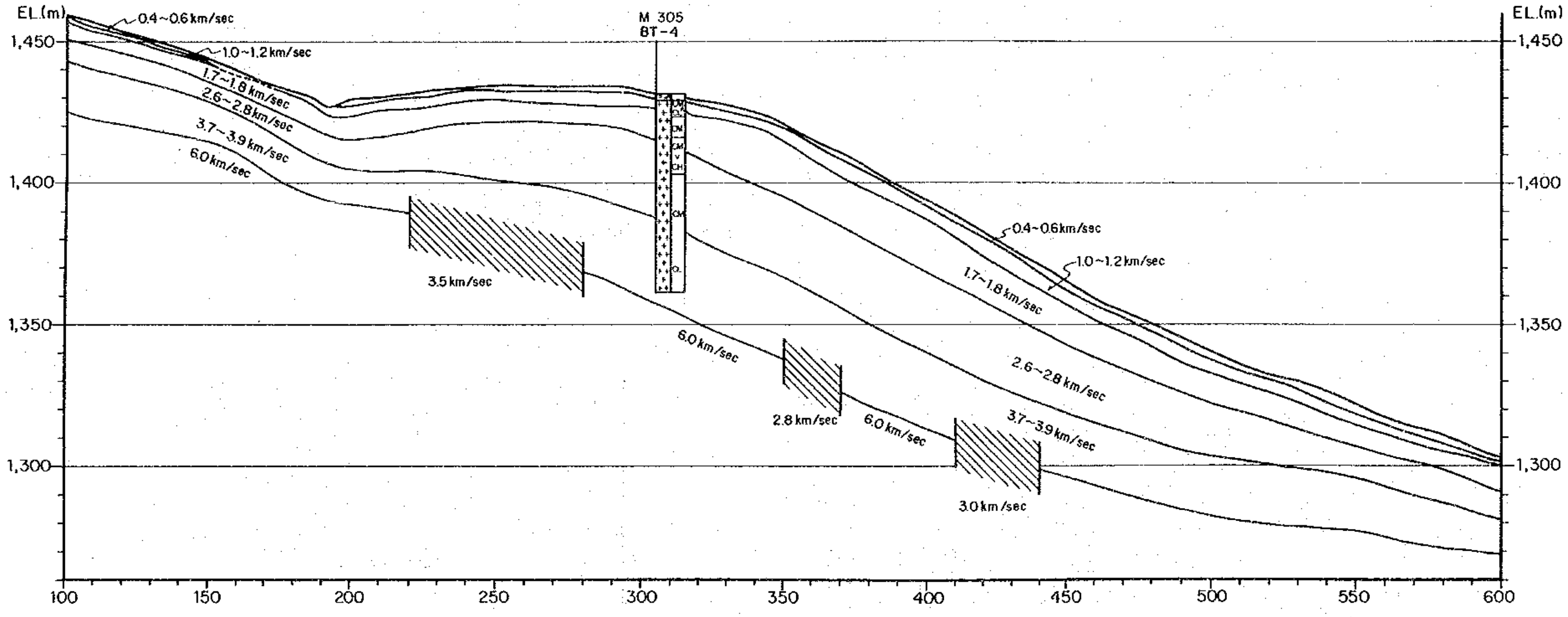
Geological Section for Waterway

Figure 4.2
Geological Sections (3/6)

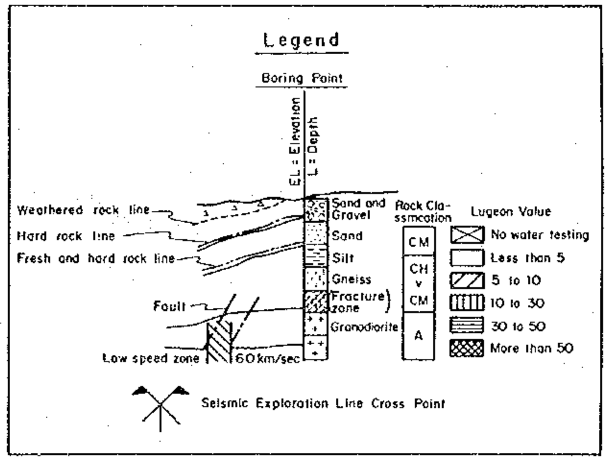
REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

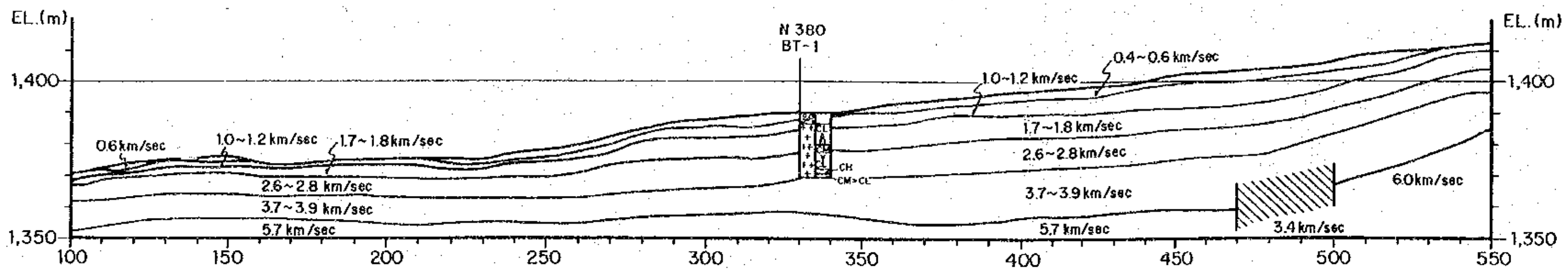


Geological Section for M-Line



Geological Section for M-Line

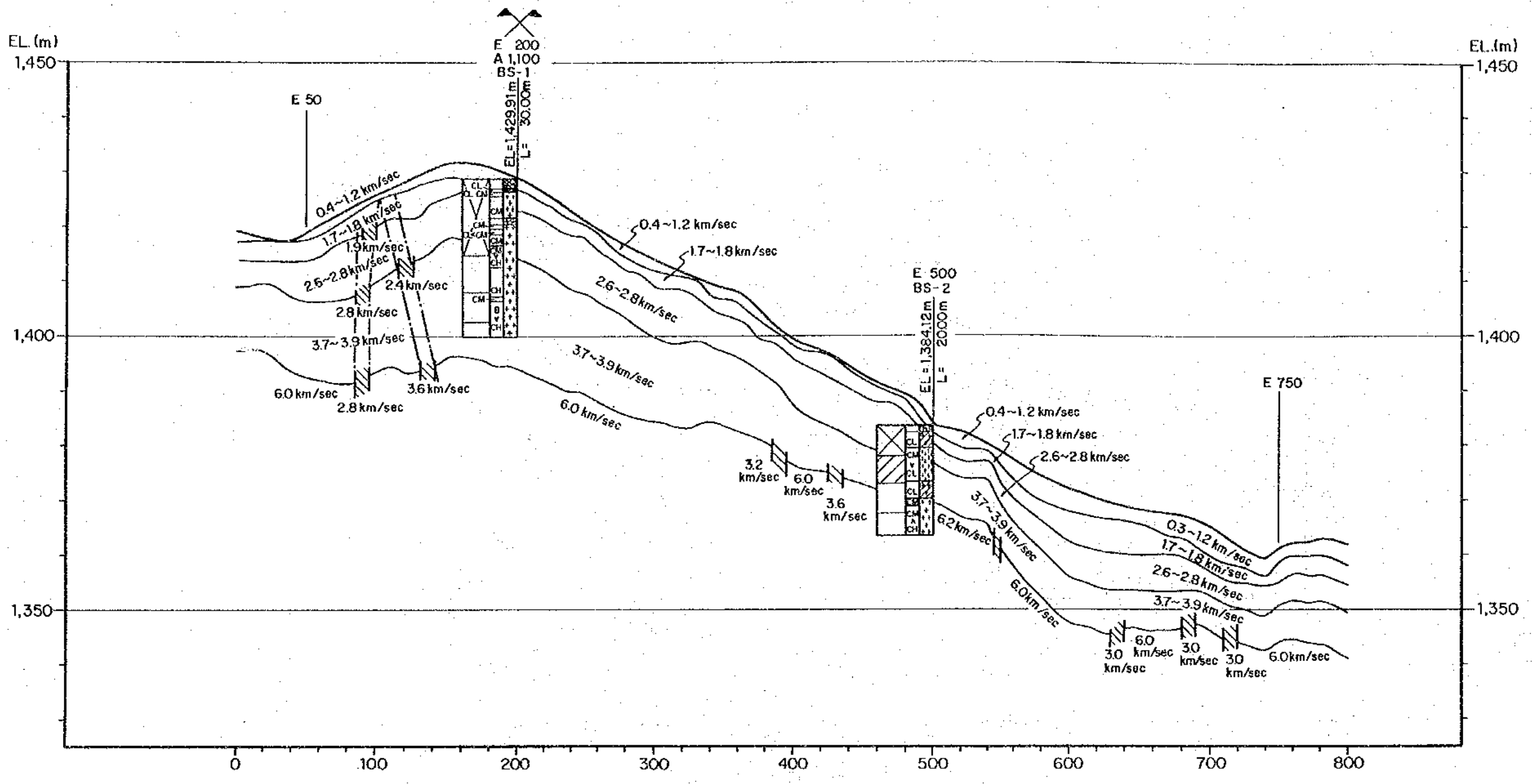




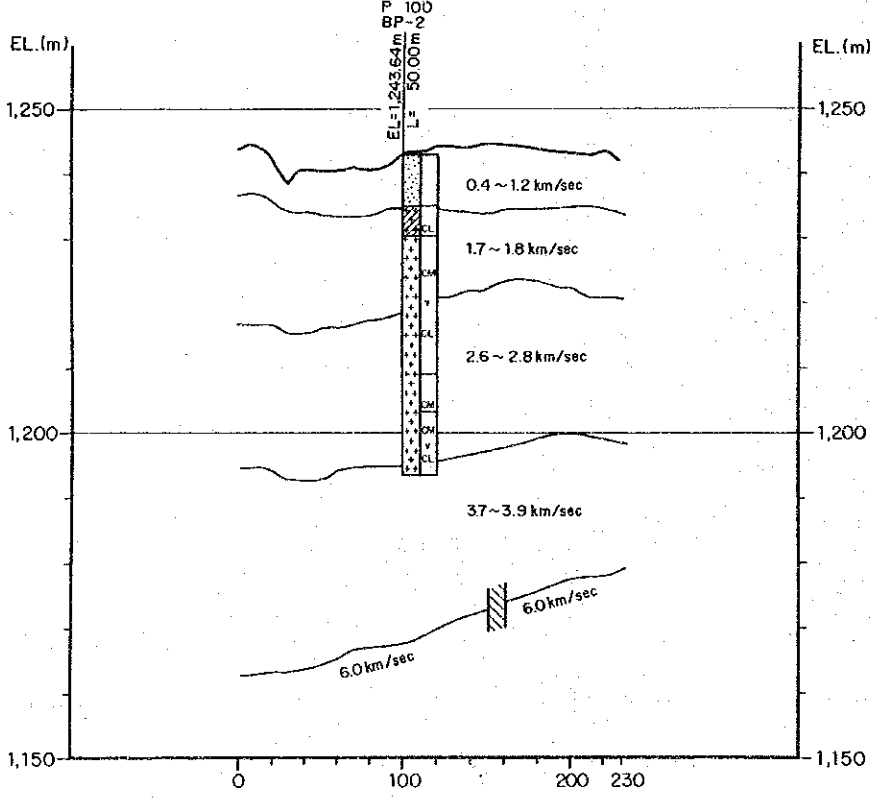
Geological Section for N-Line

Figure 4.2
Geological Sections (4/6)

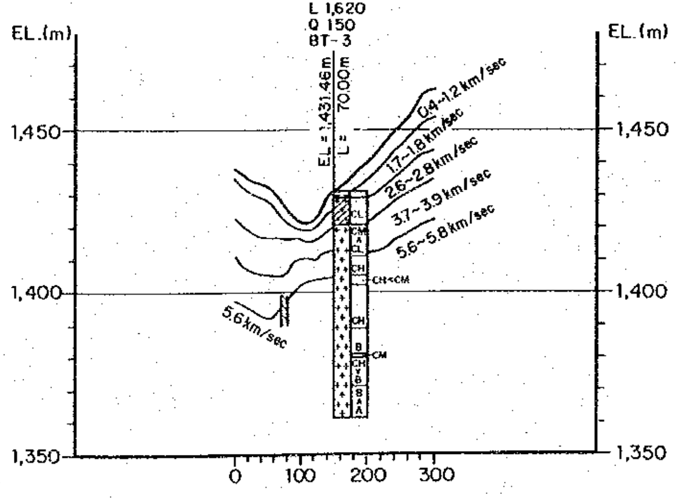
REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY



Geological Section for E-Line



Geological Section for P-Line



Geological Section for Q-Line

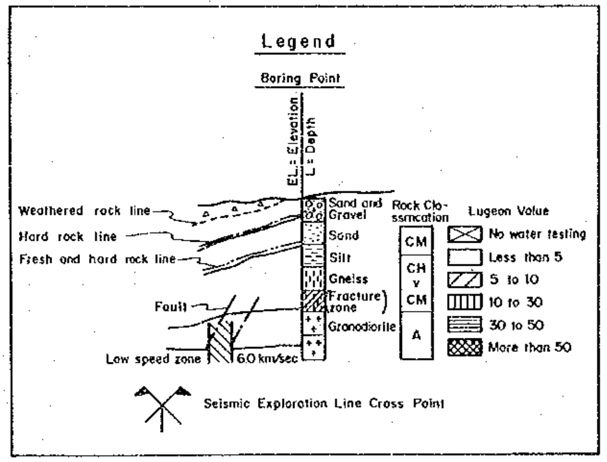
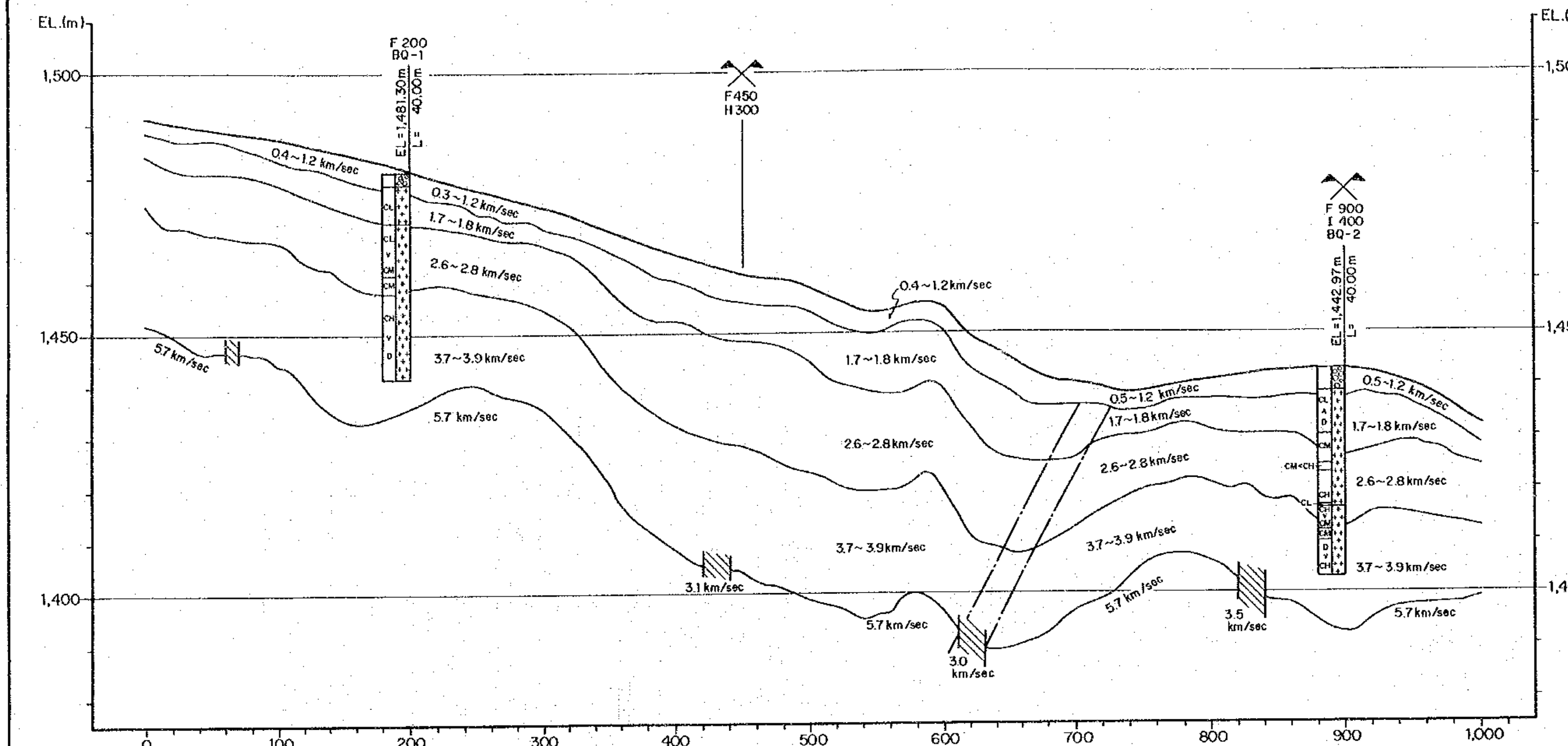
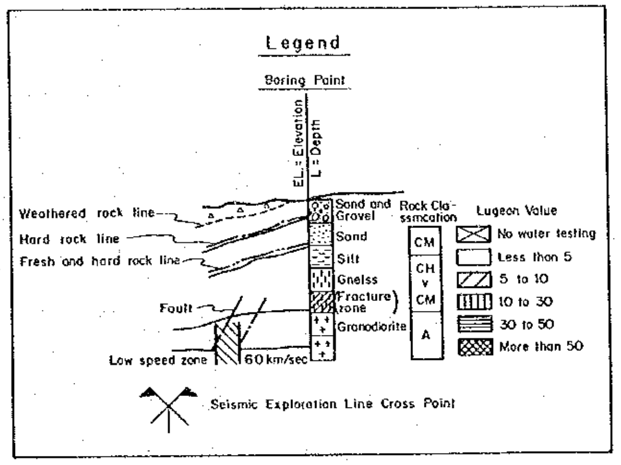


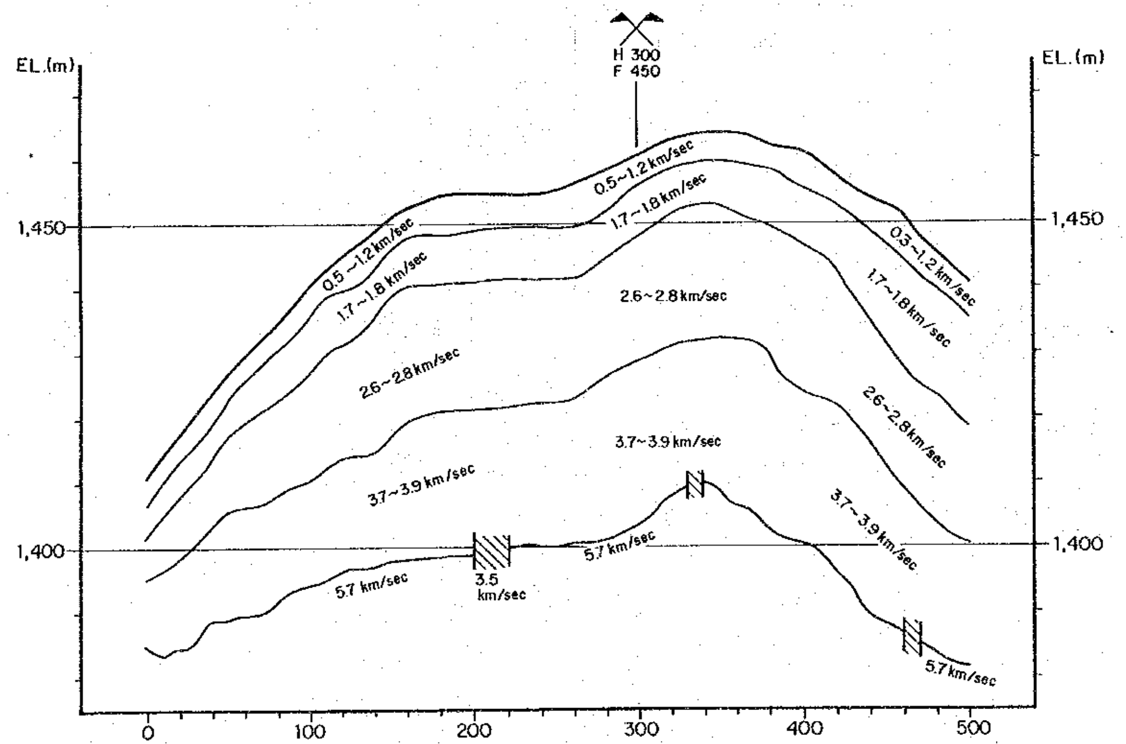
Figure 4.2
Geological Sections (5/6)

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

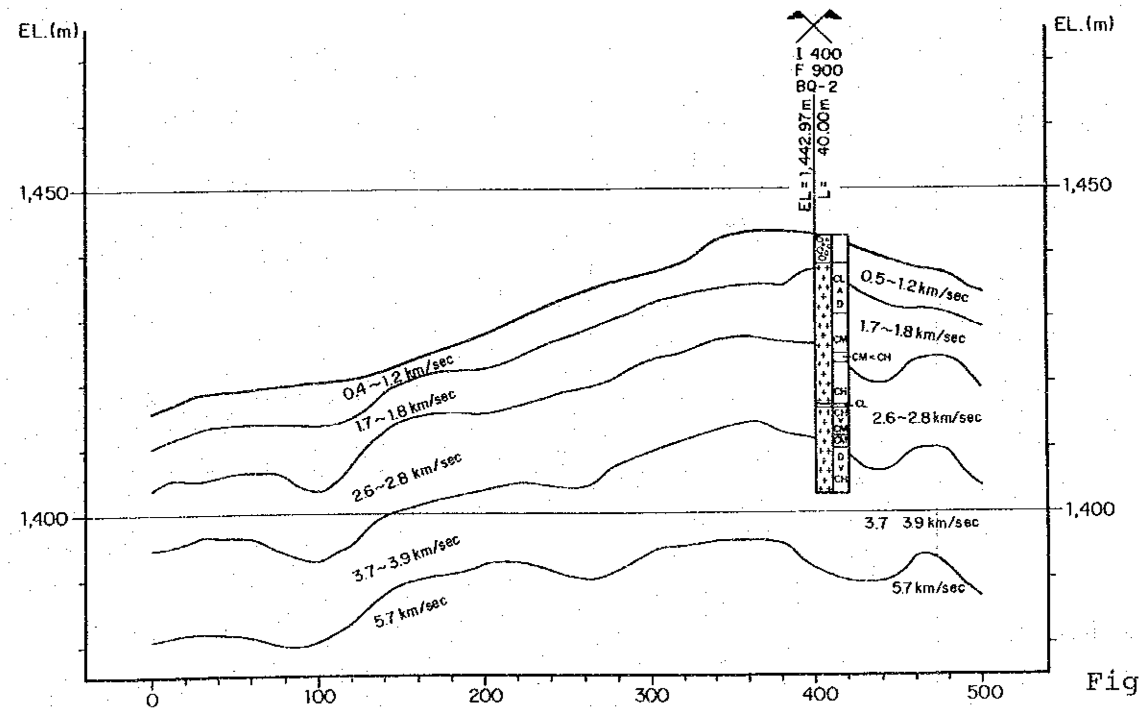


Geological Section for F-Line





Geological Section for H-Line



Geological Section for I-Line

Figure 4.2
Geological Sections (6/6)

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

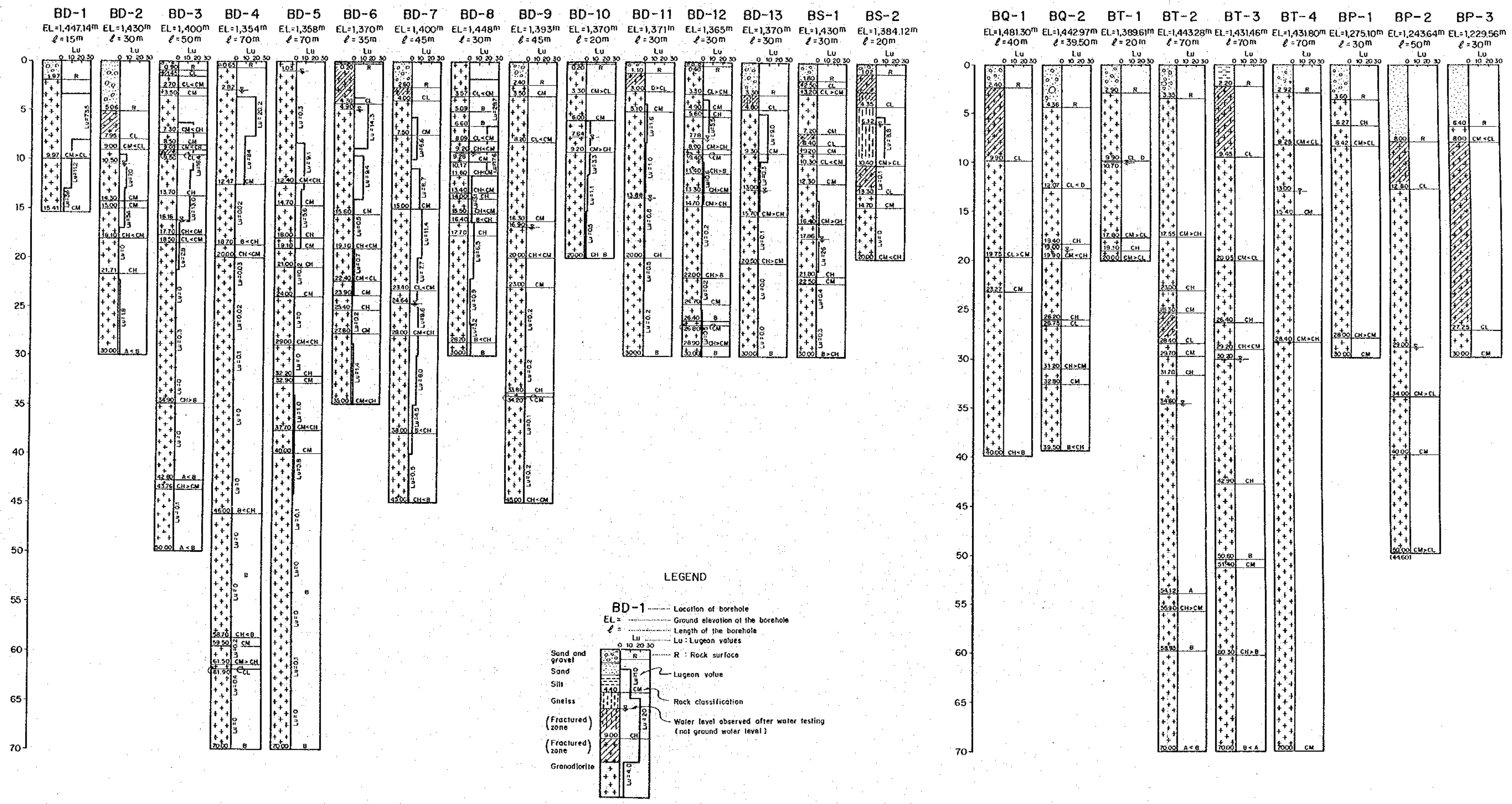


Figure 4.3
Summary of Cored Logs
(Rock Classification and Water Test)

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

APPENDIX II CONSTRUCTION MATERIAL STUDY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1. INTRODUCTION

1.1 Scope of Investigation

The broad objectives of the materials exploration carried out from February to November, 1984 with some intermissions, are to determine the availability and quality of construction materials in the project area in close association with the geological investigations.

After a brief field reconnaissance of the area carried out during the inception stage of February to March, 1984, to locate all likely sources of earthfill, rockfill and gravel-sands, the most promising sites were explored in detail from June to November, 1984.

The surface exploration at the inception stage was carried out primarily at and around the Sondu/Miriu dam site jointly by the geologist and the soil mechanics engineer covering the river-bed upstream and downstream of the lower storage damsite, possible quarry sites, possible borrow area and proposed power station site. At the end of the inception stage, the location of the proposed borrow area and the specification for the site investigation works and laboratory tests to be done by the local engineering firm were prepared.

The construction material survey started on June 27, 1984 with test pitting works in the proposed borrow area. From each test pit, the materials to be used for the impervious core were sampled for laboratory testing. Concerning quarried rock materials to be used for the rock zone as well as for the concrete aggregate, the rock materials were sampled from the bored cores for laboratory testing. In addition to those samples, sands occurring at and around the power station site were also sampled for laboratory testing. All the samples were hauled to the Gauff's laboratory in Nairobi.

1.2 Prospective Material Sources

The proposed borrow area for the core material is located on the left bank just upstream of the dam site, and is situated on the flat area and on the gentle slope in the northern part of the existing road between Ramula and Ramba.

The proposed quarry site consists mainly of granodiorites with a band of gneiss which seems to run across the river and to extend to the possible quarry sites on both banks.

The surface exploration along the river has revealed that deposits of river sand are found in quite limited localities and scarce in quantity. Therefore, any idea of designating the borrow sites along the river had to be abandoned for providing gravel-sands to be used as filter and concrete aggregates. On the other hand, near the power station site, there occur in places small streams and gullies formed on the hill-wash immediately on the north of the escarpment. They are expected to be possible sites which will provide sands, but with minor problem of quantity available.

1.3 Site Investigation Works

1.3.1 Test Pitting

Thirteen test pits were dug by hand to a maximum depth of 5 m. These test pits were explored for the sources of the earthfill material, and numbered from TP. No.1 to TP.No.13. The other numbers designated as TP.No.14, TP.No.15 and S/006 were used for the sources of sand material, where only sampling was made from the sand deposits. The location of the above test pits and sampling is presented in Figure 1.1.

1.3.2 Laboratory Testing

All the materials sampled for the earthfill, the sand and the quarried rock were hauled to the Gauff's laboratory in Nairobi. Field and laboratory test results for earthfill material are summarized in Table 1.1. The details of the results of laboratory tests are compiled in the report "Site Investigation Works, Volume III, MATERIAL REPORT" prepared by the GAUFF.

Chapter 2. IMPERVIOUS CORE MATERIALS

2.1 General

The weathered granodiorite, which is widely distributed on the gentle slope in the proposed borrow area, is able to be easily exploited with common bulldozers to produce a fine to medium grained soils and could be considered for use as impervious earthfill. However, the soil to be exploited, even if some breakdown of the weathered granodiorite is taken into account, is silty sand of moderate plasticity compared with the commonly used core material. And concerning the permeability characteristics, which is the most important factor for evaluating the suitability for the impervious core, the laboratory permeability test did not show the results as had been expected, due to insufficient test data.

2.2 Methods of Field Investigation

Prior to determining the location of any test pit on the map, a brief ground reconnaissance along creeks and ridges around the proposed borrow area was carried out to check the presence of the required materials in the inception stage. The location map of the test pits was prepared for tendering at the end of the inception stage. The test pits are located within a band of 0.5 km wide and 2.0 km long. All the test pits were excavated by man-power to a depth of 5 m. The upper portion of each pit to 1.0 meter below the ground level was shored and braced to prevent the collapse of exposed wall into the pit. The excavated material was sampled regularly in each test pit for laboratory testing, following the sampling schedule shown in Figure 2.1.

2.3 Sources Considered for the Earthfill Materials

The borrow area is situated on the left bank of the Sondu River and extends on the gently slope within a 3.0 km radius upstream of the damsite bounded to the south by the existing road between Ramba and Ramula.

Exploration was concentrated in an area of a 0.5 km wide band for about 2.0 km on the gentle slope. Inspection of creeks and eroded gullies throughout the area confirmed that weathered granodiorite is the principal rock type and excavations showed the following general profile:

- 0.1 m to 0.5 m of clayey or lateritic topsoil
- 0.5 m to 1.0 m of weathered gneiss or granodiorite containing hard fragments with 5 to 10 cm in size
- 2.0 m to 4.0 m of heavily weathered granodiorite.

Samples of material were taken from the test pit excavations for laboratory testing. Results are presented in the subsequent Section 3.4.2.

2.4 Properties of the Earthfill Materials

Under a precondition that the weathered granodiorite was considered to be the most probable sources for the impervious earthfill materials, the materials sampled from each test pit were used for laboratory testing to determine the basic engineering properties such as specific gravity, gradation, consistency, natural water content and compaction. On the other hand, the materials sampled from T.P. No.1, T.P. No.4 and T.P. No.8 being likely representative of the weathered granodiorite occurred in the proposed borrow area, were used for the laboratory permeability and triaxial shear tests. The following descriptions are made on the engineering properties of the weathered granodiorite.

2.4.1 Field Testing

(a) In-situ moisture content and density

The in-situ moisture contents of the weathered granodiorite ranged around 3% to 30%, the average being about 9.0%, while the optimum moisture contents were in the order of 10% to 17%.

In-situ density tests were carried out at a depth of 1.5 m at 6 test pits. The in-situ dry density was of the order of 1.50 t/m3 to 1.95 t/m3, as shown in Figure 2.2.

(b) General profile

The soil profiles of each test pit are presented in Figure 2.3.

2.4.2 Laboratory Testing

(a) General

All laboratory testing was done either at Gauff's laboratory or at other laboratories of Gauff's associates in Nairobi. Laboratory tests conducted mainly on weathered granodiorite, included specific gravity, gradation analysis, consistency and compaction tests, triaxial shear strength and permeability tests.

(b) Classification Tests

(i) Grading analysis

Tests were carried out only by mechanical sieving on 22 samples of weathered granodiorite and 4 of lateritized red soil. The curves for the weathered granodiorite lie within a relatively narrow band except for a few samples from T.P. No.12, of which grading curves are slightly on the coarser side of the average band.

The curves for the lateritized red soils are on the finer side of the above-mentioned band, and show values of silt size fractions ranged 20% to 40%.

Figures 2.4 show the results of the grading analysis.

(ii) Consistency Tests

Atterberg tests for liquid and plastic limits were carried out on 22 samples and 5 samples for the weathered granodiorite and the lateritized red soil, respectively. The result is shown below.

	Liquid Limit W_L (%)	Plastic Limit W_p (%)	Plasticity Index I_p (%)
Weathered granodiorite	39.5 (σ=8.5)	26.3 (σ=6.0)	13.2 (σ=4.2)
	(22 values & non-plastic for 2 samples)		
Lateritized red soil	45	26	19

Figure 2.5 shows the plasticity range of the weathered granodiorite and the lateritized red soil on a Casagrande Classification Chart.

(c) Engineering Properties

Compaction, permeability and triaxial shear strength tests were carried out on the weathered granodiorite.

(i) Compaction

Standard laboratory compaction for maximum dry density and optimum moisture content of weathered granodiorite were carried out on 10 samples.

One sample of the lateritized red soil gave distinctively greater optimum moisture content and lower maximum dry density than the corresponding average on the above-mentioned 10 samples for the weathered granodiorite. The compaction curves for the two types of soil are shown in Figure 2.6 and Figure 2.7 based on the following data.

	O.M.C (%)	M.D.D (t/m^2)	N.M.C (%)
Weathered granodiorite	13.4 (σ=2.0) (10 samples)	1.832 (σ=0.09) (10 samples)	9.0 (σ=4.8) (36 samples)
Lateritized red soil	17.5	1.715	8.6

Specific gravities were tested on 20 samples for the weathered granodiorite and on 4 samples for the lateritized red soil.

The field moisture contents of in-situ weathered granodiorite are lower than optimum, so that moisture will have to be sufficiently added to the earthfill material during embankment operation to produce the required moisture content, supposed to be 2 to 3% above optimum.

(ii) Permeability

Laboratory permeability tests were carried out on three samples of the weathered granodiorite, which were taken from T.P. No.1, T.P. No.4 and T.P. No.8. The relationship among moisture content, dry density and coefficient of permeability of each sample is shown in Figure 2.8. The variable-head test was employed on all specimens and values obtained under no surcharge were in the range from 1.0×10^{-4} cm/sec to 3.0×10^{-4} cm/sec, indicating a soil of rather high permeability that may be marginally allowable, if adequate construction procedures are employed for use in the impervious core of a rockfill dam.

The relationship among in-situ, optimum moisture contents, moisture content at which the minimum coefficient of permeability is expected to be obtained and construction moisture content to be recommended, is illustrated in Figure 2.9. Figure 2.9 is compiled based on the values shown on Table 2.1, which are inferred from Figure 2.10. It will be recommended that water should be added to such a large extent that the moisture content be increased to 3 to 4% above the optimum or more as far as the trafficability of the construction equipment is not hampered. Consequently, what is most vital to the proposed core materials in the construction stage will be a moisture control, that is, "On the wet side of the optimum moisture content" compaction in order to build an impervious wall in the rockfill dam.

(iii) Triaxial Shear Strength

Three samples of weathered granodiorite were tested in triaxial shear. The multi-stage triaxial shear tests were carried out under the unconsolidated and undrained condition without pore-pressure measurement. The test conditions are described on Table 2.2. Mohr-circle diagrams have been plotted for the three multi-stage undrained triaxial tests as shown in Figure 2.11.

Design shear strength parameters on effective stress basis could not be determined from these undrained shear tests, but the following parameters are recommended to be tentatively adopted at this stage for the impervious thin core of the rockfill dam:

Cohesion	C' = 0.2 kg/cm2
Friction angle	$\phi = 30^{\circ}$.

More detailed triaxial tests inclusive of consolidated-undrained tests with pore-pressure measurement will be necessary at the next stage.

2.5 Tentative Design Values

The tentative design values for the embankment materials are presented in Table 2.3 for the dam design at the feasibility study stage.

2.6 Quantities Available

A simple and rough calculation based on the explored plan area (about 500 m x 2,000m) and allowing a nominally proven depth of 5 m and a probable top soil stripping and associated waste depth of 1 m to 2 m yields an available quantity in the borrow area of not less than 1,000,000 m^3, even if much conservatively estimated.

The most portion of the earthfill will consist of weathered granodiorite with a bulking factor of 0.95, offset by waste during excavating, stockpiling, loading, hauling and placing. It is roughly assumed that a net overall bulking factor be around 0.85.

Chapter 3. ALLUVIAL GRAVEL-SANDS

3.1 General

No significant reserves of gravel-sands occur within the project area as alluvial deposits in the bed and banks of the Sondu River. The surface exploration along the river has revealed that deposits of river sand are found in quite limited localities and scarce in quantity. Furthermore, based on the brief reconnaissance in the project area and the geological interpretations in the area concerned, any idea of designating the borrow site along the river had to be abandoned for obtaining sand and gravel materials to be used for filter and concrete aggregates. Therefore, no exploratory excavation was carried out at this stage except sampling river sands which occur in places along the small streams and the gullies formed on the hill-wash on the foot of the escarpment. These sands are now seen to be used for the concrete works such as bridge construction around there.

3.2 Methods of Field Investigation

Since no significant sources were found out except, there find sand deposits in several places along the small streams and gullies on the foot of the escarpment. From there, sands were taken for laboratory testing, where no exploratory excavation was carried out.

3.3 Sources Considered for Concrete Aggregate and Filter Materials

Principally, the sand and gravel materials are intended to borrow from the quarry site, for the use of concrete aggregate and filter. Therefore, the engineering properties are discussed on the quarried rock in the subsequent Section 4.3.

3.4 Properties of the Sands

The materials were sampled from the sand stockpiled near the stream, which was used for bridge construction, designated as T.P.15. The others were sampled in the gully near the proposed power station site, the material designated as T.P.14 being from the deposit of the dried stream base of gully and the material designated as S/006 from the exposed wall of the gully. Based on the basic engineering properties such as specific gravity and gradation as shown in Figure 3.1, the sands occurring along the stream are considered to be suitable for fine aggregate but the materials forming the gully itself are considered to be unsuitable. No survey of available quantity for the sands concerned was carried out at this stage.

Chapter 4. QUARRIED ROCK (ROCKFILL AND CONCRETE AGGREGATE)

4.1 General

The most promising source of quarried rock was investigated with one bore-hole and one line of seismic exploration on the right bank immediately downstream of the dam site. In addition to the samples taken from drilled cores, those taken from the drilled cores obtained in two bore-holes made along the dam axis were used for laboratory testing, because the rock condition of the dam foundation was considered to be quite similar to those in the quarry site. Both are in granodiorite areas. The right bank ridge downstream of the dam site is designated as "the quarry site". The rock to be excavated from the dam foundation may be also a potential source for concrete aggregate and rockfill, or random-fill. Another source of granodiorite on the left bank immediately downstream of the dam site was initially considered but was judged to be of inferior quality because of the intrusion of gneiss.

4.2 Method of Field Investigation

The quarry site is located on the right bank, about 1 to 2 km downstream of the damsite. Its location is shown on Figure 1.1.

Geologically the feature is dominated by granodiorite, but occasionally by gneiss. Outcrop exposures of granodiorite appeared mostly to be hard and durable. Exploration of this feature included 84-98 mm diameter core boring of 80 m and one seismic traverse of 2,000 m on the ridge of the quarry mountain. It is expected that most of the deposit with a thin overburden is capable of yielding rock up to riprap size.

4.3 Engineering Properties

Total ten samples of drilled core were taken from the exploratory holes in the quarry site and the dam site. These samples were subjected to unconfined compressive tests in both the air-dried and saturated conditions together with specific gravity, absorption, abrasion and sodium sulphate soundness tests. Specimens for unconfined compressive strength were cut to have length of core at a length/diameter ratio of 2.0. However, for the remainder of the tests, the individual pieces from the core sample were combined for testing. The test results are summarized in Table 4.1.

The granodiorite in the quarry site and the dam site is strong and durable, suitable for rockfill and it would be suitable for use as aggregate for concrete after processing which would include crushing, screening, and washing.

The gradation for filter materials to be produced from the quarry mountain is recommended as shown on Figure 4.1.

4.4 Quantities Available

It is conservatively estimated that the deposit of the proposed quarry mountain contains about 4,000,000 m^3 or more for the granodiorite bedrock with a seismic wave velocity of 2.6 to 2.8 km/sec.

Chapter 5. RECOMMENDATIONS FOR FURTHER INVESTIGATION

5.1 General

The investigations carried out during the feasibility study have identified the various aspects of the study warranting further work at the next stage. These will be directed towards clarifying uncertainties and confirming the information now available. Comprehensive data are still necessary for detailed design, tendering and guidance during construction.

5.2 Earthfill Materials

The earth borrow area for the rockfill dam as an alternative plan of the Sondu/Miriu development scheme, is considered to provide sufficient material. Additional investigation is however very necessary to clarify and confirm the permeability characteristics which indicate the relationship between moisture content and compaction. This is vital to the final judgement on the suitability of weathered granodiorite for use of the impervious core.

Subsurface exploration by test pitting on 200 m grid across the necessary area would be recommended at the next stage, with supplements of excavation by bulldozer or back-hoe trenches, is available. In association with these works, a detailed record of the magnitude and variation with depth of in-site moisture contents of weathered granodiorite throughout the borrow area will be necessary.

A programme of careful sampling and laboratory testing will be necessary to provide a clear but common characteristics of permeability in association with moisture content.

5.3 Sands

An extensive programme will be required to confirm the quantity and distribution of sand deposits in the small streams and gullies formed on the hill-wash close to the proposed power station site. Extensive sampling will be also necessary in all deposits explored.

5.4 Rockfill and Concrete Aggregates

A programme of core drilling and geological mapping should be carried out in the quarry site in consideration of preliminary construction planning. This information will assist in developing quarrying methods.

Trial quarry blasts should be performed to assess the effects of joints on fragment size and the yield of the explosive. The quarried rock after these blasts will be sampled for laboratory testing to reconfirm the physical properties.

TABLES

Table 1.1 Summary of Field & Laboratory Test Results for the Eathfill Material (1/3)

Location of Test Pit	Depth m	Unified Classification	Gradation										Consistency			Moistuer Content %	Specific Gravity, GS	Compaction		Field		Remarks
			Max. Size	Gravel			Sand					Silt	LL	PL	PI			MDD	OMC	Density t/m³	Moisture Content %	
			mm	20 mm	10 mm	6.8 mm	4 mm	2.36 mm	1 mm	0.425 mm	0.150 mm	0.014 mm	%	%	%			t/m³	%			
T.P.1	0.5	SM	6.8	-		100	92	-	76	61	-	44	46	25	21	12.7	2.67					
	1.0															7.5						Weathered Granodiorite
	1.5	SM	6.8	-		100	96	73	50	32	24	20	41	28	13	6.0	2.65	1.88	12.2	1.819	6.2	
	2.0															8.0						
	2.5	SM	25	99	97	93	-	68	49	33	-	20	39	25	14	3.0	2.66					
	3.0	SM	10	-	100	96	89	64	42	24	16	12				6.6	2.67					
T.P.2	1.0	ML	20	100	92	83	-	79	-	74	-	67	45	24	21	23.6	-					Weathered Gneiss
	2.0	ML	37.5	94	91	87	-	77	73	69	-	60	36	23	6	19.7	-	2.01	8.6			
T.P.3	0.5	ML	10		100	97	-	89	83	77	-	54	45	30	15	14.3	2.59					
	1.0															15.1						Weathered Gneiss
	1.5	SM	37.5	85		80	77	72	68	62	51	42	43	24	19	11.2	2.75	1.83	15.5			
	2.0															16.1						
	2.5	SM	20	100		95	-	87	82	72	-	46	38	25	13	11.5	2.66					
	3.5	SM	10	-	100	99	98	94	90	72	50	39	36	24	12	10.6	2.61					
T.P.4	0.5	SM	20	100	99	96	-	71	53	39	-	25	43	23	20	5.9	2.62					
	1.0															2.6						Weathered Granodiorite
	1.5	SM	20		99	93	84	63	45	27	20	17	43	23	20	4.6	2.62	1.89	12.0			
	2.0															5.0						
	2.5	SM	6.8			100	-	83	59	34	-	15	34	23	11	5.7	2.52					
	5.0		20		99	97	95	85	59	40	26	18	29	19	10	3.5						
T.P.5	0.5	SM	20		99	94	88	72	62	52	45	40	50	25	25	9.4	2.64					
	1.0															9.6						Weathered Granodiorite
	1.5															6.4				1.677	10.2	
	2.0	SM	6.8			100	99	90	71	46	33	28	33	22	11	3.9	2.64					
	2.5	SM			96	95	94	82	62	44	27	22	32	21	11	9.3	2.64	1.83	13.5			
	5.0	SM			99	98	95	81	60	34	22	17	27	19	8	2.7	2.56					

Table 1.1 Summary of Field & Laboratory Test Results for the Eathfill Material (2/3)

Location of Test Pit	Depth m	Unified Classification	Gradation										Consistency			Moisture Content %	Specific Gravity, GS	Compaction		Field		Remarks
			Max. Size	Gravel				Sand				Silt	LL	PL	PI			MDD	OMC	Density t/m^3	Moistuer Content %	
			mm	20 mm	10 mm	6.8 mm	4 mm	2.36 mm	1 mm	0.425 mm	0.150 mm	0.014 mm	%	%	%			t/m^3	%			
T.P.6	0.5	SM	10	-	100	93	87	68	54	42	34	30	50	27	23	6.8						
	1.0															6.6						Lateritized Red Soil
	1.5															9.2				1.344	14.6	
	2.0	SM		-	99	96	93	86	75	56	48	42	40	25	15	9.0	2.68	1.72	17.5			
	2.5				97	94	92	86	73	47	35	29	38	20	18	7.9	2.62					
	3.0	SM	20	100	98	94	91	83	71	49	37	30	46	27	19	11.9	2.69					
T.P.7	1.0															9.5						
	1.5															13.9						
	2.0	SM	4	-		-	100	95	80	60	49	43	50	33	17	12.7	2.64	1.63	16			Weathered Granodiorite
	2.5	SM	4	-		-	100	97	84	65	-	46	47	27	20	13.3	2.65					
	4.8	SM	4	-		-	100	88	64	38	27	20	36	27	9	6.1	2.67					
T.P.8	0.5	ML	6.8	-		100	-	-	99	95	-	65	44	27	17	26.8	2.50					
	1.0															24.5						Weathered Granodiorite
	1.5	SM	6.8			100	-	88	69	48	-	29	48	39	9	16.4	2.71			1.656	19.6	
	2.0															10.6						
	2.5	GM	10		100	96	-	72	49	29	-	12	37	28	9	10.2						
	5.0															16.5						
T.P.9	0.5	GM	37.5	78	49	33	27	18	17	16	13	11	36	20	16	5.0	2.59	1.88	12.5			
	1.0															7.5						Weathered Granodiorite
	1.5	SM		99	89	81	76	65	57	48	39	33	54	22	32	11.2	2.66					
	2.0															15.7						
	2.5	MH	28	98	97	92	-	90	89	77	-	60	62	41	21	30.1	2.61					
	5.0	SM	20	100		99	-	98	93	72	47	37	43	29	14	15.0	2.50					

Table 1.1 Summary of Field & Laboratory Test Results for the Eathfill Material (3/3)

Location of Test Pit	Depth m	Unified Classification	Gradation										Consis-tency			Moisture Content %	Specific Gravity, GS	Compaction		Field		Remarks
			Max. Size	Gravel			Sand					Silt	LL	PL	PI			MDD	OMC	Density t/m3	Moisture Content %	
			mm	20 mm	10 mm	6.8 mm	4 mm	2.36 mm	1 mm	0.425 mm	0.150 mm	0.014 mm	%	%	%			t/m3	%			
T.P.10	0.5	ML	10		100	99	-	89	81	74	-	59	50	23	27	17.1	2.70					
	1.0															9.2						
	1.5	SM	6.8			100	99	91	74	52	38	32	45	25	20	8.3	2.64	1.76	16.5	1.499	20.7	Weathered Granodiorite
	2.0															8.8						
	2.5	SM	4				100	96	88	58	-	33	38	25	13	13.2	2.74					
	4.5	SM	4				100	95	79	49	30	21	Non plastic			6.7	2.76					
T.P.11	0.5			80	64	50	44	40	35	28	19		Non plastic			-	2.60					
	1.0	SM	20	100	97	90	-	81	70	47	-	27	34	21	13	12.8						Quartize
	2.0															4.7						
	2.5	SM	20	100	94	89	85	64	45	29	23	19										
	3.9			82	69	61	56	44	33	22	15	13	35	24	11	-	2.63					
T.P.12	0.5	SM				100	-	88	70	55	-	43	57	37	20	12.1						
	1.0															6.3						
	1.5	SM	10		100	99	94	68	46	28	20	17	42	30	12	3.6	2.62	1.97	10	1.955	5.3	Weathered Granodiorite
	2.5	SM			99	96	89	55	34	19	13	10	30	21	9	3.6						
	3.0	SM	37.5	96		94	89	61	37	19	12	9	Mon plastic			3.2						
T.P.13	1.0	SM	28	99	94	88	79	54	38	29	24	21	50	32	18	32	2.66					Lateritized Red Soil

Table 2.1 Difference between O.M.C. and Moisture Content

(a) Permeability characteristics for decomposed granite in Japan

	O.M.C.	Moisture Content*	Difference
1	12.5 %	14.0 %	1.5 %
2	10.5 %	13.0 %	2.5 %
3	10.0 %	15.0 %	5.0 %
4	11.5 %	12.5 %	1.0 %
5	11.0 %	14.0 %	3.0 %
6	10.5 %	13.0 %	2.5 %
7	8.0 %	10.0 %	2.0 %
8	8.5 %	11.0 %	2.5 %
9	9.0 %	11.0 %	2 %
10	10.0 %	12.0 %	2 %
11	9.0 %	10.0 %	1 %

$\overline{X}$ 2.27%

σ_{n-1} 1.10%

(b) Permeability characteristics for the core material of decomposed granite in Andong dam of South Korea

	O.M.C.	Moisture Content*	Difference
1	11.0 %	14.5 %	3.5 %
2	11.5 %	15 %	3.5 %
3	12.0 %	15 %	3 %
4	13 %	17.5 %	4.5 %
5	13.5 %	18 %	4.5 %
6	14.0 %	18 %	4 %
7	10.5 %	14 %	3.5 %
8	11.0 %	14.5 %	3.5 %
9	11.5 %	14 %	2.5 %
10	11.5 %	16 %	4.5 %
11	13.5 %	17 %	3.5 %
12	14.0 %	14 %	0 %

$\overline{X}$ 3.375%

σ_{n-1} 1.23%

Table 2.2 Triaxial Shear Strength Tests on Weathered Granodiorite

Sample No.	Compaction Test		Specimen Condition Prior to Shear Test			Shear Parameters	
	MDD t/m^3	OMC %	d t/m^3	W %	Sr %	Cu KN/m^2	Øu o
T.P. No.1	1.78	14	1.750	15.8	81.5	60	23
T.P. No.4	1.88	12	1.843	14.2	85.9	25	30
T.P. No.8	1.838	14.5	1.796	17.0	94.6	65	27

Note: The multiple stage type is applied for the undrained shear tests. Specimen conditions prior to test are as follows:

Moisture content	OMC + 2%
Dry density	98% of MDD

Table 2.3 Tentative Design Values of the Construction Materials

		Earthfill Zone (1)	Filter Zone (2)	Drain Filter Zone (3)	Random Zone (4)	Rock/ Riprap Zone (5)
	Specific gravity GS	2.65	2.62	2.62	2.60	2.60
Density	γ_d (t/m^3)	1.80	1.82	1.92	1.95	1.90
	W (%)	15	10	8	6	4
	γ_t (t/m^3)	2.07	2.0	2.07	2.07	1.98
	γ_{sat} (t/m^3)	2.12	2.13	2.19	2.20	2.17
Shear Strength	C' (t/m^2)	2	0	0	0	0
	ϕ' (o)	30	33	33	38	40
Perme-ability	K (cm/sec)	5×10^{-5}	1×10^{-3}	1×10^{-3}	Free drained	Free drained

7

Table 4.1 Summary of Rock Material Test

Site Marking	Depth (m)	Specific gravity	Water Absorption (%)	Los Angeles Abrasion (%)	Sulphate Soundness (%)		Unconfined Compressive Sgrength	
					+No.4 Sieve	-No.4 Sieve	Bulk Density (kg/m^3)	Compressive Strength (kg/cm^2)
BQ-1	24.30 - 26.50	2.66	0.4	17	1.7	5.0	2,679	1,297
BQ-1	26.50 - 29.40	2.60	0.3	18	1.7	5.7	2,678	1,441
BQ-1	34.70 - 37.20	2.67	0.4	18	3.4	7.9	2,639	1,115
BQ-1	37.40 - 40.00	2.67	0.4	16	3.1	4.4	2,471	1,376
BD-3	21.26 - 24.00	2.66	0.1	16	1.1	3.7	2,678	1,039
BD-3	43.41 - 45.40	2.67	0.3	16	0.9	2.6	2,678	1,431
BD-9	25.50 - 31.00	2.67	0.5	17	2.9	5.9	2,681	1,388
BD-9	31.00 - 35.00	2.61	0.7	17	2.6	3.6	2,660	808
BD-9	35.50 - 39.30	2.67	0.5	16	1.1	3.1	2,671	1,164
BD-9	43.00 - 45.00	2.69	0.4	14	0.9	2.7	2,678	1,039