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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
THE REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN

FEASIBILITY STUDY ON MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT

FINAL REPORT
APPENDIX II

GEOLOGY AND CONSTRUCTION MATERIALS

OCTOBER 1993

NIPPON KOEI CO., LTD.

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List of Report

EXECUTIVE SUMMARY

MAIN TEXT

APPENDICES

I. TOPOGRAPHY

II. GEOLOGY AND CONSTRUCTION MATERIALS

III. HYDROLOGY AND METEOROLOGY

IV. ENVIRONMENTAL ASPECTS

V. HYDRAULIC CALCULATIONS

VI. DRAWINGS

FEASIBILITY STUDY
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APPENDIX II GEOLOGY AND CONSTRUCTION MATERIALS

Table of Contents

PART I GEOLOGY

1. General .... I - 1

2. Topography .... I - 1

3. Regional Geology .... I - 2

4. Seismicity .... I - 2

4.1 Collected Data for Seismicity Analysis .... I - 2

4.2 Analysis of Earthquake Coefficient .... I - 3

5. Geology of the Site .... I - 4

5.1 Geological Condition of the Reservoir Area .... I - 4

5.2 Geology of Alternative Dam Sites .... I - 5

5.2.1 Alternative Dam Site 1 .... I - 5

5.2.2 Alternative Dam Site 2 .... I - 5

5.2.3 Alternative Dam Site 3 .... I - 6

5.2.4 Alternative Dam Axis 4 .... I - 6

5.2.5 Alternative Dam Site 5 .... I - 7

5.2.6 Conclusion .... I - 7

6. Geology of the Waterway Routes .... I - 8

6.1. Downstream alternative .... I - 8

6.2. Pondage scheme at the middle reaches of the downstream waterway route .... I - 8

6.3 Upstream alternative .... I - 8

7. Geology of Quarry and Borrow Sites for Construction Materials .... I - 9

7.1 Rock Quarry Site .... I - 9

7.2 Borrow Sites for Earthfill Materials and Sand for Concrete Material .... I - 9

PART II CONSTRUCTION MATERIALS

1. General .... II - 1

1.1 Introduction .... II - 1

1.2 Method of Investigation .... II - 1

1.2.1 Field Reconnaissance, Core drilling and Test Pitting .... II - 1

1.2.2 Laboratory Testing .... II - 2

1.2.3 Alkali Aggregate Reaction Test .... II - 2

2. Sources of Construction Materials .... II - 3

2.1 Earth Fill Materials .... II - 3

2.2 River Sand and Gravel .... II - 3

2.3 Quarry Rock .... II - 3

3. Quantities Available .... II - 3

4. Properties of Construction Materials .... II - 5

4.1 Earth fill Materials .... II - 5

4.2 Sand and Gravels .... II - 5

4.3 Quarry Rock .... II - 5

5. Type of Dam Embankment .... II - 6

6. Conclusion .... II - 6

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FINAL REPORT

APPENDIX II GEOLOGY AND CONSTRUCTION MATERIALS

PART I GEOLOGY

PART I GEOLOGY

1. GENERAL

The geological investigation work has been carried out from January, 1991 to September, 1992. The work comprises of 1) First Site Reconnaissance (January, 1991 to March, 1991), 2) Seismic Exploration and Drilling Campaign (May, 1991 to September, 1991), and 3) Analysis of Seismic Data and Drilling Campaign (May, 1992 to September, 1992).

By the findings in the First Site Reconnaissance, it was clear the site is covered by dense tropical forest without any available access road to reach the respective site. Therefore, the geological investigation such as seismic exploration and drilling made best endeavors for smooth execution of the work by using portable equipment for such difficult site conditions.

The investigation work has been concentrated at the most promising dam axes, waterway routes, and powerhouse sites based on the first geological survey result. The investigated sites are 5 alternative dam sites, the 2 alternative waterway routes, and rock quarry sites, borrow sites for earth fill and sand materials. The quantity of the geological investigation work is listed in Table 2.1.

2 TOPOGRAPHY

The Memvé Elé project site is located at the lower reaches of the Ntem river which drains the south to south-most area of Cameroon. The total catchment of the Ntem river is some 31,000km2 at the estuary at Rio Campo. The land of catchment area is a plateau having an elevation mostly from 400 m to 700 m in elevation. The Memvé Elé dam site is located at some 90 km upstream from the estuary. The elevation of the site is about 400 m, where the Memvé Elé waterfalls of some 35 m in head is located at immediately downstream of the dam site.

The river in the upstream of the dam site has rather gentle gradient of Vertical/Horizontal (V/H) = 1/2000 to 1/3000. Several tributaries such as the Mvila river, the Ndjo'o river, the Biwome river and so on are distributed there. Their rivers are flowing down from east to west or northeast to southwest direction.

After confluence of the tributaries and the waterfalls, the Ntem river flows down linearly and rapidly in the southwest direction with the steep gorge of some 40 km long and river gradient of V/H = 1/200.

The river courses of the last section of 50 km to reach Atlantic Ocean is also gently flowing down in the west direction with the another branch (Bongola river).

As shown in Fig. 2.1 "Interpretation of Lineament", the steep gorge of 40 km long might be formed along the existing fault line of NE-SW which is concordant with the geology occupying in and around the project area.

All the surfaces in the vicinity of the area are densely covered by rain forest.

3. REGIONAL GEOLOGY

In the southern area of Cameroon, it is occupied by the Ntem formations of migmatite and/or gneiss metamorphosed in the lower stage of Pre-Cambrian period, and by limestone to magnesite.

The project area and its vicinity area are developed by the above mentioned Ntem formations, which was originally of sedimentary rocks of argilla-calcareous and sandstone having vast geosynclines. These, crossed by intrusions of crystalline rocks, were folded in a generally NE-SW direction and underwent a metamorphism.

The Memvé Elé site is based on the lower Pre-Cambrian rocks of orthogneiss (Gn2) with pyroxene (Py), as shown in Table 2.2.

Lower gneiss (Gn1) and old syntectonic granite (Gr) are distributed downstream of the Memvé Elé site. Meanwhile, Granite and granodiorite with pyroxene (GD) are distributed upstream of the Memvé Elé site. A fault is observed along the river course of the Ntem, downstream of the waterfalls (Fig. 2.2).

Though the site is seismologically located in very stable zone in the world as mentioned in the next clause 4 "Seismicity", it was pointed out a probability of active fault along the Gorge Du Ntem. There are no available data from the existing geological references whether a fault is active or not. The fact obtained from the geological investigation by drilling and so on suggests that a fault might have moved in past long geological period. The movement is that the northwest side of the fault line is sunk and the southeast side of the fault is risen, also the northwest side of the fault is risen and the southwest side of the fault is sunk (hinge fault). As a result, the present river course is linearly running along the fault line and its course of the upstream, which is far apart from the fault, is meandering to the northeast direction due to developing depression zone there by fault movement. However, there are found out no fact of very recent movement by the fault. The conglomerate along the fault line is well consolidated and matrix is tightly cemented, which is presumably resulted by the fault activity. It is inferred that the conglomerate might be formed at very old geological period and probably in Mesozoic to Palaeogene period.

The problem whether the fault is active or not should be examined in D/D stage if the alternative dam site 5 is selected, because the alternative should across the fault at the right half corner of the dam axis.

4. SEISMICITY

4.1 Collected Data for Seismicity Analysis

Earthquake data of the area bounded by latitude 4.33 degrees N - 0.33 degrees S and longitude 8.25 degrees E - 12.25 degrees E for the site of 2.25 degrees N and 10.23 degrees E was searched by International Seismological Centre (ISC) in United Kingdom by the request of JICA study team.

According to it, no earthquake likely affected to the site was found out from the ISC historical file 1904 - 1990 and ISC comprehensive catalogue file 1964 - 1988 in the site being considered.

However, Ambrasey and Adams studied in the report of Seismicity of West Africa (11 August 1986, Annales Geophicae, 4, B, 6, 679-702) for the vicinity of the area by using a historical references in and around Cameroon. The earliest event, from 1615 onward, have been culled from a careful study of historical sources. As the results, the following three events only are depicted in the report which might be affected to the site;

DATE	EPICENTER	M(*)	r;DIS(*)	i;INT.(*)	ah;ACC.*
1903 June 10	3 N 10.0E	4.4	79.4	3.7	13.0
1911 March 26	3.1N11.0E	5.7	119.3	4.6	24.8
1913 October 9	3.8N12.3E	5.1	280.0	1.6	3.1

Note;(*)M, Magnitude(assumed)

r, Distance from the epicenter of earthquake to the site in kilometer

i, Intensity by Modified Mercalli Scale (refer to Table 2.3) theoretically calculated for the site

ah, Acceleration in cm/sec2 theoretically calculated

$i = 8.0 + 1.5 M - 2.5 \ln r$ (by Cornell, 1968)

$\log ah = 0.014 + 0.30 i$ (by Trifunac and Brady, 1975)

The details for the above events are described in Table 2.3, and plotted in Fig. 2.3 "Location Map of Earthquakes Likely Felt at the Site (1615 - 1990)".

4.2 Analysis of Earthquake Coefficient

Fig. 2.4 shows the analysis for an earthquake coefficient based on the relationship between intensity felt at the site as above listed and frequency of occurrence (Nc) in the period for 100 years and 250 years by ISC method, Japan Meteorological Agency (JMA) method and Munich Reinsurance (M.R.) Company.

The results of the analysis are calculated and summarized below;

RETURN PERIOD	ISC method (*1)	JMA method (*2)	M.R. company (*1)
100 years	2.5 (=5.8 gal)	I - II (=2.5 gal)	------
250 years	4.0 (=16.4 gal)	III (=14 gal)	5 or below (< 32.7 gal)

Note; *1 $\log ah = 0.014 + 0.30 i$ (i; Intensity in ISC scale)

*2 $a (gal) = 0.45 * 10^{S/2}$ (S; Intensity in JMA scale)

From the above calculated, the earthquake coefficient (k = gal/980) is resulted as k = 0.006, say k = 0.01 for the return period of 100 years and k = 0.03 for 250 years respectively.

This value of k = 0.01 is the same earthquake coefficient as the Nachtigal Amont Hydropower Project locating some 250 km northeast of this site.

5. GEOLOGY OF THE SITE

The site reconnaissance was carried out in the first stage for identifying possible dam sites and for formulation of the second stage investigation work by seismic exploration and drilling.

As the site is densely covered with rain forest, and few foot paths were available, the topographic mapping work by ground survey method and the seismic reflection survey work at each site were very important to grasp the sites and before proceeding drilling work. The seismic work of the total 17 km long and the drilling campaign of the total 19 holes (491m) had been successfully conducted by Sep. 1992. The geological investigation result for each site is as hereinafter;

5.1 Geological Condition of the Reservoir Area

The geological investigation for the reservoir area was done mainly by mapping, and by supplemental or conventional test pitting and penetration test for selected site which should be clarified under geological conditions.

The most area of the reservoir to be submerged are composed thick laterite and residual soil having average permeability coefficient of 1 x 10-5 cm/sec which were carried out in drilling holes along the dam axes. No serious problem such as land slide and leakage of reservoir water can be expected except with the following;

a. Upstream Area of the Reservoir along the Right Bank of Ntem (Fig. 2.5 to Fig. 2.8)

In case of the El. 395 m of high water level was selected, the existing main road shall be submerged at the tributaries of the Ntem river between the villages such as Akom to Nsebito, Nsebito to Nemeyong, Melen to Allen-Bekoell, and Ntebezok.

Taking account of the local community, it is recommended to construct an embankment with bridge/culvert to keep the present condition.

b. Southwest most Area of the Reservoir along the Watershed between Ntem river and Gorge Du Ntem (Fig. 2.9 to Fig. 2.10)

The watershed between Ntem and Gorge Du Ntem catchment, the southwest most area of the reservoir, has the elevation 400 m to 402.5 m in the lowest. Though the overburden of 5 m to 7.5 m thick can be expected at the lowest, the area is composed of fine sand near in its summit as revealed by the Penetration Test of PP 9, PP 10 and PP 11. Careful further investigation by means of test pitting and detail topographic survey shall be required in D/D stage. The area is also located on the fault line of the

depression zone investigated by the drilling BW 10, BD 16, BQ 17 and BD 18. A construction of blanket zone or cut off trench for water tightness of the sand layer is recommended if HWL of 395 m is planned.

5.2 Geology of Alternative Dam Sites

5.2.1 Alternative Dam Site 1

The site is located at the riverbed elevation of some 384 m, some 800 m upstream of existing boat station of Nyabessan. The river in this site forms a rapid and shows shallower water depth than 2 m. Several islands exist in the riverbed of some 470 m wide (Fig. 2.11).

The right bank of the axis forms favorable topography for dam abutment having an elevation of 410 m at the highest portion.

The riverbed and the foot portions of the both banks expose a fresh and sound basement rocks of granitic gneiss (migmatite). However, the upper portion of the banks is wholly covered by residual soil. The boundary between basement rock and residual soil is inferred as lower than the elevation of 379 m (BD 18 at the right bank and BD 19 at the left side of the river), and 393 m (BD 9 of the left bank). Therefore, dam foundation in the upper portion of the both banks is compelled to rest on the consolidated residual soil.

Judging from the above mentioned topographical and geological conditions, it is conceivable to make a plan by earth fill type dam of several meters in height (HWL : 390 m) and 2,200 m in crest length at maximum, as listed in Table 2.5, which gives the highest water supply level of 390 m in elevation though the water of Biwome and Ndjo'o rivers is not readily to use unless an additional diversion facility in the rivers is constructed.

At the immediately downstream of the axis, a conspicuous depression zone exists along the fault, in addition, the another depression zone exists at the foot portion of the left bank. It is inferred that the treatment for the dam foundation at the said two depression zones is, therefore, the most important one.

5.2.2 Alternative Dam Site 2

The site is located at the riverbed elevation of some 382 m and some 300 m downstream of the existing boat station. The river width in the site is 220 m. The river water is gently flowing. The depth may be within 3 to 5 m. Small scale several outcrops of fresh gneiss are sporadically distributed in the vicinity of the riverbed (Fig. 2.12).

It is clear by the topographical survey that the right bank forms rather complicated topography as shown in Fig. 2.12. That is, a small stream exists in the middle portion of the right bank. The elevation of this stream bed is 387 m. The upper portion of the right bank is covered by thick residual soil of 10 to 20 m. The boundary between basement rock and residual soil layer in this upper portion may be lowered to the elevation of 383 m.

While the left bank forms very flat land having 2 to 9 m higher elevation than the river water level. A fine to medium sand layer of average 4 m thick covers widely on the basement rock of fresh gneiss. The geological and topographical conditions of the left bank are the same as the Alternative 1.

Considering the above mentioned conditions, dam shall be planned by homogeneous earthfill with the height of 8 m(crest elevation: 390 m, HWL.: 388 m) and crest length of some 2300 m long.

5.2.3 Alternative Dam Site 3

The site is located at the riverbed elevation of some 382 m and some 800 m downstream of the existing boat station. The river width in the site is 300 m. The river water is gently flowing and water depth may vary from 2 to 10 m. Small scale several outcrops of fresh gneiss are sporadically distributed in the vicinity of the riverbed (Fig. 2.13).

The upper portion of the right bank is covered by thick residual soil of 8 to 10 m. It is inferred that the boundary between basement rock and residual soil layer in this upper portion is in the elevation of 390 m from the seismic result of SD3(2). While the geological and topographical conditions of the left bank are the same as the Alternative 1 and 2.

Considering the above mentioned conditions, dam shall be planned by homogeneous earthfill with the height of 8 - 10 m (crest elevation: 392 m, HWL.: 389 - 390 m) and crest length of some 1900 m long.

5.2.4 Alternative Dam Axis 4

The site is located in the widely expanded area of the Ntem river, Ndjo'o river and Biwome river immediately upstream and/or just on several rapids. Diverted several streams of the Ntem river and isolated several islands of various scale are scattered in the vicinity of the site. The riverbed elevation of the site is in the range from 381 to 382 m (Fig. 2.14).

The right bank forms a preferable topographic features as the dam abutment as well as the left bank. However, the results of BD 1 and BD 5 drilled at the right bank top show that the sound rock of gneiss is lowered to the elevation of 375 m which is 6 to 8 m below the present river bed elevation.

Several isolated islands are mostly covered by fine to medium sand layer of a few meters thick on the fresh basement rock of gneiss.

A depression zone exists at about 100 m upstream of the axis, which is one of the objectionable geology for foundation. A detail investigation in future shall be required when the dam site is selected for D/D stage.

The left bank of the Ntem river forms steep, sharp and conspicuous ridge, demonstrating a preferable topography for dam axis. The ridge is continuously rising up to the elevation of 420 m or more. A residual soil layer covers there with 20 m thick (El.393 m). As the basement rock of gneiss may be mostly developed at the subsurface

of 390 m in elevation, the dam construction for the HWL. of 390 m is feasible though a foundation treatment in the right abutment is costly.

The dam may be planned by homogeneous earthfill type with 10 m height(crest elevation: 391 to 393 m, HWL.: 390 m) and some 2000 m long.

5.2.5 Alternative Dam Site 5

The site is located in the most widely expanded area of the Ntem river, Ndjo'o river and Biwome river immediately upstream and/or just on several waterfalls and rapids. Diverted several streams of the Ntem river and isolated several islands of various scale are scattered in the vicinity of the site.

The elevation of riverbed of the site may be in the range from 378 m (Biwome river) to 380 m (Ndjo'o river) (Fig. 2.15 and 2.16).

According to the topographical and geological survey results in the right bank (BD 2 and BD 3), the thickness of laterite soil and residual soil at the right bank is ranged from 8 m to 14 m (mostly El. 375 m) with undulating at places.

Several isolated islands are mostly covered by a fine to medium sand layer of average 4 m thick on the fresh basement rock of gneiss. The island of the rightmost corner is covered by thick residual soil derived from the fault fractured zone (9 m thick in BD 4). It is assumed that the basement rock line may be lowered toward the right bank side to the elevation of 374 m (BD 3) and 368 m (BD 2), which is 4 m to 10 m lower than the elevation of the Biwome river bed.

A few faults are running in the direction from NE to SW, which is traced to the Gorge de Ntem. The location of the faults is detected by the seismic lines of SD5(3), SD5(4), and SD5(5) as shown in Fig. 2.9, Fig. 2.15 and Fig. 2.16. BD 3 hole was drilled on the low velocity zone by the seismic exploration.

The topographic and geologic conditions in the left bank of the Ntem river are the same alternative 4 as explained already. In case of these detected faults are not active, the dam construction of crest elevation 390 m is feasible though a foundation treatment in the right abutment is costly.

The dam may be planned by homogeneous earthfill type with 12 m to 15 m height(crest elevation: 390m, HWL.: 385 m) and some 4200 m long.

5.2.6 Conclusion

Table 2.5 shows the summary of comparative study result for the alternatives of the five dam sites mentioned above.

According to the result, the alternative 4 is recommendable for the proceeding study of D/D stage.

6. GEOLOGY OF THE WATERWAY ROUTES

As shown in Fig. 2.10, the upstream and the downstream alternatives were investigated. The result is;

6.1. Downstream alternative

The river water level in the tailrace of the waterway is the elevation of some 335 m (Fig. 2.18). The highest altitude along the waterway is 420 m at the middle reach between reservoir area of the alternative dam site 1, 2, 3, 4 and 5, and Gorge Du Ntem.

The low land at the upper reaches of the waterway below the elevation of 390 m comprises mostly of swamp deposits of fine sand with organic clay which has the thickness of 4 to 7 m. It is considered that the swamp deposits may be resulted by meandering of the river and a hinterland of the Ntem river.

The ridges along the route are mainly covered by residual soil derived from weathered gneiss underlying in subsurface. The thickness of residual soil varies in places from 1 m (BW 11), 3 m (BP 15), 19 m (BW 12), and 4m (BQ 13). The basement rock is mostly of fresh gneiss with very thin weathered zone on its upper part.

The one fault is running near the outlet of the tailrace in the Gorge de Ntem (BQ 14). The fault fractured zone has a width of some 10 m at BQ 14, and many cracks developing with a interval of 2 to 5 cm without weak clayey material.

6.2. Pondage scheme at the middle reaches of the downstream waterway route

Through the course of topographic mapping, a preferable site for pondage dam axis is found out. The pondage plan has merits of 1) flexibility to load fluctuation and easy operation for removal of silted sand, 2) minimize a waterway route, and 3) effective use of excavated rock material.

The result of BP 15 drilled at the left bank of the axis shows 3.2 m thick residual soil and rather sound rock of gneiss develops up to the hole bottom (20 m).

6.3 Upstream alternative

The river water level at the tailrace of the waterway is the elevation of 342.5 m (Fig. 2.18). The route is located at the right bank side of the pondage dam (Fig. 2.19), and 1.2 km upstream of the alternative downstream waterway.

Seismic exploration survey of SW 6(2) was carried out along the route. The result is a little worse than that of the downstream route, i.e., one another low velocity zone of 20 m wide is detected between the pondage site and Gorges Du Ntem. Furthermore, the route has demerit of 1) losing of 7 or 8 m water head, and 2) not effective for pondage plan, though it is a little shorter distance than that of the downstream one.

The surface and subsurface geological condition of the upper reaches of the route is the same as the downstream route.

7. GEOLOGY OF QUARRY AND BORROW SITES FOR CONSTRUCTION MATERIALS

7.1 Rock Quarry Site

In case of dam plans by rockfill type for the alternative dam of 1, 2, 3, 4 and 5, a huge amount of rock shall be required. Possible rock quarry sites are found out at the ridge (R 1) investigated by BW 11 between the reservoir area and Gorge Du Ntem, the Gorge Du Ntem (R 2) investigated by BQ 13 and BQ 14, the southeast most area of the reservoir area (R 3), and the Mt Ebungu (R 4 shown in Fig. 2.1). The rock in these sites is of very hard pyroxene-hornblende gneiss or granitic gneiss. No serious problem for quality is expected. It is judged that the most promising sites are R 1 and R 2. The study result for rock quality and quantity is described in Appendixes III "Construction Material Survey".

Considering hauling distance from the quarry sites to each dam site, the R 3 and R 4 sites are very far(4 km from R 3 to dam site 5 and 5 km to 7 km from R 4 to dam site). Therefore, the selection of the dam site shall be also checked from the view point of easiness of quarrying for rock and sand materials.

7.2 Borrow Sites for Earthfill Materials and Sand for Concrete Material

There found out borrow sites in many places for embankment materials of earthfill type dam, which are located in the upper slopes of the both banks of the Ntem river, Ndjo'o river and Biwome river.

According to the test pit results dug for a well at the Nyabessan camp site, residual soil is developed thickly to the depth of 15 m. The soil is composed of top soil (0 - 0.5 m), reddish brown clay (0.5 - 3.0 m), pale brown clay (3.0 - 10.0 m), and highly moistures, whitish to reddish brown clay with gravels of weathered gneiss (10.0 - 15.0 m) which means the soil immediately on the weathered gneiss and below ground water level.

It is expected from test pit results that the soil is suitable to use for impervious material of earthfill type dam, though proportion of contents of fine particle (clay) is dominant.

There is a sand deposit immediately upstream of Nyabessan boat station. The sand obtained is relatively coarse having low uniformity coefficient. For the purpose of fine concrete aggregate, this river sand shall be passed through rod mill in an aggregate production plant so as to improve gradation.

Coarse concrete aggregate shall be produced by quarry rock at the aggregate production plant. Filter material will be mixed the river sand with aggregate passing through a secondary crusher.

Table 2.1 Quantity of Geological Investigation (Excluding of Laboratory Test) (1/2)

a. Seismic Exploration Survey

Seismic Line Nos.	Length*1(m)	Location
SD3(1)	1150	Left bank of dam axis 2,3
SD3(2)	690	Right bank of dam axis 3
SD4(1)	585	Island(dam axis 4)
SD4(2)	775	Right bank of dam axis 4
SD5(1)	400	Left bank of dam axis 5
SD5(2)	1210	Island of dam axis 4,5
SD5(3)	540	Island of dam axis 5
SD5(4)	770	Island of dam axis 5
SD5(5)	570	Left bank of dam axis 5
SD5(5')	420	Left bank of dam axis 5
SD5(6)	600	Left bank of dam axis 5
SW1(1)	1300	The ridge of Pondage and Reservoir area
SW1(2)	1750	Waterway(downstream)
SW1(3)	840	Waterway(pondage to downstream)
SW2	2600	Waterway(upstream)
SW6(1)	1000	Left bank of dam axis 1-5
SW6(2)	1430	Waterway(upstream)

b. Drilling

Hole Nos.	length(m)	Location
BD 1	20	Right bank near Nyabessan
BD 2	20	Right bank near Biwome
BD 3	25	-Do-
BD 4	20	Island(axis 5)
BD 5	30	Right bank near Nyabessan
BD 6	20	Island(axis 4,5)
BD 7	20	Left bank near boat station
BD 8	20	Island(axis 4,5)
BD 9	35	Left bank near Intake
BW10	34.7	Waterway near Intake
BW11	30	Waterway
BW12	30	Waterway
BQ13	40	Power station
BQ14	40	Tailrace
BP15	20	Pondage axis(left)
BD16	30	Right bank near boat station
BQ17	15	Right bank near boat station
BD18	21.2	-Do-
BD19	20	Left bank near boat station

Table 2.1 Quantity of Geological Investigation (Excluding of Laboratory Test) (2/2)

c. Test Pit

Test Pit Nos.	depth(m)	Location*2
TP 1	4.7	Right bank of Biwome
TP 2	8.5	Right bank of Ndjo'o(E4)
TP 3	7.7	Near Nyabessan(E3)
TP 4	2.5	Left bank near boat station
TP 5	10	Left bank(E7)
TP 6	10	-Do-
TP 7	7.7	Left bank(E6)
TP 8	5.0	Right bank near Nyabessan(E2)
TP 9	5.3	Right bank near boat station(E1)
TP10	4.5	-Do-
TP11	4.0	-Do-
TP12	2.1	-Do-
TP13	4.0	Right bank near Nyabessan
TP14	9.7	Right bank near Nyabessan(E2)
TP15	4.8	Left bank of Ndjo'o
TP16	5.2	-Do-
TP17	0.5	Right bank of Ndjo'o
TP18	0.8	-Do-
TP19	5.0	Near Nyabessan
Camp well	16	Near Nyabessan(SONEL camp)

d. Penetration Test

Pit Nos.	depth(m)	Location
PP 1	2.4	Left bank(swamp zone)
PP 2	5.0	-Do-
PP 3	5.0	-Do-
PP 4	5.0	-Do-
PP 5	5.0	Left bank(near Intake)
PP 6	5.0	-Do-
PP 7	5.0	Left bank(near Chute Du Memve Elé
PP 8	1.1	Left bank, river side
PP 9	5.0	The lowest ridge(south most)
PP10	2.5	-Do-
PP11	5.5	-Do-

Note *1 : The length taken actual seismic records
*2 : "E" means borrow site nos.

Table 2.2 Geological Sequence of the Project Area

SYMBOL	FORMATION	GEOLOGY
Al	Alluvial Deposits	Clay, silt and sand along the river course
Dt	Residual soil	Clay and sand with debris
Gn1	Middle Pre-Cambrian	Gneiss and ectinite
MG	Middle Pre-Cambrian	Migmatite
Py	Middle Pre Cambrian	Orthopyroxinite
Gn2	Middle Pre-Cambrian	Orthogneiss of pyroxinite
GD	Middle Pre-Cambrian	Granite and granodiorite

Table 2.3 Records of Historical Earthquakes Likely Felt at the Site

DATA OF EVENT	DESCRIPTION
1903 June 10	Not described.
1911 March 26	A widely and strongly felt earthquake in Cameroon. Maximum observed intensity, which did not exceed 6 (MM scale) was reported from the region Lolodorf and Ebolowa, and if damage occurred in this region, this is not indicated by available information collected. The earthquake, which was recorded instrumentally and had a teleseismic surface- wave magnitude of 5.7, possibly affected sparsely populated area of Lolodorf in the south of town. The shock was strongly felt within a radius of at least 250 km. Information from Gabon and Equatorial Guinea in the south is totally lacking (Koert, 1913; Anonymous, 1911; Sieberg, 1932).
1913 October 9	The epicentral region of this earthquake must be near Akono-Linga in south Cameroon, where despite evidence of violent shaking of the ground the intensity was no more than 6 (MM scale). The few details we have of this event and the fact that it was widely felt indicate an earthquake of medium magnitude (Sieberg, 1932; Press Report).

(quoted from the report Seismicity of West Africa)

Fig. 2.4 Expansion of Intensity of Earthquake Shock by Modified Mercalli Scale and Japan Meteorological Agency Scale

MODIFIED MERCALLI INTENSITY (DAMAGE) SCALE OF 1931 (ABRIDGED)

1	Not felt except by a very few under especially favourable circumstances.
2	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
3	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognise it as an earthquake. Standing motorcars may rock slightly. Vibration like passing truck. Duration estimated.
4	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, and doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.
5	Felt by nearly everyone; many awakened. Some dishes, windows, etc. broken. A few instances of cracked plaster. Unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
6	Felt by all; many frightened and run outdoors. Some heavy furniture moved. A few instances of fallen plaster or damaged chimneys. Damage slight.
7	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly-built or badly-designed structures. Some chimneys broken. Noticed by persons driving motorcars.
8	Damage slight in specially-designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly-built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.
9	Damage considerable in specially-designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
10	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
11	Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
12	Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

JAPAN METEOROLOGICAL AGENCY INTENSITY SCALE

O	*No sensation:* registered by seismographs but no perception by the human body.
I	*Slight:* felt by persons at rest or persons especially sensitive to earthquakes.
II	*Weak:* felt by most persons. Slight rattling of doors and Japanese latticed paper sliding doors (shōji).
III	*Rather strong:* shaking of houses and buildings. Heavy rattling of doors and shōji, swinging of chandeliers and other hanging objects. Movement of liquids in vessels.
IV	*Strong:* strong shaking of houses and buildings. Overturning of unstable objects. Spilling of liquids out of vessels four-fifths full.
V	*Very strong:* cracking of plaster walls. Overturning of tombstones and stone lanterns. Damage to masonry chimneys and mud-plastered warehouses.
VI	*Disastrous:* demolition of up to 30 per cent of Japanese wooden houses. Numerous landslides and embankment failures; fissures on flat ground.
VII	*Ruinous:* demolition of more than 30 per cent of Japanese wooden houses.

Table 2.5 Comparison of Dam Axes

Alternatives Check Items	Dam site 1	Dam site 2	Dam site 3	Dam site 4	Dam site 5
Utilization of Water	Ntem river water only. Diversion scheme shall be needed.	Ntem river water only. Diversion scheme shall be needed.	Ntem river water only. Diversion scheme shall be needed.	Ntem river water only. Diversion scheme shall be needed.	All the river water
FSL/Tailrace Cross Head	390 m / 335 m (55 m)	388 m / 335 m (53 m)	389 - 390 m / 335 m (54 m)	390 m / 335 m (55 m)	390 m / 335 m (55 m)
Probable Dam Scale	H = 10 m (maximum) l = 2,200 m	H = 8 m (maximum) l = 2,300 m	H = 10 m (maximum) l =1,900 m	H = 10 m (maximum) l = 2,000 m	H = 15 m (maximum) l = 4,200 m
Dam Type	Earth fill	Earth fill	Earth fill	Earth fill	Earth fill
Topographic Condition					
Right Bank	Very Good	Fair (complicated topographic condition)	Good	Very Good	Fair (complicated topographic condition)
River bed	Rock exposed (470 m wide)	Medium (water depth, 3 - 5)	Rock scattered	Medium	Poor (water depth, 3 - 5)
Left Bank	Long and flat (low)	Long and flat (low)	Long and Flat (low)	Fairly Good	Long and flat (low)
Geological Condition	Two depression zones to be acrossed. Lowered the rock line at the right bank. Thick soil at the right bank.	One depression zone to be acrossed. Rock line of the right bank is El. 383 m.	One depression zone to be acrossed. Rock line at the right bank is below El. 390 m.	One depression zone at the 100 m upstream of the axis. Rock line lowered at the right bank (El. 375 m).	Faults problem (active or stable) should be clear. Very thick laterite at the right half of the axis.
Local Communication	Expected to improve	Expected to improve	Not change	Not change	Change to Inconvenient
Impact to Memve Ele waterfalls	Not serious	Not serious	Not serious	Not serious	Not serious
Recommendation	To be abandoned	To be abandoned	To be abandoned	To be studied	To be abandoned

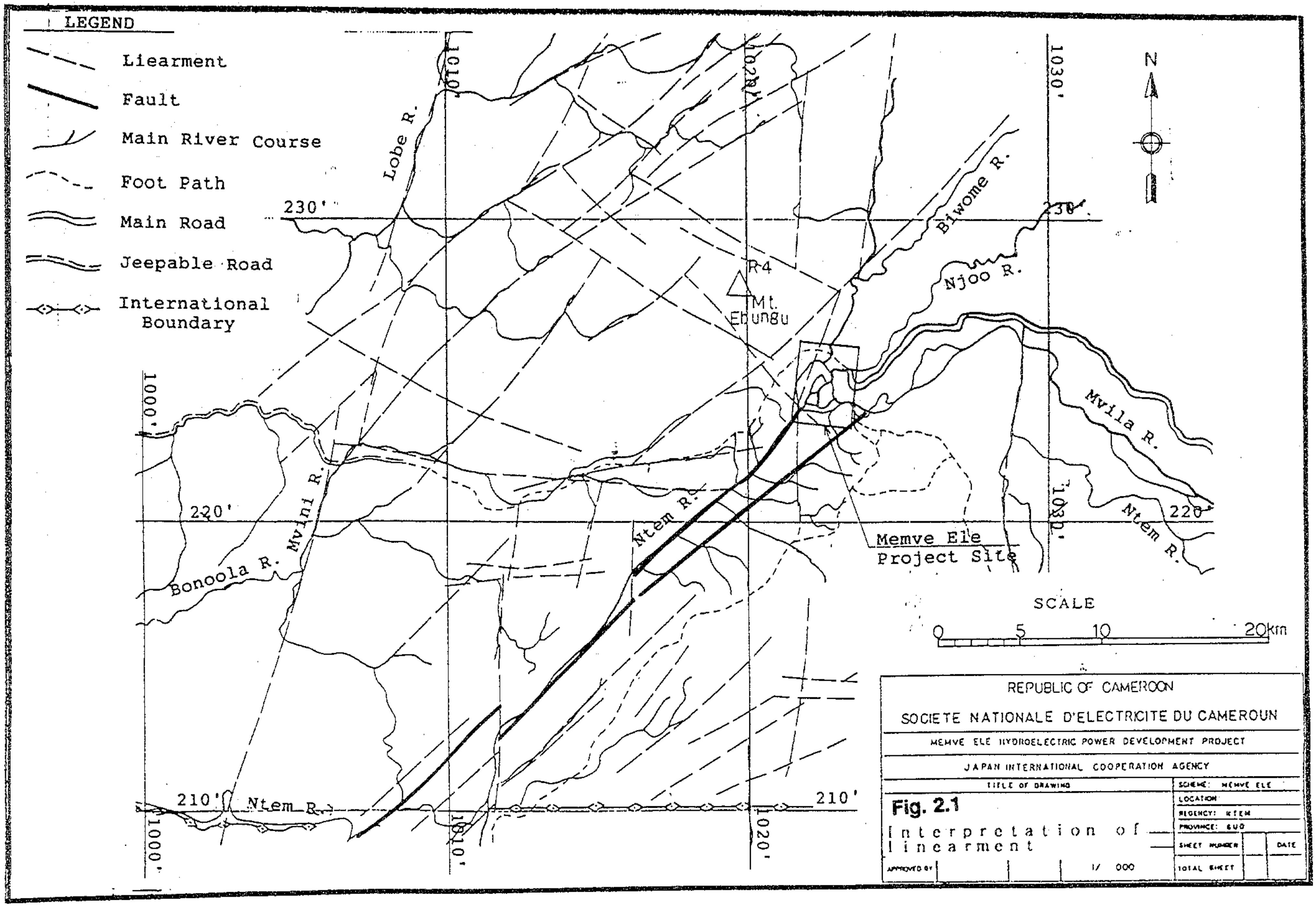
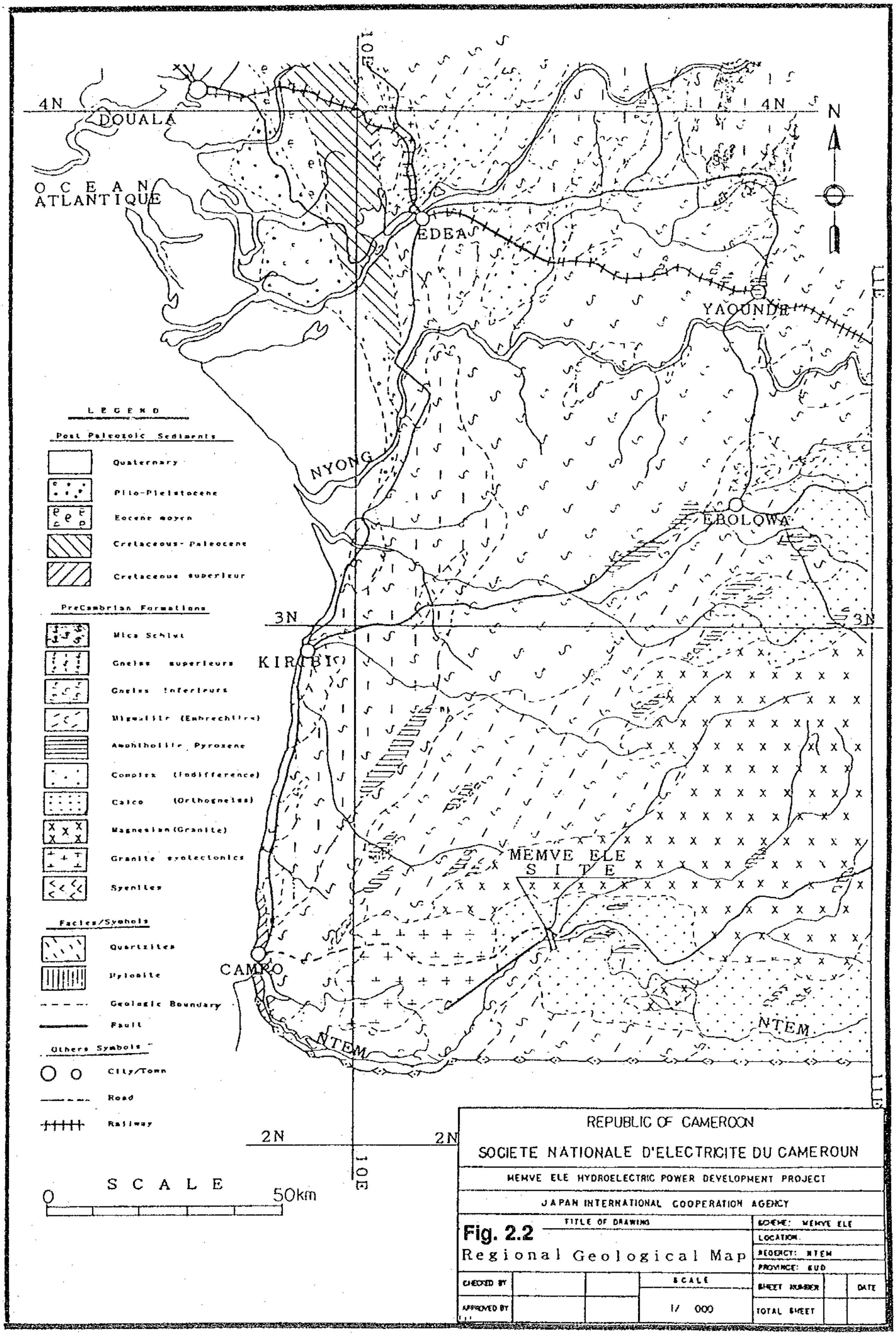


Fig. 2.1 Interpretation of lineament



REPUBLIC OF CAMEROON

SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN

MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE OF DRAWING			SCHEME: MEMVE ELE		
Fig. 2.2 Regional Geological Map			LOCATION:		
			REGENCY: NTEM		
			PROVINCE: SUD		
CHECKED BY		SCALE	SHEET NUMBER		DATE
APPROVED BY		1/ 000	TOTAL SHEET		

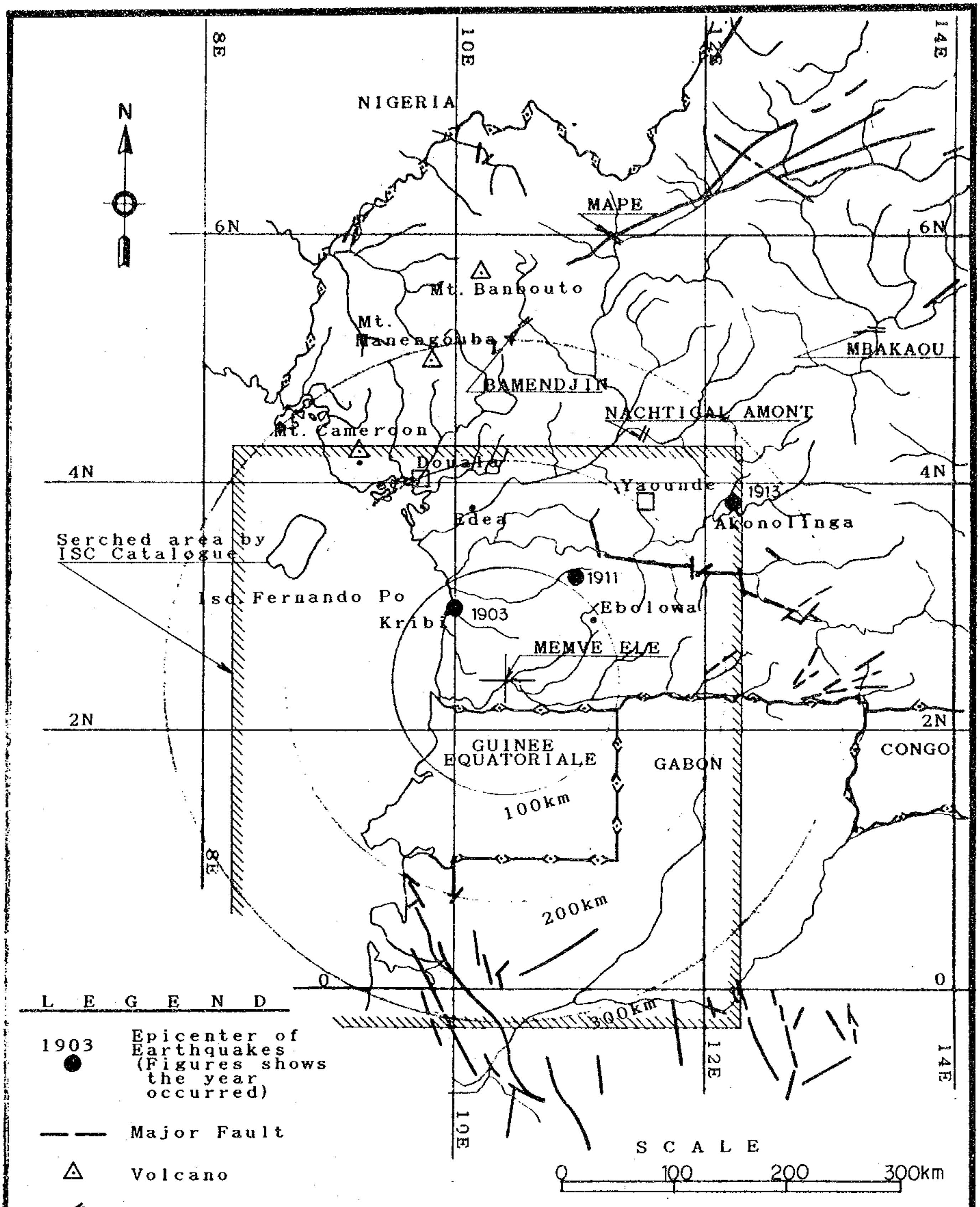
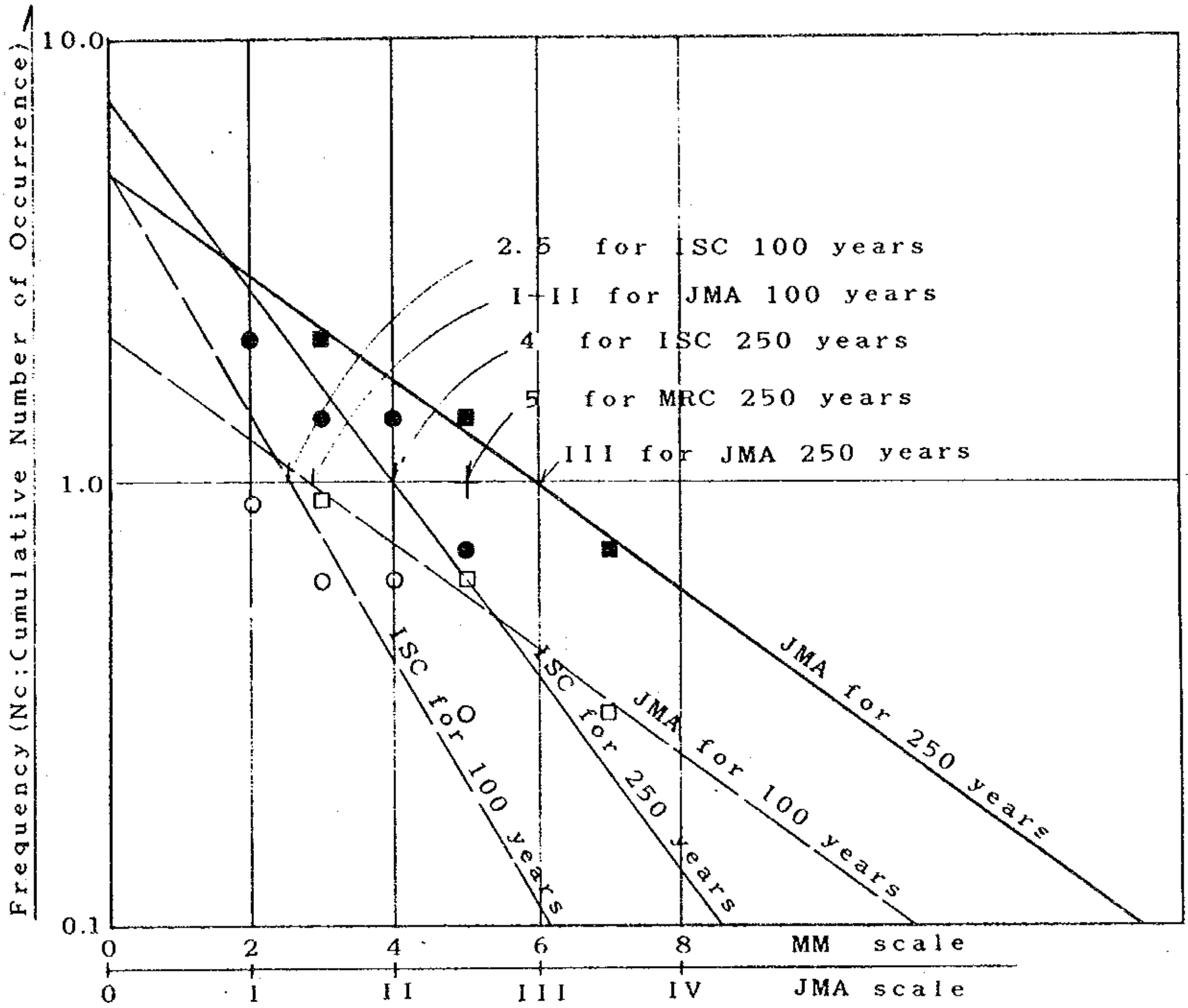


Fig. 2.3

REPUBLIC OF CAMEROON			
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN			
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT			
JAPAN INTERNATIONAL COOPERATION AGENCY			
TITLE OF DRAWING		SCHEME: MEMVE ELE	
Location Map of Earthquakes Likely Felt at the Site		LOCATION:	
		REGENCY: NTEM	
		PROVINCE: SUD	
CHECKED BY	SCALE	SHEET NUMBER	DATE
APPROVED BY	1/5,000,000	TOTAL SHEET	

	Intencity	Frequency in 375 years (1615-1990)	Frequency in 100 years	Frequency in 250 years	Cumulative Nos. (Nc) 100 years	Cumulative Nos. (Nc) 250 years
M M scale	1.5 – 2.4	1	0.3	0.7	0.9	2.1
	2.5 – 3.4	0	–	–	0.6	1.4
	3.5 – 4.4	1	0.3	0.7	0.6	1.4
	4.5 – 5.4	1	0.3	0.7	0.3	0.7
	5.5 <	0	–	–	–	–
	(Total)	(3)	(0.9)	(2.1)		
JMA scale	I – II	1	0.3	0.7	0.9	2.1
	II – III	1	0.3	0.7	0.6	1.4
	III – IV	1	0.3	0.7	0.3	0.7
	IV <	0	–	–	–	–
	(Total)	(3)	(0.9)	(2.1)		



Note:

□ ■ JMA, Japan Meteological Agency scale

○ ● MM, Modified Mercalli scale for ISC method

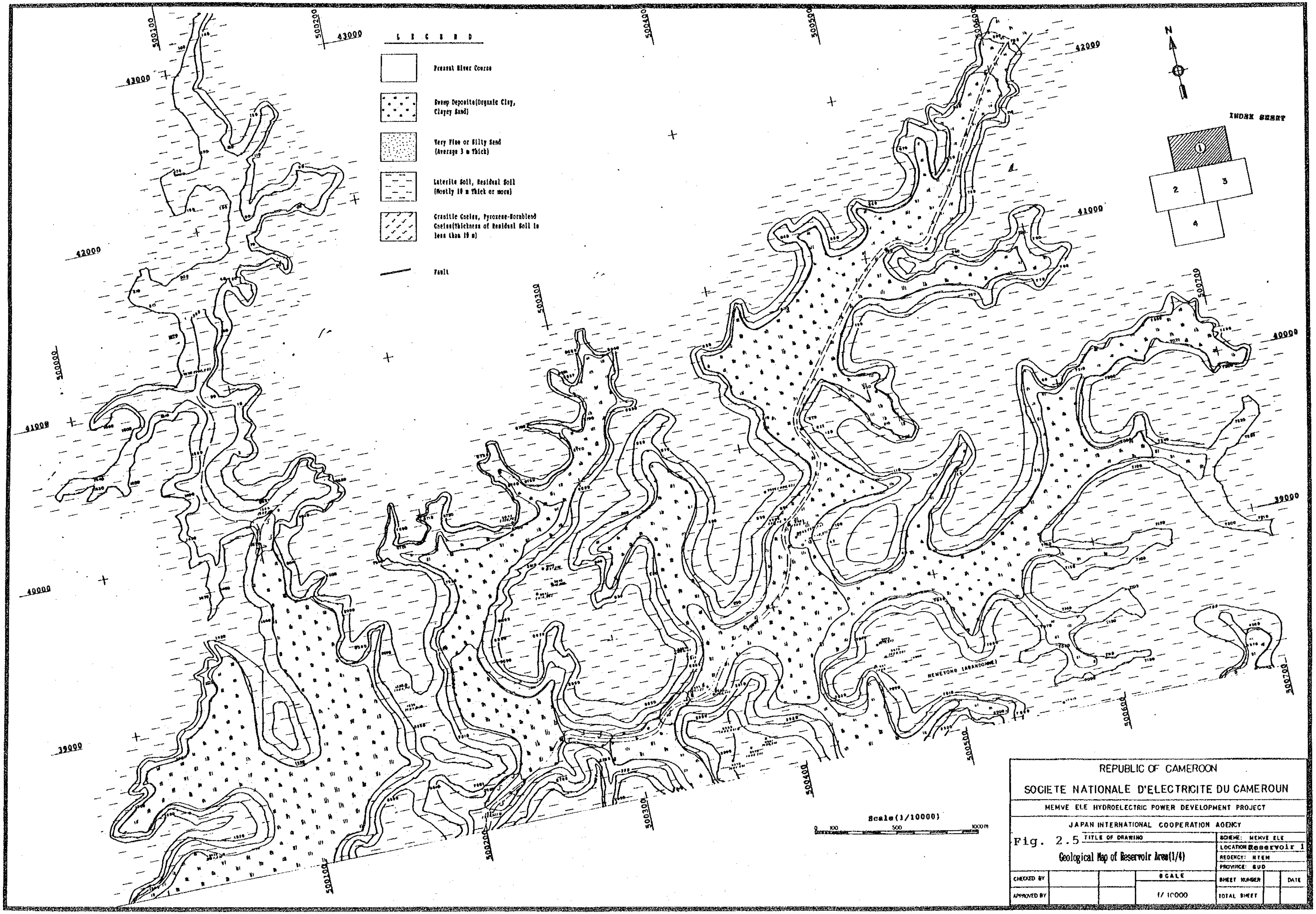
\+ MRC, Munic Reinsurance Company

Broken line with Open symbols shows return period of 100 years

Solid line with Black symbols shows return period of 250 years

Fig. 2.4

REPUBLIC OF CAMEROON						
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN						
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT						
JAPAN INTERNATIONAL COOPERATION AGENCY						
TITLE OF DRAWING				SCHEME: MEMVE ELE		
Analysis of Earthquake Coefficient				LOCATION:		
				REGENCY: NTEM		
				PROVINCE: SUD		
CHECKED BY			SCALE	SHEET NUMBER		DATE
APPROVED BY			1/ 000	TOTAL SHEET		



REPUBLIC OF CAMEROON

SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN

MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 2.5 TITLE OF DRAWING
Geological Map of Reservoir Area(1/4)

SCHEME: MEMVE ELE
LOCATION Reservoir 1
REGENCY: NTEM
PROVINCE: SUD

CHECKED BY			SCALE	SHEET NUMBER		DATE
APPROVED BY			1/ 10000	TOTAL SHEET		

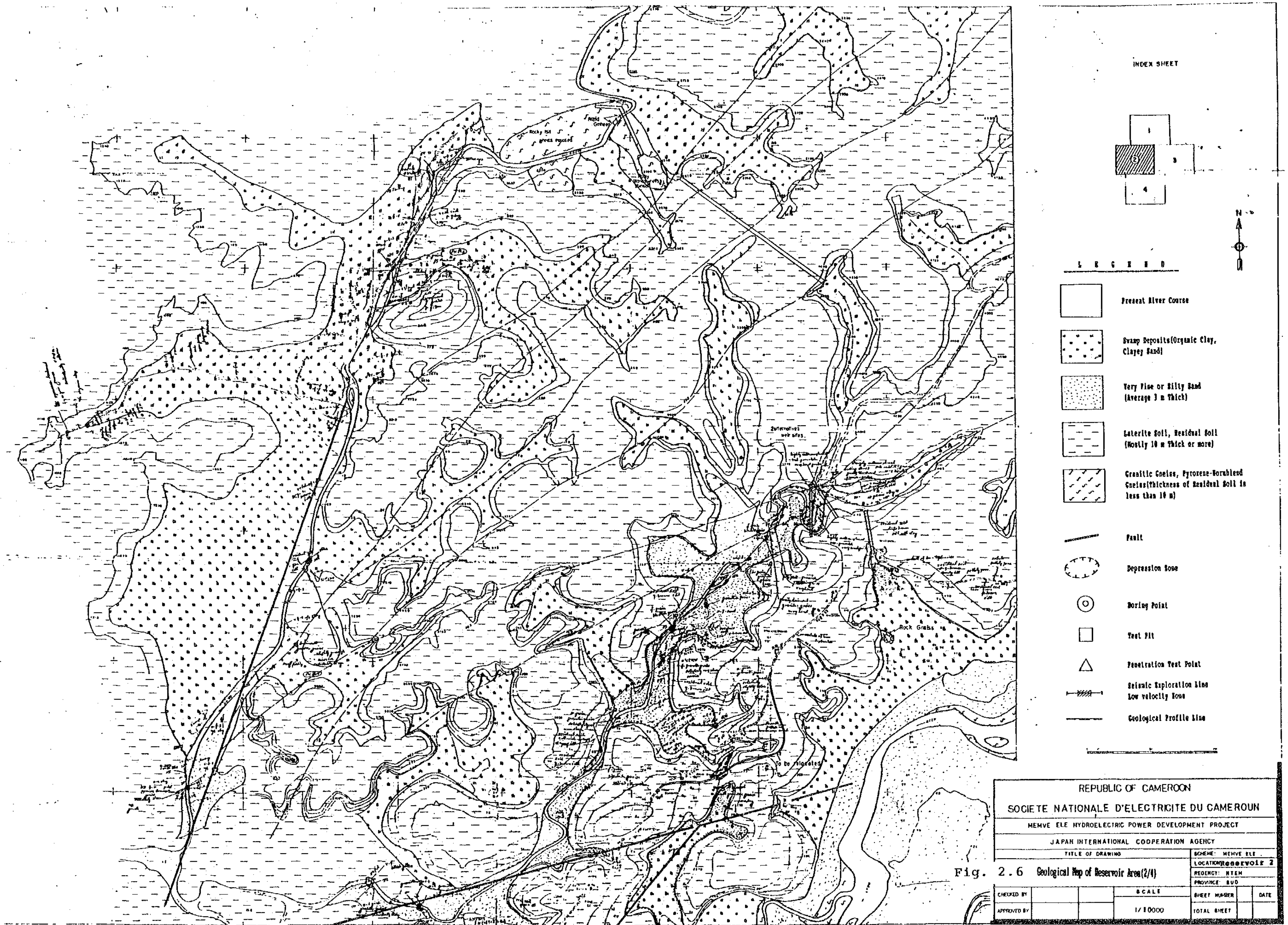


Fig. 2.6 Geological Map of Reservoir Area(2/4)

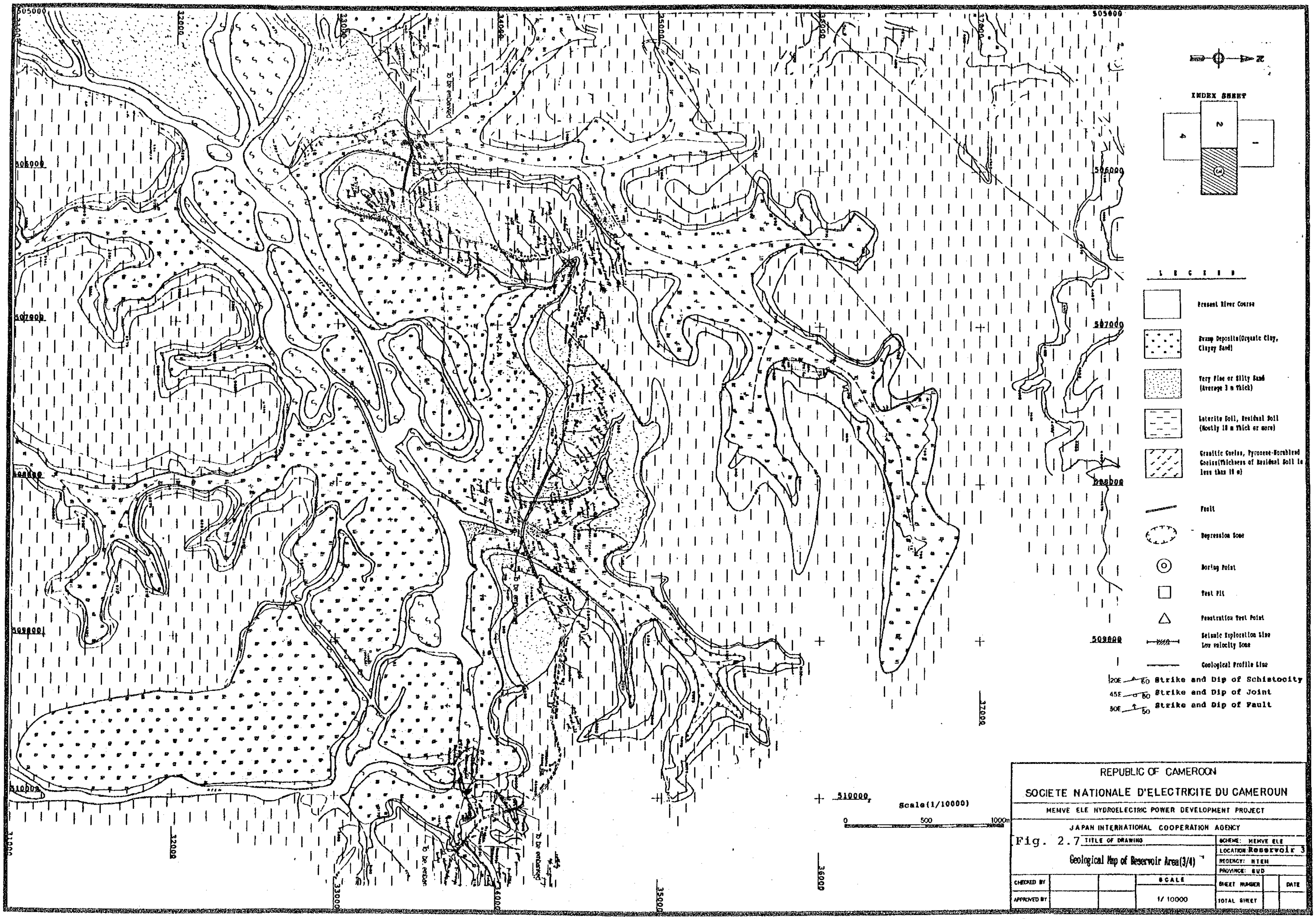


Fig. 2.7 Geological Map of Reservoir Area(3/4)

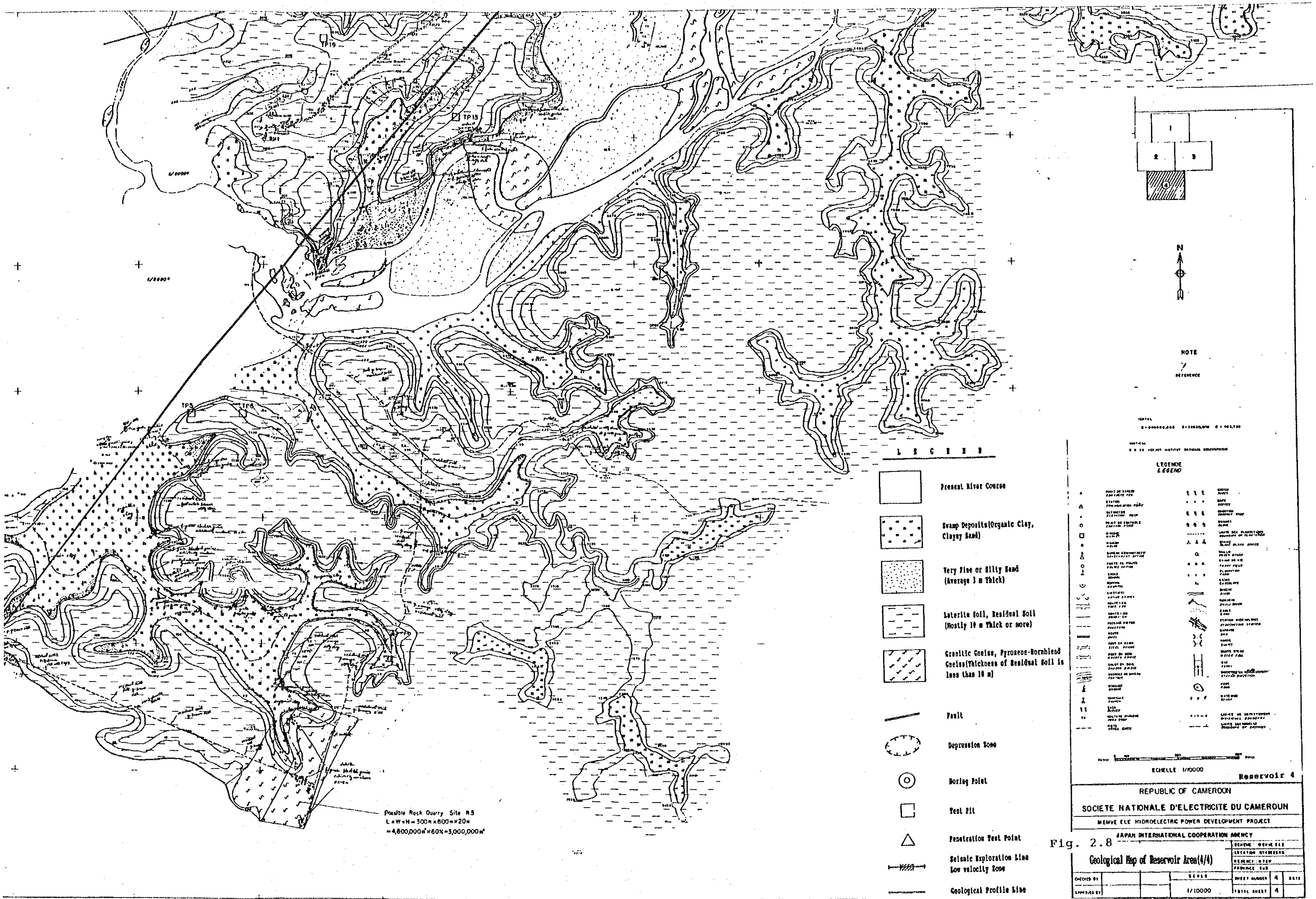


Fig. 2.8 Geological Map of Reservoir Area(4/4)

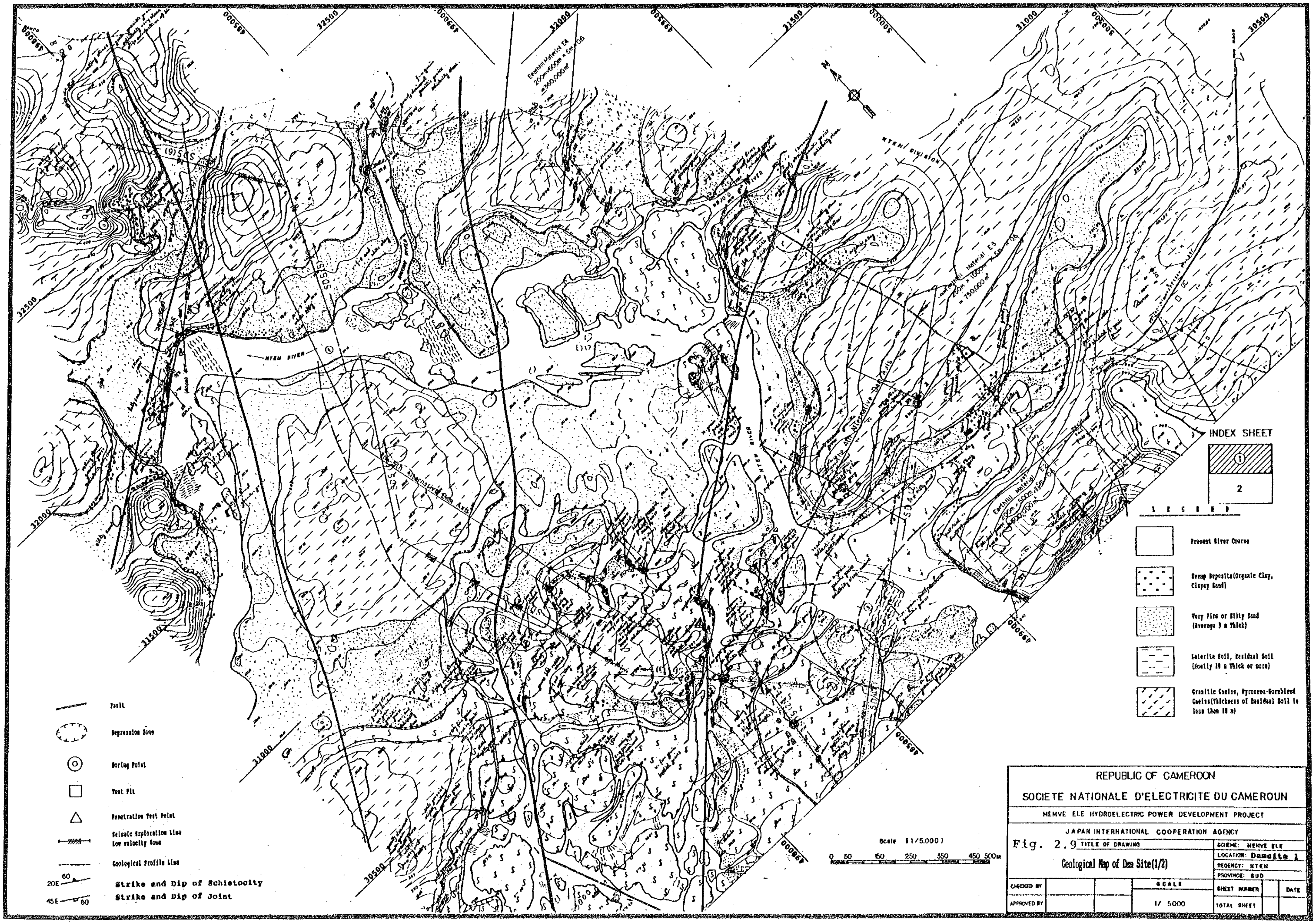
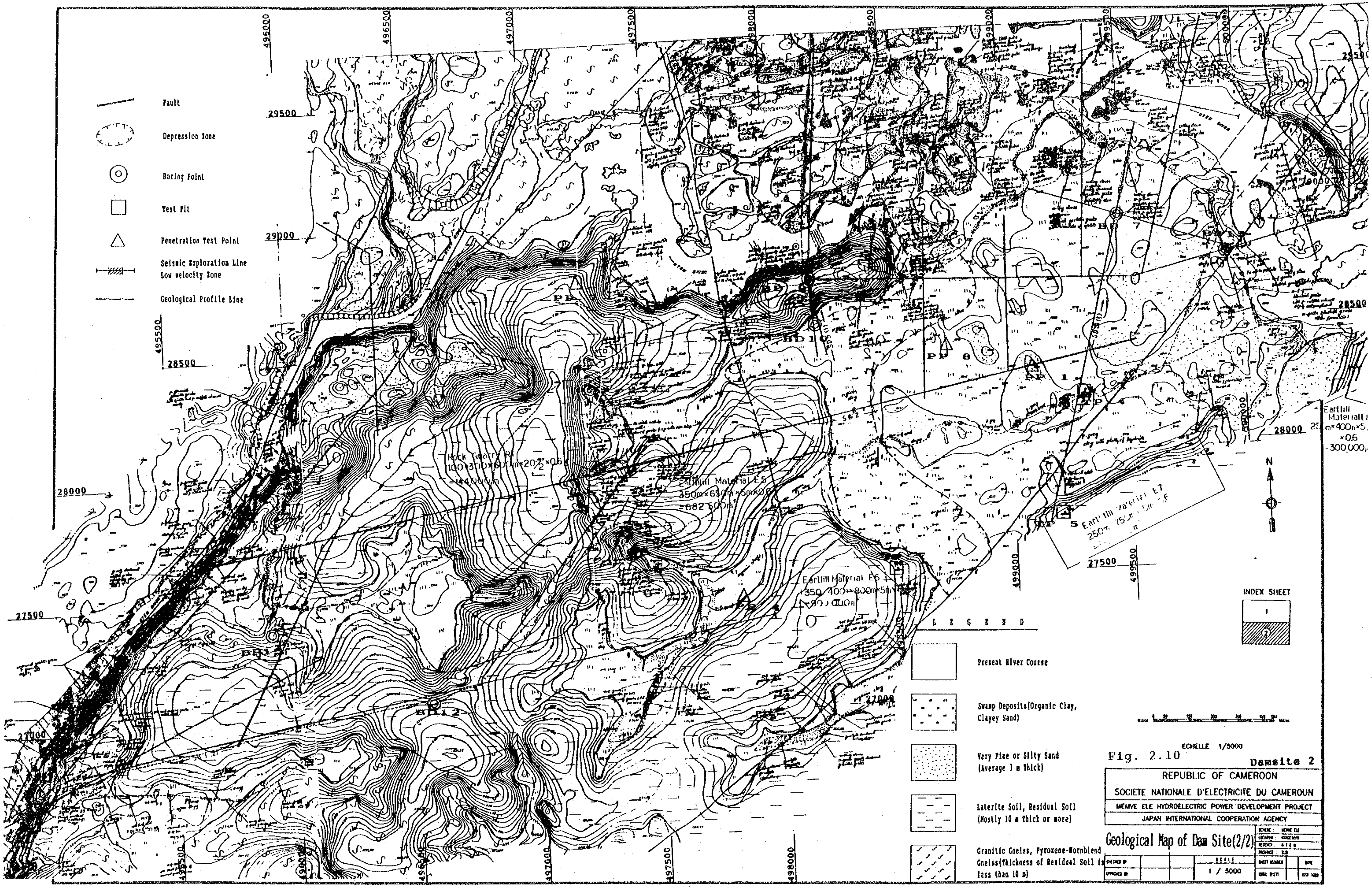


Fig. 2.9 Geological Map of Dam Site(1/2)


Fault
Depression Zone
Boring Point
Test Pit
Penetration Test Point
Seismic Exploration Line
Low velocity Zone
Geological Profile Line
LEGEND
Present River Course
Swamp Deposits(Organic Clay, Clayey Sand)
Very Fine or Silty Sand (Average 3 m Thick)
Laterite Soil, Residual Soil (Mostly 10 m Thick or more)
Granitic Gneiss, Pyroxene-Hornblend Gneiss(Thickness of Residual Soil is less than 10 m)
INDEX SHEET
1
2
ECHELLE 1/5000
Damsite 2
REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
Geological Map of Dam Site(2/2)
SCALE
1 / 5000
N
BB12
PP 8
28000
28500
29000
29500
27500
27000
Fig. 2.10

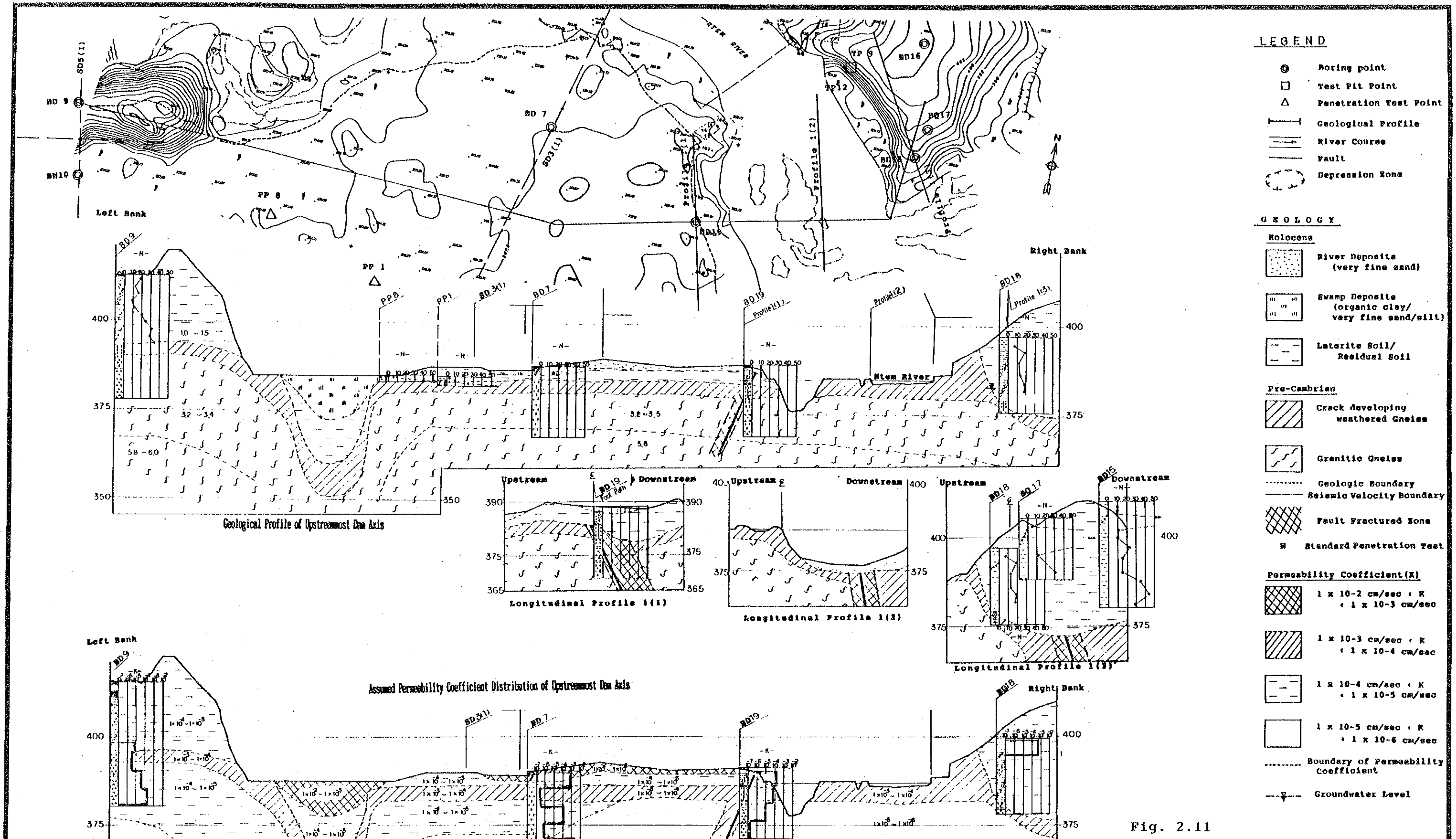


Fig. 2.11

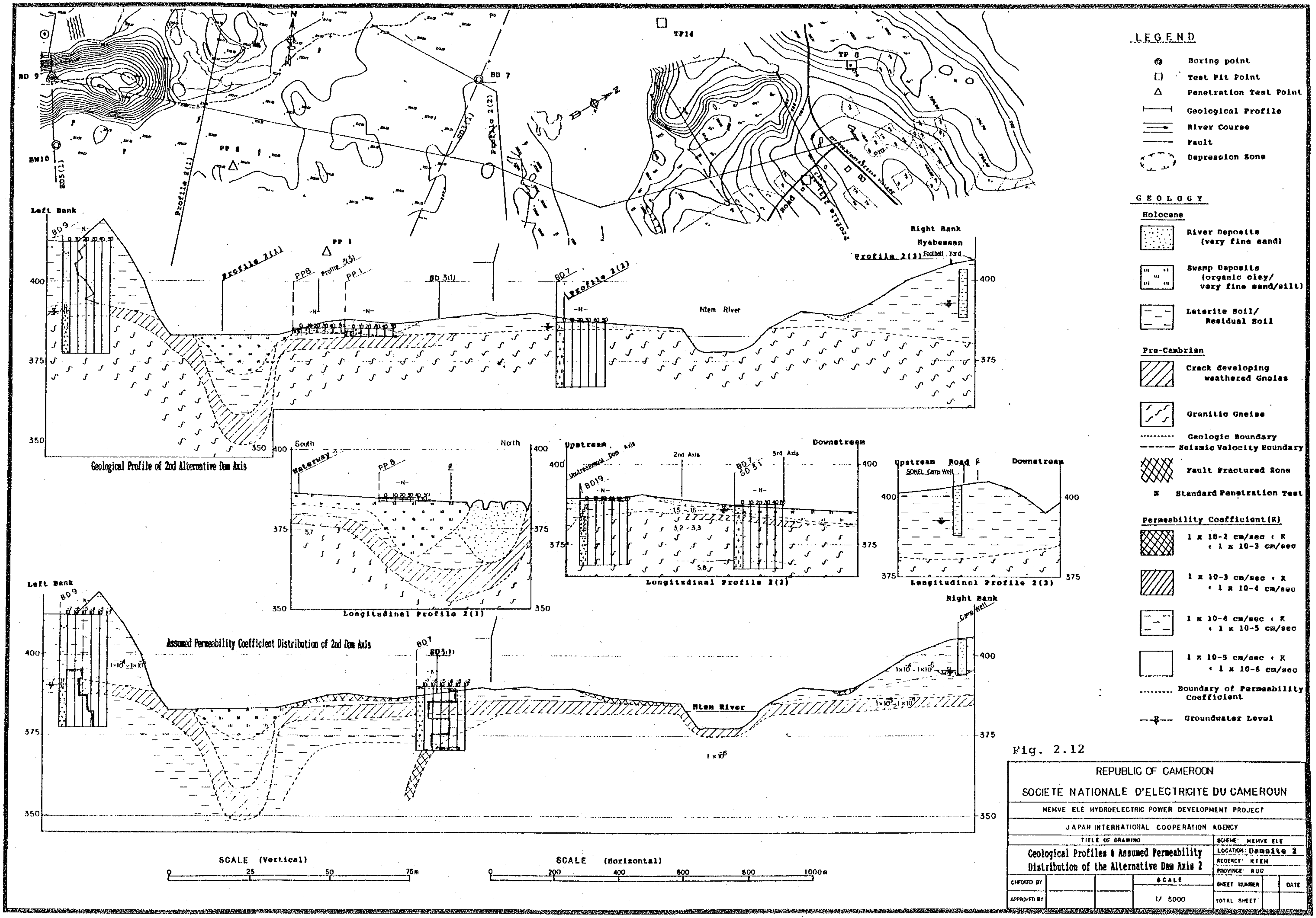
REPUBLIC OF CAMEROON

SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN

MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE OF DRAWING		SCHEME: MEMVE ELE
Geological Profiles & Assumed Permeability Distribution of the Alternative Dam Axis I		LOCATION: Damsite 1
		REGENCY: NTEM
		PROVINCE: SUD
CHECKED BY	SCALE	SHEET NUMBER / DATE
APPROVED BY	1/ 5000	TOTAL SHEET


LEGEND
Boring point
Test Pit Point
Penetration Test Point
Geological Profile
River Course
Fault
Depression Zone
GEOLOGY
Holocene
River Deposits (very fine sand)
Swamp Deposits (organic clay/ very fine sand/silt)
Laterite Soil/ Residual Soil
Pre-Cambrian
Crack developing weathered Gneiss
Granitic Gneiss
Geologic Boundary
Seismic Velocity Boundary
Fault Fractured Zone
N Standard Penetration Test
Permeability Coefficient(K)
1 x 10-2 cm/sec < K < 1 x 10-3 cm/sec
1 x 10-3 cm/sec < K < 1 x 10-4 cm/sec
1 x 10-4 cm/sec < K < 1 x 10-5 cm/sec
1 x 10-5 cm/sec < K < 1 x 10-6 cm/sec
Boundary of Permeability Coefficient
Groundwater Level
BD 9
BW10
BD 7
TP14
TP 8
PP 8
PP 1
Profile 2(1)
Profile 2(2)
Profile 2(3)
Road
Left Bank
Right Bank
Nyabessan
Football Yard
Ntem River
Geological Profile of 2nd Alternative Dam Axis
South
North
Waterway
Longitudinal Profile 2(1)
Upstream
Downstream
2nd Axis
3rd Axis
BD19
Longitudinal Profile 2(2)
SONEL Camp Well
Longitudinal Profile 2(3)
Assumed Permeability Coefficient Distribution of 2nd Dam Axis
Camp Well
SCALE (Vertical)
0 25 50 75m
SCALE (Horizontal)
0 200 400 600 800 1000m
Fig. 2.12
REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE OF DRAWING
Geological Profiles & Assumed Permeability Distribution of the Alternative Dam Axis 2
SCHEME: MEMVE ELE
LOCATION: Damsite 2
REGENCY: NTEM
PROVINCE: SUD
CHECKED BY
APPROVED BY
SCALE
1/ 5000
SHEET NUMBER
TOTAL SHEET
DATE

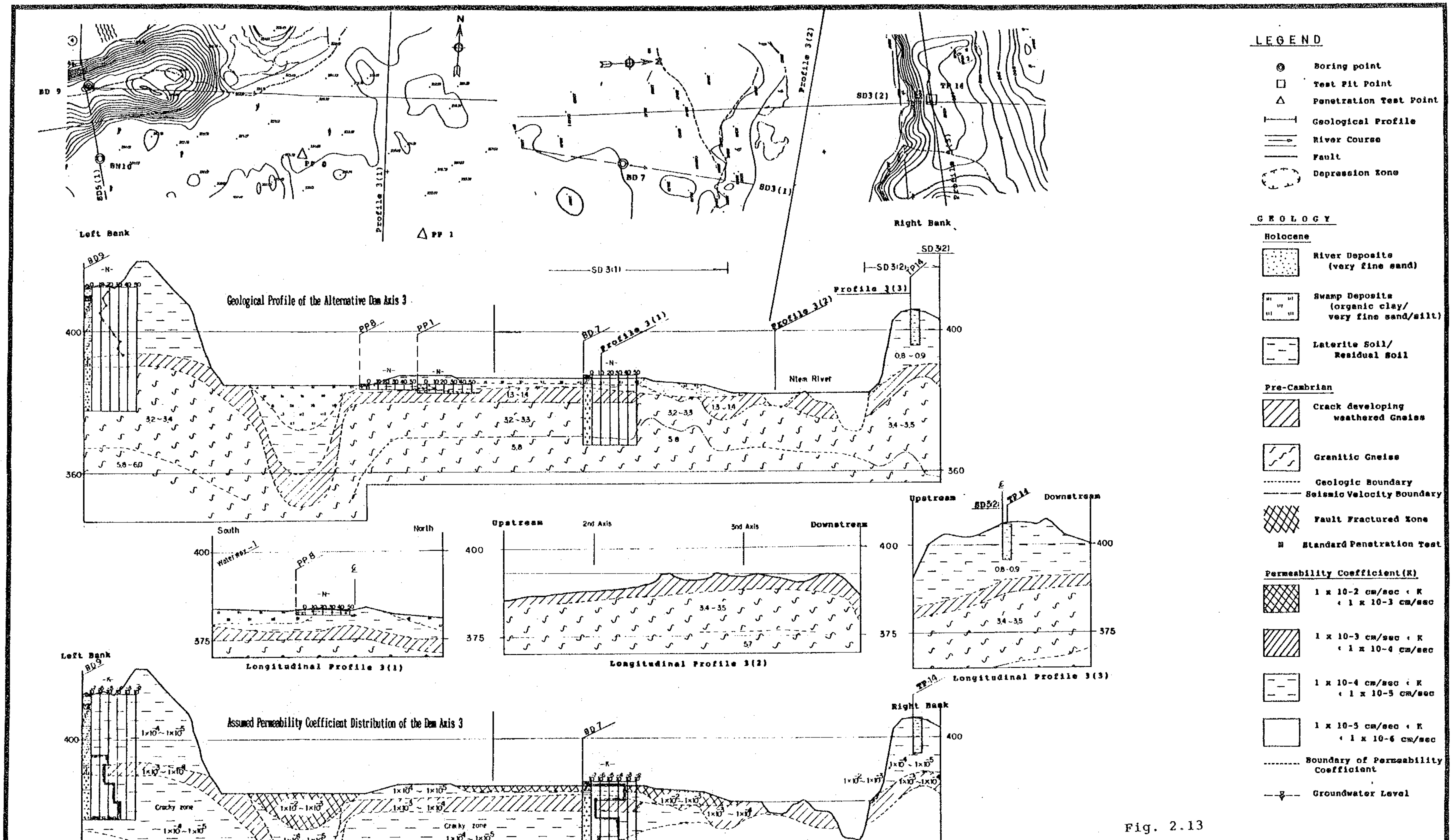


Fig. 2.13

REPUBLIC OF CAMEROON

SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN

MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE OF DRAWING		SCHEME: MEMVE ELE
Geological Profiles & Assumed Permeability Distribution of the Alternative Dam Axis 3		LOCATION: Damsite 3
		REGENCY: NTEM
		PROVINCE: SUD
CHECKED BY	SCALE	SHEET NUMBER / DATE
APPROVED BY	1/ 5000	TOTAL SHEET

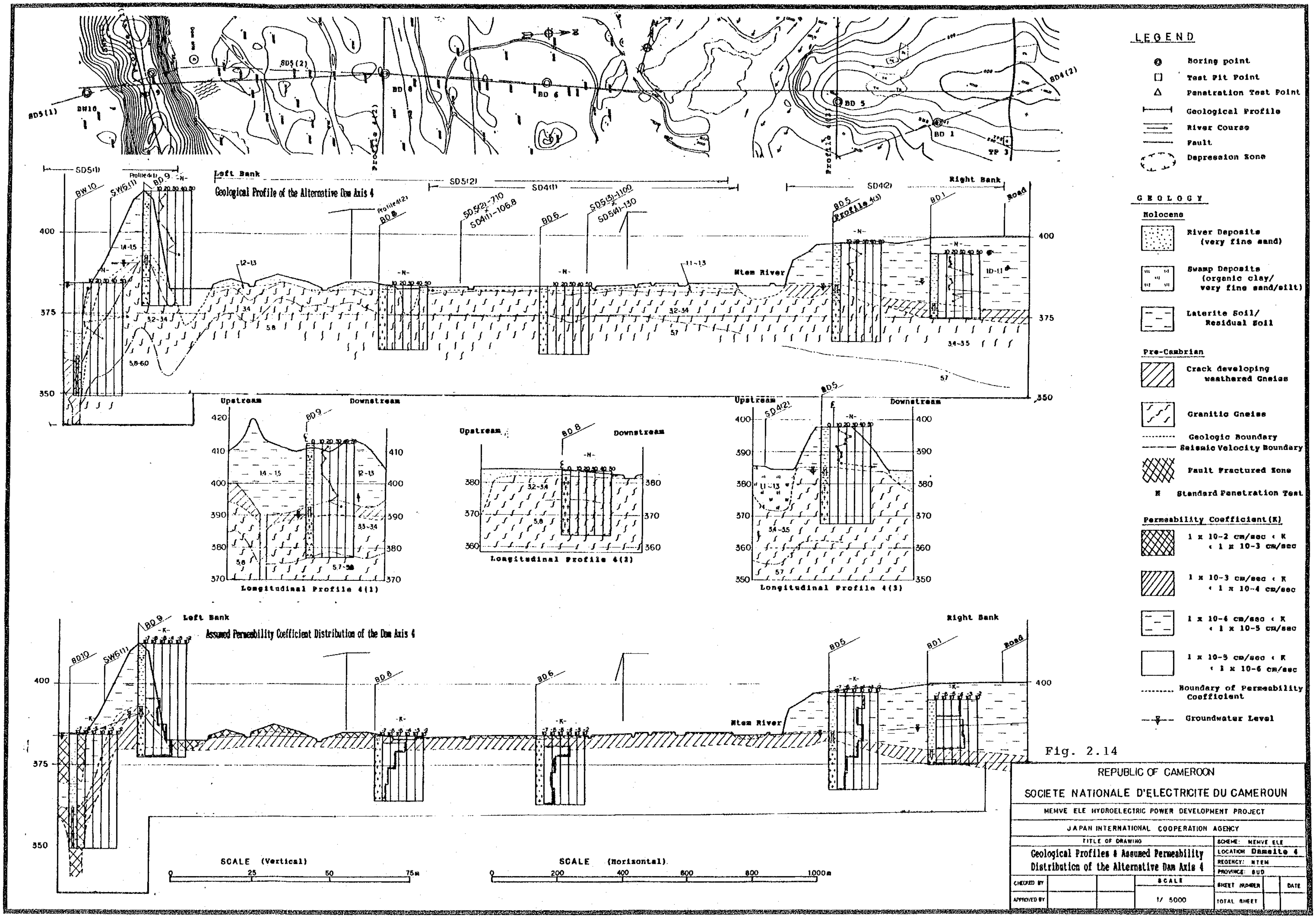
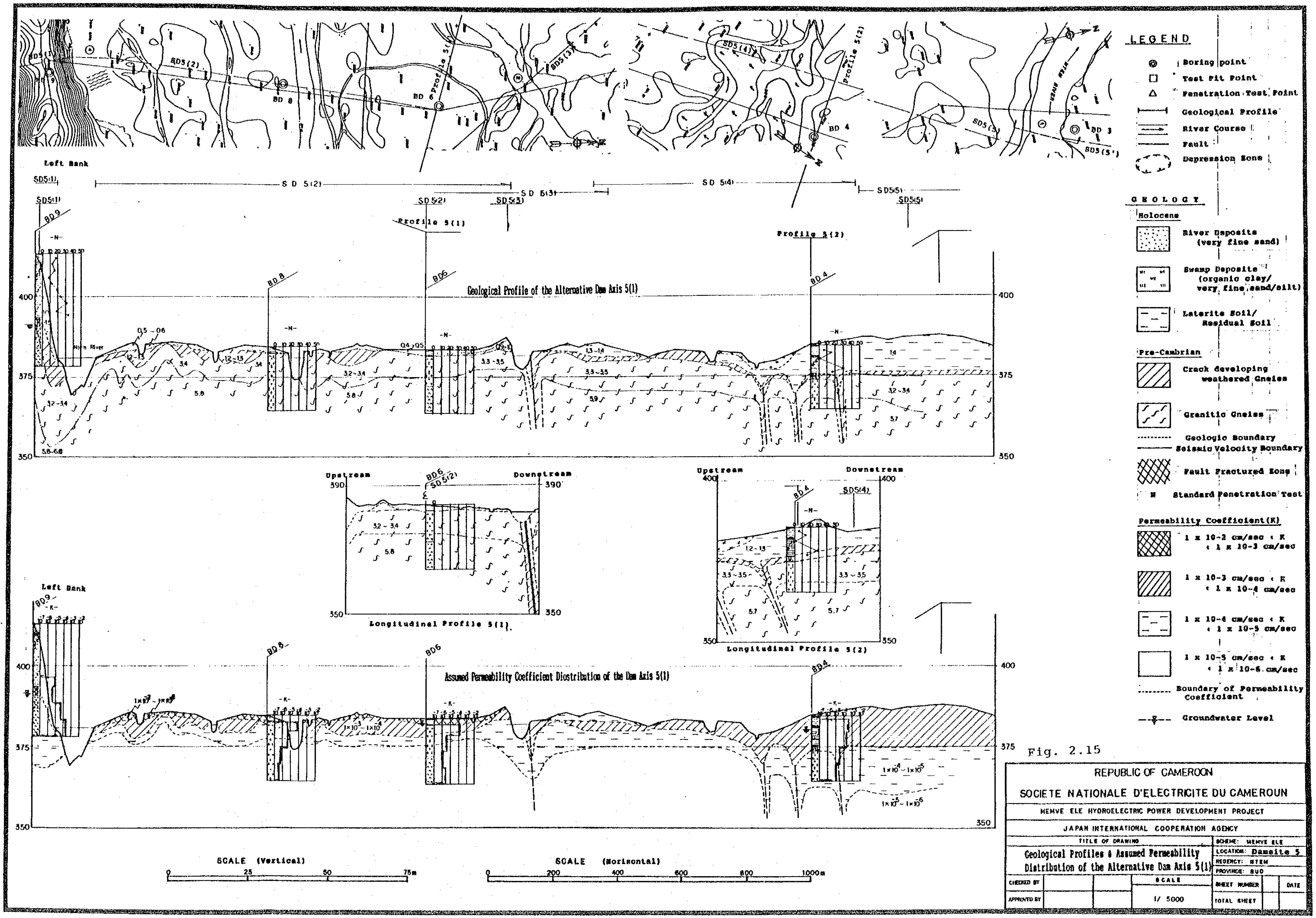
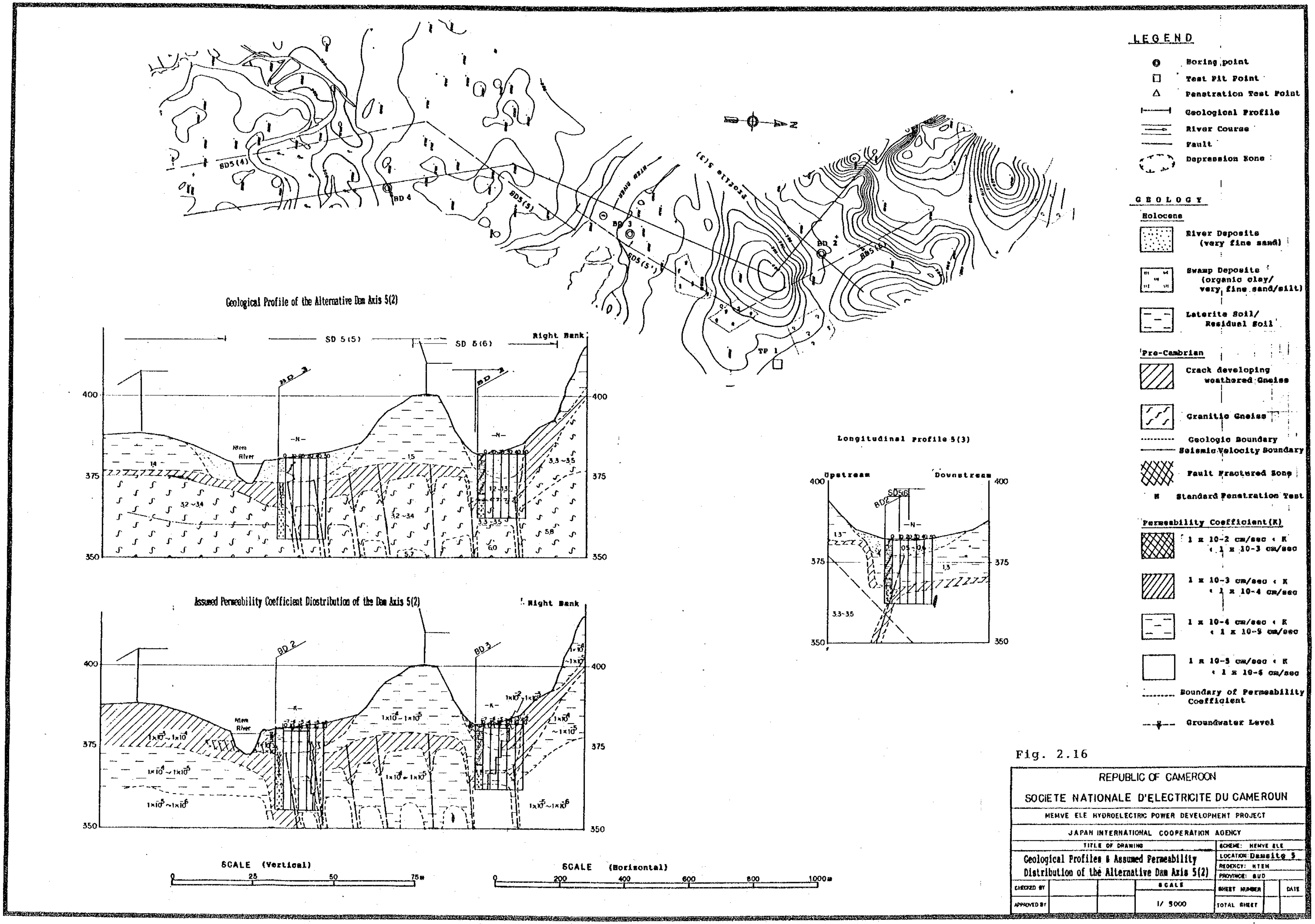

Geological Profile of the Alternative Dam Axis 4
Left Bank
Right Bank
Ntem River
Road
Upstream
Downstream
Longitudinal Profile 4(1)
Longitudinal Profile 4(2)
Longitudinal Profile 4(3)
Assumed Permeability Coefficient Distribution of the Dam Axis 4
SCALE (Vertical)
SCALE (Horizontal)
LEGEND
Boring point
Test Pit Point
Penetration Test Point
Geological Profile
River Course
Fault
Depression Zone
GEOLOGY
Holocene
River Deposits (very fine sand)
Swamp Deposits (organic clay/ very fine sand/silt)
Laterite Soil/ Residual Soil
Pre-Cambrian
Crack developing weathered Gneiss
Granitic Gneiss
Geologic Boundary
Seismic Velocity Boundary
Fault Fractured Zone
N Standard Penetration Test
Permeability Coefficient(K)
1 x 10-2 cm/sec < K < 1 x 10-3 cm/sec
1 x 10-3 cm/sec < K < 1 x 10-4 cm/sec
1 x 10-4 cm/sec < K < 1 x 10-5 cm/sec
1 x 10-5 cm/sec < K < 1 x 10-6 cm/sec
Boundary of Permeability Coefficient
Groundwater Level
REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE OF DRAWING
Geological Profiles & Assumed Permeability Distribution of the Alternative Dam Axis 4
SCHEME: MEMVE ELE
LOCATION: Damsite 4
REGENCY: NTEM
PROVINCE: SUD
SCALE 1/ 5000
CHECKED BY
APPROVED BY
SHEET NUMBER
TOTAL SHEET
DATE

Fig. 2.14



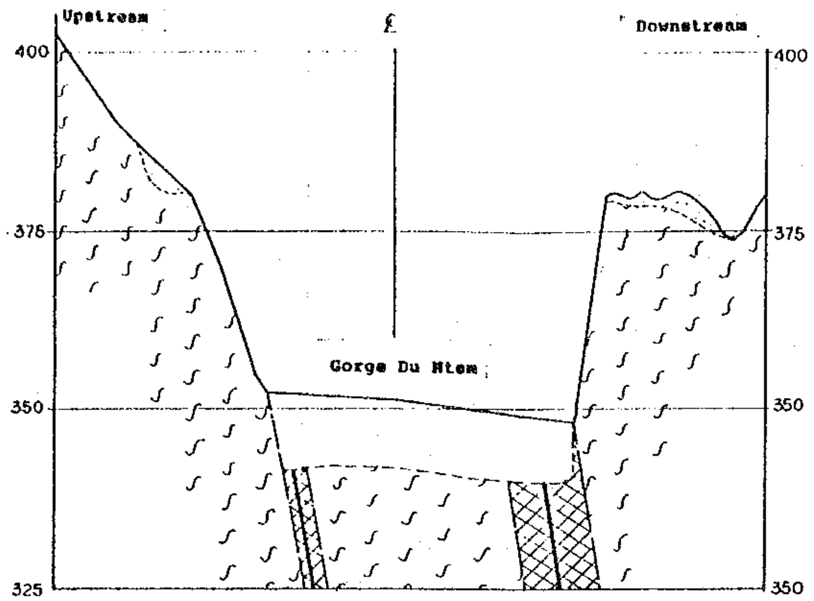
LEGEND
Boring point
Test Pit Point
Penetration Test Point
Geological Profile
River Course
Fault
Depression Zone
GEOLOGY
Holocene
River Deposits (very fine sand)
Swamp Deposits (organic clay/ very fine sand/silt)
Laterite Soil/ Residual Soil
Pre-Cambrian
Crack developing weathered Gneiss
Granitic Gneiss
Geologic Boundary
Seismic Velocity Boundary
Fault Fractured Zone
N Standard Penetration Test
Permeability Coefficient(K)
1 x 10-2 cm/sec < K < 1 x 10-3 cm/sec
1 x 10-3 cm/sec < K < 1 x 10-4 cm/sec
1 x 10-4 cm/sec < K < 1 x 10-5 cm/sec
1 x 10-5 cm/sec < K < 1 x 10-6 cm/sec
Boundary of Permeability Coefficient
Groundwater Level
Left Bank
SD5(1)
SD 5(2)
SD 5(3)
SD 5(4)
SD5(5)
BD9
BD 8
BD6
BD 4
BD 3
Profile 5(1)
Profile 5(2)
Ntem River
Geological Profile of the Alternative Dam Axis 5(1)
Upstream
Downstream
Longitudinal Profile 5(1)
Longitudinal Profile 5(2)
Assumed Permeability Coefficient Diostribution of the Dam Axis 5(1)
SCALE (Vertical)
SCALE (Horizontal)
REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE OF DRAWING
Geological Profiles & Assumed Permeability Distribution of the Alternative Dam Axis 5(1)
SCHEME: MEMVE ELE
LOCATION: Damsite 5
REGENCY: NTEM
PROVINCE: SUD
CHECKED BY
APPROVED BY
SCALE
1/ 5000
SHEET NUMBER
TOTAL SHEET
DATE

Fig. 2.15

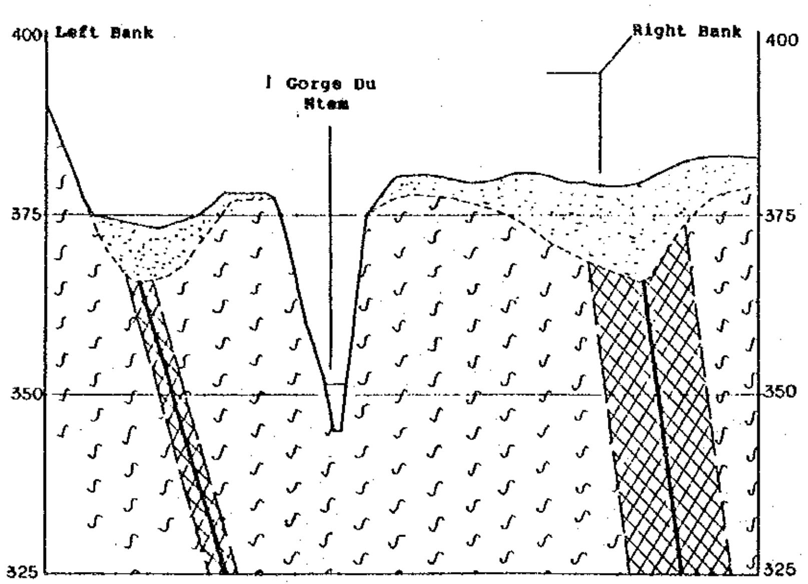


LEGEND
Boring point
Test Pit Point
Penetration Test Point
Geological Profile
River Course
Fault
Depression Zone
GEOLOGY
Holocene
River Deposits (very fine sand)
Swamp Deposits (organic clay/ very fine sand/silt)
Laterite Soil/ Residual Soil
Pre-Cambrian
Crack developing weathered Gneiss
Granitic Gneiss
Geologic Boundary
Seismic Velocity Boundary
Fault Fractured Zone
N Standard Penetration Test
Permeability Coefficient(K)
1 x 10-2 cm/sec < K < 1 x 10-3 cm/sec
1 x 10-3 cm/sec < K < 1 x 10-4 cm/sec
1 x 10-4 cm/sec < K < 1 x 10-5 cm/sec
1 x 10-5 cm/sec < K < 1 x 10-6 cm/sec
Boundary of Permeability Coefficient
Groundwater Level
BD5(4)
BD 4
BD5(5)
BD 3
BD5(5')
Profile 5(3)
BD 2
BD5(6)
TP 1
Geological Profile of the Alternative Dam Axis 5(2)
SD 5(5)
SD 5(6)
Right Bank
BD 3
BD 2
Ntem River
400
375
350
Assumed Permeability Coefficient Distribution of the Dam Axis 5(2)
Right Bank
Longitudinal Profile 5(3)
Upstream
Downstream
SCALE (Vertical)
0 25 50 75m
SCALE (Horizontal)
0 200 400 600 800 1000m
REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE OF DRAWING
Geological Profiles & Assumed Permeability Distribution of the Alternative Dam Axis 5(2)
SCHEME: MEMVE ELE
LOCATION: Damsite 5
AGENCY: NTEM
PROVINCE: SUD
CHECKED BY
APPROVED BY
SCALE
1/ 5000
SHEET NUMBER
TOTAL SHEET
DATE

Fig. 2.16



Longitudinal Profile



Profile of Dam Axis- 6

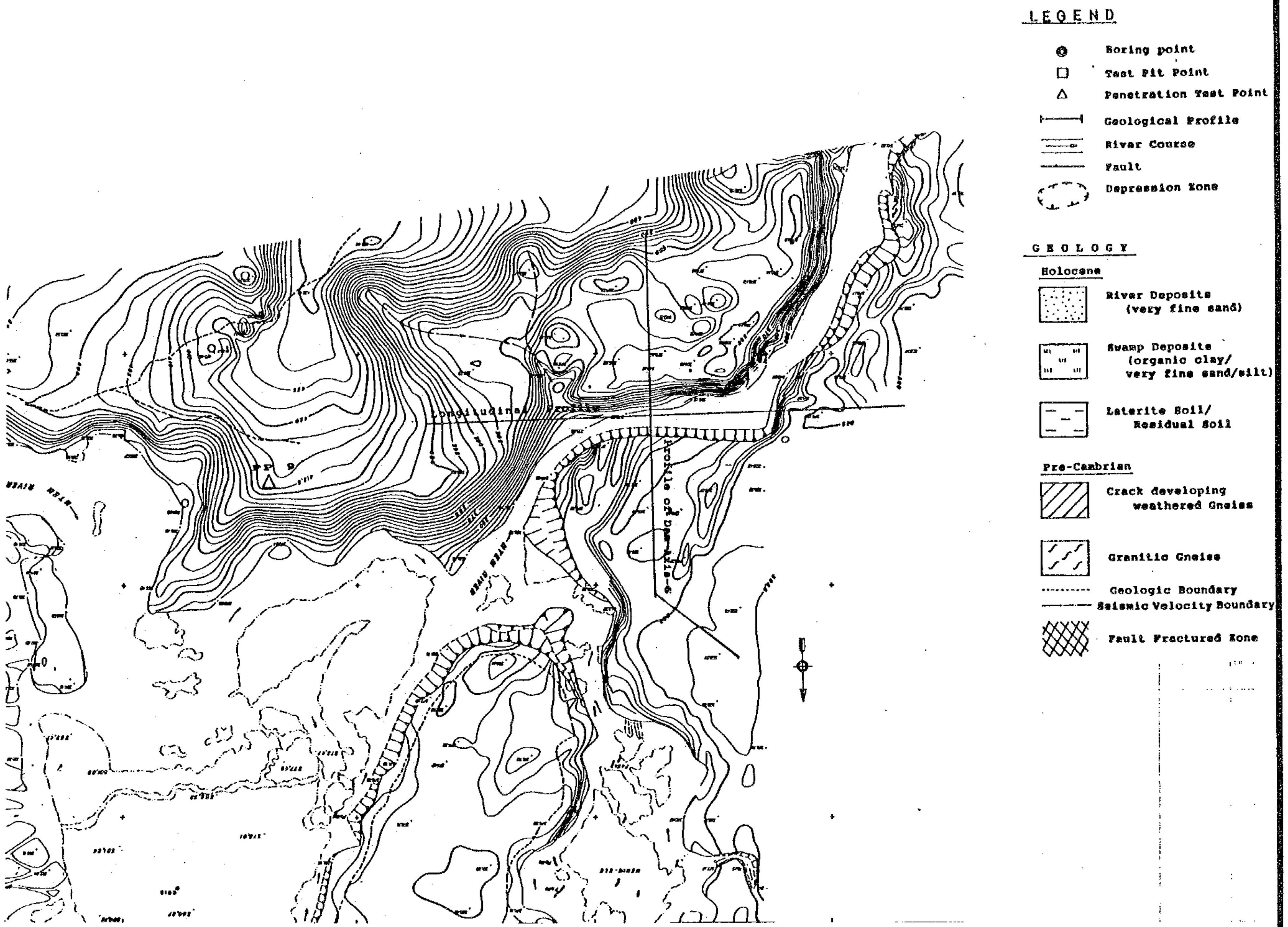


Fig. 2.17

REPUBLIC OF CAMEROON

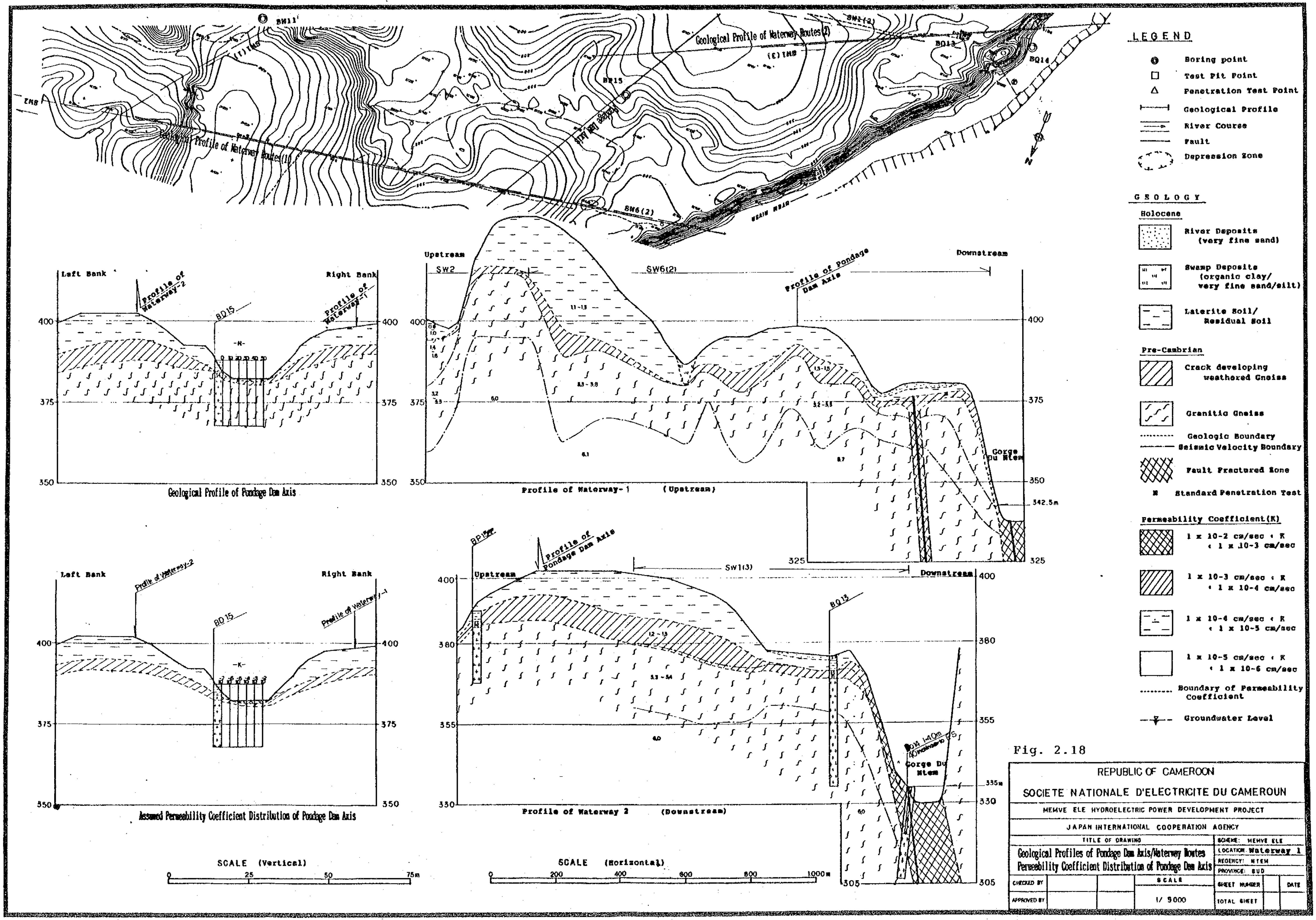
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN

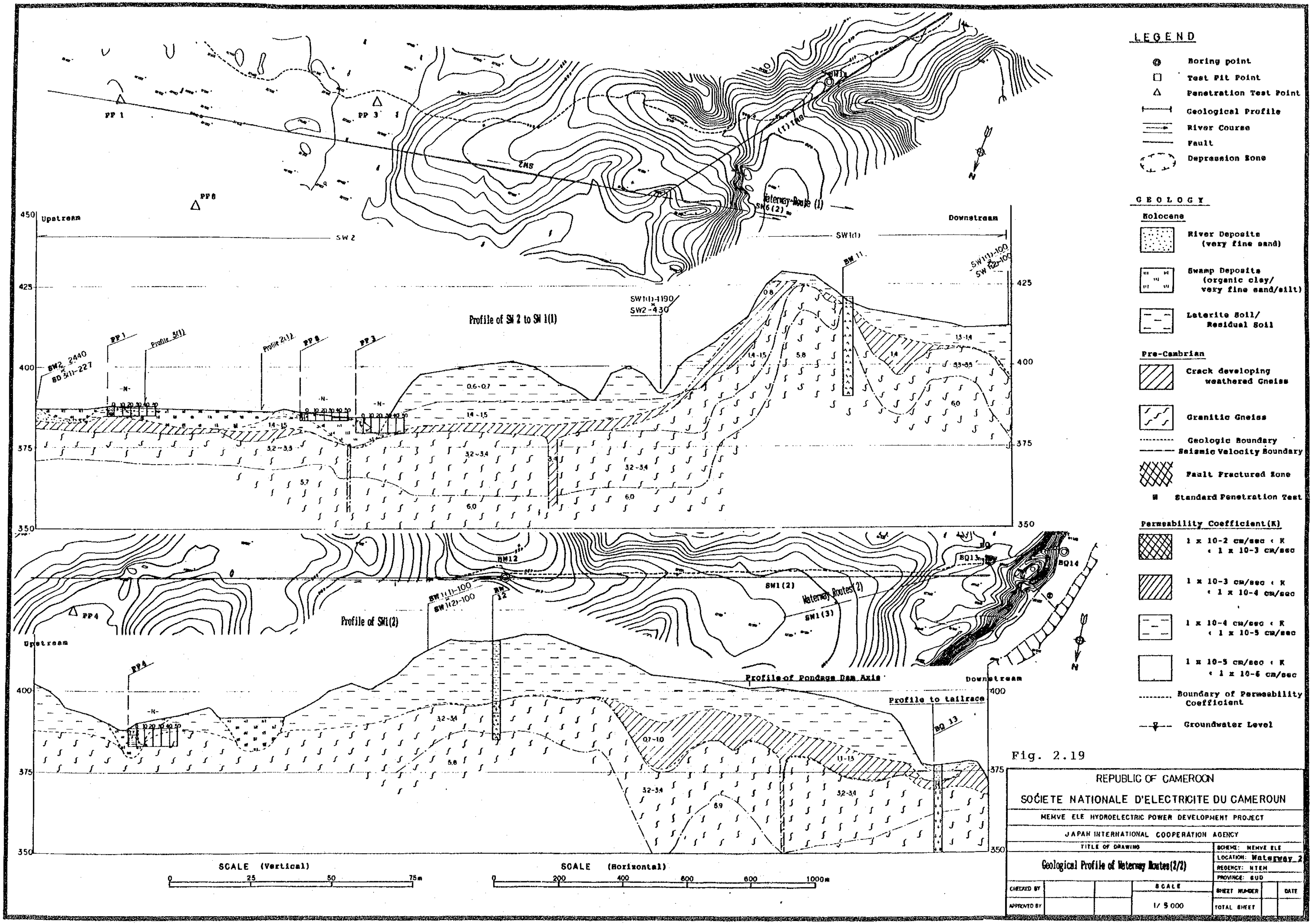
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE OF DRAWING	SCHEME: MEMVE ELE
Geological Profiles of the Alternative Dam Axis 6	LOCATION: Damsite 6
	REGENCY: NTEM
	PROVINCE: SUD

CHECKED BY			SCALE	SHEET NUMBER		DATE
APPROVED BY			1/ 5000	TOTAL SHEET		


LEGEND
Boring point
Test Pit Point
Penetration Test Point
Geological Profile
River Course
Fault
Depression Zone
GEOLOGY
Holocene
River Deposits (very fine sand)
Swamp Deposits (organic clay/ very fine sand/silt)
Laterite Soil/ Residual Soil
Pre-Cambrian
Crack developing weathered Gneiss
Granitic Gneiss
Geologic Boundary
Seismic Velocity Boundary
Fault Fractured Zone
N Standard Penetration Test
Permeability Coefficient(K)
1 x 10-2 cm/sec < K < 1 x 10-3 cm/sec
1 x 10-3 cm/sec < K < 1 x 10-4 cm/sec
1 x 10-4 cm/sec < K < 1 x 10-5 cm/sec
1 x 10-5 cm/sec < K < 1 x 10-6 cm/sec
Boundary of Permeability Coefficient
Groundwater Level
Geological Profile of Waterway Routes(1)
Geological Profile of Waterway Routes(2)
BW11
BQ13
BQ14
BQ15
BW6(2)
Left Bank
Right Bank
Profile of Waterway-2
Profile of Waterway-1
Geological Profile of Pondage Dam Axis
Upstream
Downstream
SW2
SW6(2)
Profile of Pondage Dam Axis
Gorge du Ntem
342.5m
Profile of Waterway-1 (Upstream)
Assumed Permeability Coefficient Distribution of Pondage Dam Axis
SW1(3)
Profile of Waterway 2 (Downstream)
335m
SCALE (Vertical)
0 25 50 75m
SCALE (Horizontal)
0 200 400 600 800 1000m
Fig. 2.18
REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE OF DRAWING
Geological Profiles of Pondage Dam Axis/Waterway Routes
Permeability Coefficient Distribution of Pondage Dam Axis
SCHEME: MEMVE ELE
LOCATION: Waterway 1
REGENCY: NTEM
PROVINCE: SUD
CHECKED BY
APPROVED BY
SCALE
1/ 5000
SHEET NUMBER
DATE
TOTAL SHEET


LEGEND
Boring point
Test Pit Point
Penetration Test Point
Geological Profile
River Course
Fault
Depression Zone
GEOLOGY
Holocene
River Deposits (very fine sand)
Swamp Deposits (organic clay/ very fine sand/silt)
Laterite Soil/ Residual Soil
Pre-Cambrian
Crack developing weathered Gneiss
Granitic Gneiss
Geologic Boundary
Seismic Velocity Boundary
Fault Fractured Zone
Standard Penetration Test
Permeability Coefficient(K)
1 x 10-2 cm/sec < K < 1 x 10-3 cm/sec
1 x 10-3 cm/sec < K < 1 x 10-4 cm/sec
1 x 10-4 cm/sec < K < 1 x 10-5 cm/sec
1 x 10-5 cm/sec < K < 1 x 10-6 cm/sec
Boundary of Permeability Coefficient
Groundwater Level
PP 1
PP 3
PP 8
PP 4
SW 2
SW 1(1)
Waterway Route (1)
Waterway Route (2)
BH 11
BH 12
BQ 13
BQ 14
Upstream
Downstream
Profile of SW 2 to SW 1(1)
Profile of SW 1(2)
Profile of Pondage Dam Axis
Profile to tailrace
SCALE (Vertical)
0 25 50 75m
SCALE (Horizontal)
0 200 400 600 800 1000m
Fig. 2.19
REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE OF DRAWING
Geological Profile of Waterway Routes(2/2)
SCHEME: MEMVE ELE
LOCATION: Waterway 2
REGENCY: NTEM
PROVINCE: SUD
CHECKED BY
APPROVED BY
SCALE
1/ 5 000
SHEET NUMBER
TOTAL SHEET
DATE

FEASIBILITY STUDY

ON

MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT

FINAL REPORT

APPENDIX II GEOLOGY AND CONSTRUCTION MATERIALS

PART II CONSTRUCTION MATERIALS

PART II CONSTRUCTION MATERIALS

1. GENERAL

1.1 Introduction

Construction Material Survey was carried out for the purpose of 1) check available quantity and quality near the project site, and 2) clarifying the constricted problem on the construction materials for the project. The survey works are composed of field investigation and surveying, sampling for laboratory test, and laboratory tests. The detail of the survey work and their results are mentioned hereinafter. The obtained data is compiled in a Data Book (Geological Study and Construction Material Survey).

1.2 Method of Investigation

1.2.1 Field Reconnaissance, Core drilling and Test Pitting

Through the course of the field work of 1) Identification stage (December 1990 to February 1991), and 2) Field Investigation stage (May 1991 to September 1992) several potential borrow sites were proposed in and around the alternative 1 to 5 dam sites. The location of the potential borrow sites and rock quarry sites (except with Mt. Ebungu) etc., are shown in Fig. 3.1 "Location Map of Construction Material Survey".

Since the laterite soil in the site is abundant, the river sand deposits are lean and an exploitable volume in the potential rock quarry is very limited, the survey and investigation for the river sand and rock quarry site were endeavored.

Core drilling of BW 11, BQ 13, and BQ 14 were carried out for potential rock quarry site along the downstream route of waterway. The condition at the site proved to be exploitable. Core drilling of BQ 17 at the right bank upstream of the Ntem river shows that the area is limited in locality and insufficient in quantity.

Test Pitting of TP 4 (left bank), TP 8 (right Bank), TP 17 and TP 18 (right bank downstream of the Ndjo'o river) were made to check an availability of the sand deposits and to take sample for gradation test in laboratory. However, these investigation results for the sand materials show that fine deposits along the river side sand are insufficient in quantity, very poorly sorted, and very fine. On the other hand, there is a sand bank in the Ntem river immediately upstream of Nyabessan boat station. The sand obtained from this bank is relatively coarse having low uniformity coefficient. For the purpose of fine concrete aggregate, this river sand shall be passed through a rod mill in an aggregate production plant so as to improve gradation.

The other test pits were carried out for a confirmation of quantity and quality of earth fill material. The result shows the material is suitable for earth fill dam, and enough quantity at many places.