GOVERNMENT OF MALAYSIA

FEASIBILITY STUDY
SMALL SCALE HYDROELECTRIC POWER PROJECTS IN SARAWAK

VOLUME- V
APPENDIX
FOR
FEASIBILITY STUDY
ON
MEDAMIT-2 HYDROELECTRIC POWER PROJECT

JULY 1988

JICA

JAPAN INTERNATIONAL COOPERATION AGENCY

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CHAPTER 1. INTRODUCTION

Field investigation for the Medamit-2 project was carried out for approximately two months from June to July 1987. In this Appendix I, geological condition of the project site is discussed based on the results of field investigation.

Geology of the project site was surveyed through the geological mapping, core drilling with the standard penetration and water pressure tests in the borehole and seismic prospecting, of which survey volume was as follows:

Survey Item	Quantity
Geological mapping	4.36 km^2 area in 1:5,000 scale
" "	0.25 km^2 area in 1:500 scale
Core drilling	150.41 m, at 7 boreholes
Standard penetration test	47 points, in 6 boreholes
Water pressure test	8 stages in 3 boreholes
Seismic prospecting	1,725 m long in 7 lines

Distribution of drilling points and seismic prospecting profile lines is shown in Fig. I-1, Location Map of Geological Investigation. The survey area can be divided into three sites for the sake of report discussion; i.e. the dam, waterway and powerhouse. The field campaign of core drilling and seismic prospecting was deployed into these sites as follows.

Geological mapping was performed by Sarawak Electricity Supply Corporation (SESCO) and Geological Survey Department of Sarawak at the request of SESCO.

Core drilling was performed by a contractor, Geotechnique East Malaysia PTE LTD CO., under the supervision of SESCO staff and JICA expert.

Seismic prospecting was performed by the subcontractor, Strata Recon Sdn. Bhd., under the supervision of SESCO staff and JICA expert.

CHAPTER 2. GENERAL GEOLOGY

2.1 General

State of Sarawak having an area of about 124,000km^2 along the north-west coast of the island of Borneo lies on immediately north of the Equator, between latitude 0° 50′ and 5° 00′N and longitude 109° 36′ and 115° 40′. It is bounded by Brunei and Sabah on the North and Kalimantan (Indonesia) in the Southwest.

Topography of Sarawak is dominated by the alluvial coastal plain stretched over some 700 kilometers along the coast and eastern mountainous region. Most cities and towns in Sarawak are situated sporadically on the Quaternary coastal plain.

Geology of the mountainous region mainly consists of sedimentary rocks from Paleozoic to Tertiary era.

Igneous rocks are sporadically distributed in the central and southern part of Sarawak. Strata is folded, faulted, and has a complicated geological structure. In general, younger strata is distributed at the northern part of Sarawak. The main rivers in Sarawak such as the Rajang River not only flow towards west in parallel with the geological structure, but also towards the north at right angle with the geological structure.

2.2 Topography

The project area of Medamit-2 is located on the mountainous region with elevation of 300 to 500 meters, about 50 kilometers south of Limbang town which is situated in northern part of Sarawak.

The Limbang River is flowing towards northwest from Mt. Murud (EL.2,385 meters) and Mt. Batu (EL.2,010 meters) situated at the southeastern side of the project area. The tributaries such as the Rutoh, Adangk, Salidong and Medamit rivers are flowing towards the west from Mt. Pagon (EL.1,780 meters) situated on the east of the project area. The Salidong joints into the Limbang River at 1.5 kilometers upper reach of powerhouse (refer to Alt-3 in Fig. I-1), while the Medamit merges into the Limbang River at about 25 kilometers downstream of the proposed damsite.

Mountains between the Medamit and Limbang rivers are about 500 meters high above the mean sea level. Valleys and tributaries sharply meandering are formed by erosion. However, small river terraces and gentle slopes are developed along both rivers. Collapses and landslides can be found on the mountain slopes.

2.3 Regional geology

The project area is underlain by the Mulu formation in the range of Palaeocene to Eocene age, the Melinau Limestone Formation in Eocene to Miocene age and the Setap Shale Formation in Miocene age.

Rocks related to the project area consist of the Melinau Limestone Formation and the Setap Shale Formation, however, the Mulu Formation is distributed in the southern part (left bank) of the Limbang River. Those formations are striking north-northwestwardly and dipping toward northeast. All formations are unconformable each other.

No big scale fault and sheared zone are discovered in the project area. However, five meters wide sheared zone at the mouth of the Salidong River and faults at the damsite area are exposed on outcrops. There is a possibility that the shear zone goes cross the proposed penstock line (Alternative-3) extended toward northwest. Minor faults existing at the boundary between sandstone and shale extended toward east-northwest in parallel with the strike of bedding continue until the damsite area.

The Melinau Limestone Formation, being grey and massive limestone, outcrops in a scattered pattern at the slope of the right bank along the Limbang River.

The Setap Shale Formation, consisting of shale with subordinate sandstone, siltstone and rare and thin limestone beds unconformably overlying the Melinau Limestone Formation, is extensively distributed at the right bank of the Limbang and Medamit river areas. A limestone outcrop is found at the mouth of the Salidong River.

The Setap Shale Formation in the project area mainly consists of shale unit with beds of fine-grained sandstone. The shale unit is folded and regionally metamorphosed. Cleavages in the shale are well developed. Fresh outcrops of shale are grey to dark grey and hard, and occur as the beds of about five centimeters intercalated with minor sandstone beds of two to three centimeters thick. The sandstone unit is found as lenses in a central part of the Medamit and Limbang rivers and at the proposed damsite. The sandstone at the proposed damsite is massive, fine grained and hard. Friable, soft, weathered fine grained sandstone can be found in the central part of the Medamit and Limbang rivers.

In general, the shale and sandstone units in the area have been subjected to strong weathering, although fresh and hard shale can be found in the riverbed and bottom of valley. Lateritic residual soil zone distributes thickly on the ridges and mountainside slopes. With the rocks mentioned above as the bedrock, Quaternary terrace deposits, talus deposits and riverbed deposits along the rivers are distributed in a small scale.

Fig. I-2 shows the geological map in a scale of 1 to 5,000, while Fig. I-3 is the site geological map in a scale of 1 to 500.

CHAPTER 3. SEISMICITY

3.1 General

Sarawak is located outside the Circum-Pacific seismic zone and is situated on the Sunda Shield, a stable block where almost no recent activity or block tectonics have been recorded.

During the period of late Tertiary and Quarternary, extensive volcanism occurred in the folded Upper Tertiary strata of Central Sarawak. Volcanic eruptions and subsequent basaltic extensions built the Hose Mountain Range, the Usun Apau plateau and the Linau Balia plateau. The youngest igneous rock in Western Sarawak is an andesitic lava at Sematan, possibly of early Quaternary age.

In Sarawak no volcanic activity has been detected recently. The possibilities of earthquake by volcanic activity may be scarce.

3.2 Earthquake Records around the Proposed Project Site

Earthquake records in Sarawak are available in "Micro-Seismic Study of Malaysia and Adjacent Area" prepared by Malaysian Meteological Service, in which 17 events in peninsula Malaysia, 7 events in Sabah and 2 events in Sarawak were recorded during the period from 1896 to 1976 (See Fig. I-4).

Two earthquake records in Sarawak are as follows:

a. Year and Date : 1958 June 30th
Place : Kuching
Intensity (MM scale) : V
Report of Damages : Two tremors reported sleepers awakened.
Source : North Borneo News and Sabah Times, Jessel
July 5, 1958 Sabah State library

b. Year and Date : 1965 July 21
Place : Niah and Bekenu
Fourth Division of Sarawak
Intensity (MM scale) : IV
Report of Damages : Light tremors slammed doors and smashed window panes, but no major damages were reported.
Source : The Sarawak Tribune, July 22 1965 Sabah State library.

Description of MMCM is as follows:

MODIFIED MERCALLI INTENSITY SCALE

	Intensity	Max. Acc. mm/s/s		Remarks
I.	Instrumental	less than	10	Not felt, except by very few under exceptionally favourable circumstances.
II.	Very feeble	over	10	Felt only by a few persons at rest especially on upper floors of buildings. Suspended objects may swing.
III.	Slight	over	25	Felt quite noticeably indoors, especially on upper floors, like passing of a truck. Standing motorcars may rock slightly.
IV.	Moderate	over	50	During day felt indoors, but some in many outdoors. At night some awakened. Dishes, windows, doors, loose objects disturbed. Standing motor cars rock noticeably.
V.	Rather strong	over	100	Felt by nearly everyone; many awakened. Some dishes, windows, etc. broken; unstable objects overturned. Church bells ring, pendulum clocks may stop.
VI.	Strong	over	250	Felt by all, some people frightened. Damage slight, some plaster cracked.
VII.	Very strong	over	500	Alarm general; damage negligible in buildings of sound construction. Felt by persons in moving cars.
VIII.	Destructive	over	1000	Chimneys fall; damage in substantial buildings. Persons driving motor cars disturbed.

(Continued)

	Intensity	Max. Acc.	mm/s/s	Remarks
IX.	Ruinous	over	2500	Great damage in substantial structures. Ground cracked, pipes broken.
X.	Disastrous	over	5000	Many buildings destroyed.
XI.	Very disastrous	over	7500	Few structures left standing; broad fissures in ground.
XII.	Catastrophic	over	9800	Total destruction. Waves seen on ground surface.

3.3 Evaluation on Seismic Coefficient

According to the Malaysian Meteological Service, it is stated that Sarawak was considered seismically stable, and that there were only few cases of slight tremors recorded in this state.

Two earthquake occurrences were reported at two towns in the coastal plain along the South China Sea as discussed in the preceding section, but no reports in inland area. For safety reason, it is prudent to assume that there is a possibility of earthquake occurrence in inland area.

Malaysian Meteological Service recommended that engineers and building planners in Sabah should take into account the earthquake risk factor in building design.

Although Sarawak is considered seismically stable, the seismic design coefficient of the Batang Ai rockfill type dam (1985) has adopted k = 0.05 g, while k = 0.15 g for the Bakun rockfill type dam.

In consideration of the site geology and scale of main structures as well as the past design in Sarawak, the proposed horizontal ground acceleration of 0.05 g for Medamit-2 project is considered to be conservative.

NOTE : 1/ Circum-Pacific Seismic Zone
PACIFIC SERIES, PROVINCE, or SUITE
One of two great groups of igneous rocks (along with the Atlantic group) based on their tectonic setting. Originally described as occurring on the margins of the pacific basin, hence the Circum-Pacific province. Characterized by the tholeiitic magma type, yeilding saturated or over-saturated resides. Seismic zone occurs along the above province.

CHAPTER 4. GEOLOGICAL INVESTIGATION

4.1 Core Drilling

Hole Location and Length

Totally 150.41 meters in length has been drilled at seven boreholes locations, out of which three holes are at the damsite, three holes along waterway and one hole at the powerhouse site.

The drilled length as well as the number of field permeability tests and points of the standard penetration test in a borehole is as follows:

Site	Core Drilling		S.P.T.[1/]	W.P.T.[2/]	Seismic P.[3/]	
	Holes	Length(m)	(points)	(Stages)	Lines	Length(m)
Damsite	3	64.35	8	8	2	442
Waterway[4/]	3	75.66	35	-	4	1035
Powerhouse	1	10.40	4	-	1	200
Total	7	150.41	47	8	7	1677

Notes ; 1 : S.P.T. = Standard Penetration Test
2 : W.P.T. = Water Pressure Test
3 : Seismic P. = Seismic Prospecting
4 : Including the surge tank site and penstock line

Drilling Operation

Core drilling was done by the contractor. They used one hydraulic feed rotary type drilling machine (Model : YBM-05) and drilled with a double tube core barrel.

Recovered core samples were arranged in a core box in order and stored in the warehouse of SESCO in Kuching.

Logging

Drill logs have been prepared by SESCO and compiled in Data Book.

In the drill log, ROD is measured, which is an index termed the Rock Quality Designation which is obtained by examining the core recovered from a borehole, discarding sections of core less than 10 centimeters long, and expressing the remainder as a percentage of the total core length drilled. RQD is mathematically expressed as follows:

$$RQD = \frac{\text{total length of cores longer than 10 cm}}{\text{total length drilled}} \times 100\%$$

RQD was examined every one meter in this survey, so that the above equation is modified as follows:

$$RQD = \frac{\text{total length of cores longer than 10 cm}}{\text{100 cm}} \times 100\%$$

4.2 Field Permeability Test

In-situ permeability was determined by the "water pressure test (or Lugeon Test)" for consolidated formation, in which a single rubber sleeve packer was suited to seal tightly.

Water Pressure Testing Method

For the water pressure test (or Lugeon test), a plug seal (rubber sleeve packer) was inserted at about 5 meters from the base of the hole and then water was applied under pressure through a pipe extending through the plug to the base of the hole. The flow of water was measured, at various pressures as discussed in the next paragraph. The permeability of the rock was assessed in both terms of Lugeon units and permeability coefficient. One Lugeon unit is defined as a flow of 1 liter per minute per linear-meter of hole at a standard applied pressure of 10 kg/cm^2; one Lugeon equals to about 10^{-5} cm/sec permeability coefficient , although the precise equivalence is dependent upon the diameter of test borehole and the depth to the water table. The Lugeon units and the permeability coefficient were calculated by the following equations:

Lugeon Units

$$Lu = \frac{Q}{L.P} \times 10$$

where, Lu : Lugeon units,
Q : the constant rate of flow into the hole (lit/min),
L : the length of test section (m),
P : the pumping pressure applied (kg/cm^2).

Permeability Coefficient

(From the packer test in "Earth Manual" USBR)

$$K = \frac{Q}{2.L.H} \times \log \frac{L}{r} \quad (cm/sec)$$

where, K : the permeability (cm/sec),
Q : the constant rate of flow into the hole (cm^3/sec),
L : the length of test section (cm),
H : the differential head of water, (gravity plus pressure) (cm),
r : the radius of hole tested (cm).

The testing pressure was applied changing in sevwn steps such as 1 kg/cm^2, 4 kg/cm^2, 7 kg/cm^2, 10kg/cm^2, 7 kg/cm^2, 4 kg/cm^2 and 1 kg/cm^2 in order at the top of injection pipe in principle. However, in the case that the injection water rate became very large beyond the pump capacity, the test was ceased at the maximum pressure obtained.

Permeability Test Result

The records of the test are shown in the Data Book. Determined permeability coefficients and Lugeon values are summarized in Fig. I-5.

4.3 Standard Penetration Test (SPT)

Purpose of SPT

SPT has been performed in order to obtain a record of the resistance of subsoils and the penetration strength of the Raymond sampler and to obtain disturbed samples of the soil for identification and testing purposes. The test and identification information are used to outline subsurface conditions with respect to bearing capacity for foundation design. The penetration resistance is expressed as the number of blows required to force that the sampler penetrates 30-centimeters into the soil.

Field Operation

After the drilling reached to the depth for testing, cuttings remained in the bottom of the hole were removed and the Raymond sampler connected with drill rod was inserted to the bottom of the hole. The apparatus consists of a 65 kg hammer with a tripping device that releases the hammer at a height of 76 cm. The falling energy is then transmitted via an anvil and drill rod to a standard spoon of 5.08 cm outer diameter and 3.49 cm inner diameter at the bottom of the cleaned-out borehole. The number of blows to penetrate 45 cm into the soil is recorded and the numbers of blow required to penetrate the final 30 cm is recorded as 'N' value of SPT (excluding first 15 cm seating drive).

N-values obtained

N-values obtained by SPT are shown in Fig. I-6.

4.4 Seismic prospecting

Profile Line Arrangement

According to the investigation plan, seismic refraction profile lines were arranged as shown in Fig. I-1. Profile length was 1,677 meters in total. Survey length was distributed as follows:

Site	Profile lines and length	Profile No.
Damsite	2 lines, 442 meters	A,C
Waterway (including penstock line)	4 lines, 1035 meters	B,D,F,G
Powerhouse site	1 line, 200 meters	E
Total	7 lines, 1677 meters	A to G

Field Operation

The arrangement of shots and detectors was planned to be laid out on a line (profile shooting). Before the field recording began, ground surface profiles were surveyed and shot and detector stations were marked by pegs.

In cycle of operation, the distance range was arranged in such a manner that five to seven shots of less than 50 meters intervals were picked up by 24 geophones which were spreaded at regular intervals of horizontal distance. The shot locations and geophone spreads of one operation cycle were moved progressively to give complete coverage over the refraction profile lines.

Main instruments and materials used are as follows:

Geophone

One unit of OYO MCSEIS 1500 24-CHANNEL SYSTEM comprising the following units;

- amplifier unit (TR-7)
- digital enchancement unit (MODEL 1197A)
- CRT display and printer unit (MODEL 1216A)
- disc recording and processing unit (MODEL 5744)
- 2 sets of 12-channel take-out geophone cables
- 28 units of 14 hz. geophones c/w spares
- 1 set of 200 m extension geophone cable

Seis-Gun

(1) Dimensions

- Full assembled length : 1.5 m
- Diameter of bore : 12 gauge

(2) Component parts

- T-handle with trigger connector to seismograph
- Firing piston shaft with control switch
- Extension shaft
- Firing pin double-ended connector
- Firing block and barrel

(3) Capacity

- Single shot of 12 gauge sheets
- Signal and energy level is dependent on shell type

Time-distance Plot and Profile Interpretation

Travel time of the seismic wave (primary wave) was read from recording paper to the accuracy of 1/1,000 second, and plotted on the time-distance graph. From this time-distance relation, the profile of velocity layers was deduced mainly by the Hagiwara's method. The time-distance curves and the profile interpretations are summarized in the Data Book.

CHAPTER 5. SITE GEOLOGY AND ASSESSMENT ON ENGINEERING GEOLOGY

Medamit-2 project consists of three Alternative plans; Alternative-1, Alternative-2 and Alternative-3.

The three Alternatives are making use of the same dam. The following describe the condition of foundation rock based on the interpretation and evaluation of the geological data.

5.1 Alternative-1 plan

Since the powerhouse is located just behind the dam at the right bank, geological assessment of powerhouse is discussed with the dam.

5.1.1 Damsite and powerhouse

The Medamit River bends sharply toward the west in the project area. Damsite is planned at the mouth of a gorge located 300 meters downstream from a bend, which is formed by easterly striking thin ridge, and where the Medamit River bends toward east-northeast direction.

The width of riverbed at the damsite is approximately 15 meters. The slope at the left abutment forms a cliff with a gradient of about 70 degree, however, the gradient above 20 meters from the riverbed is about 40 degree. On the other hand, right abutment has a gradient about 85 degree, however, the gradient above 6 meters from the riverbed is 20 to 40 degree, forming a thin ridge.

In the downstream reaches from the damsite, cliff is continously formed along the left bank of the river, but a gentle slope is formed on the right bank.

Three boreholes , named BMe-1, BMe-2 and BMe-4, were drilled at this site. BMe-1 and BMe-2 were drilled on the right bank of the dam axis and BMe-4 was drilled at the riverbed of left bank about 30 meters upstream from dam axis.

A summary of these drilling and field tests is as follows:

<u>BMe-1</u> : Vertical hole, 21.10 meters in length, right bank

0 to 1.60 meters	Top soil and residual soil of sandstone.
1.60 to 14.80 meters	Fine grained sandstone with laminated shale. Moderately weathered rocks. Upto 8.70 meters, open joints and oxidized joint plane are recognized. Core recovery : 100% RQD : 0 to 40% Ru-value : 5, 32.5

14.80 to 21.10 meters	Fine grained sandstone. Slightly weathered rocks. Cracky. No oxidized joint plane. Core recovery : 100% RQD : 15 TO 80% Ru-value : 11.7

<u>BMe-2</u> : Vertical hole, 20.95 meters in length, right bank

0 to 10.55 meters	Top soil, completely to moderately shale firm to hard, reddish yellow silty clay slit with fractured soft gravel. N-value : 3.6 above 3 meters in depth : over 50 below 3 to 10.55 meters in depth
10.55 to 18.50 meters	Shale Slightly weathered rocks. Cracky. Cleavage is well developed with sliken side upto 11.60 meters oxidized. Core recovery : 100% RQD : 0 to 30% Ru-value : 1
18.50 to 20.95 meters	Shale Fresh rocks. Hard, strong, sheared, to be broken easily along cleavage. Core recovery : 100% RQD : 0 to 30% Ru-value : 2.4

<u>BMe-4</u> : Vertical hole, 22.30 meters in length, riverbed

0 to 8.50 meters	Sandstone intercalated with thin beds of shale. Dipping of 5 to 15 degree. Slightly weathered rocks. Low dipping joints are well developed. Oxidized up to 3 meters in depth. Core recovery : 100% RQD : 0 to 90% Ru-value : 0.6
8.50 to 22.30 meters	Sandstone intercalated with thin beds of shale. Slightly weathered to fresh rocks. Core recovery : 100% RQD : 10 to 95% Ru-value : 3.2, 8.2

According to results of seismic prospecting (MEA line), the geology of the damsite can be classified into four layers by its velocity as shown below:

MeA Line : Left bank and riverbed

1st layer	250 m/s	(1.5 to 2.0 m in thickness)
2nd layer	500 to 600 m/s	(5 to 10 m in thickness)
3rd layer	1,200 to 1,400 m/s	(7 to 13 m in thickness)
4th layer	2,400 m/s	

Judging from these seismic velocities of MeA line carried out on the left bank along the dam axis, first layer is corresponding to top soil and soft residual soil, second layer is highly weathered rock having soil along fissures, third layer is hard and cracky sandstone and fourth layer is very hard rocks forming faults and flat-lying vertical joints.

The results of seismic prospecting for MeA line carried out on the right bank can be classified into four layers by its velocity as shown below:

1st layer	250 m/s	(less than 1 m in thickness)
2nd layer	500 to 600 m/s	(2 to 4 m in thickness)
3rd layer	1,100 to 1,500 m/s	(5 to 6 m in thickness)
4th layer	3,300 to 3,600 m/s	

Judging from these seismic velocities, first layer is thought to correspond to top soil, second layer is highly weathered sandstone having soil along joints or highly to moderately weathered shale clayey rock, third layer is cracky sandstone and shale and fourth layer is slightly weathered to fresh sandstone recognized oxidization along joints or tight shale.

Geology of the damsite consists of sandstone intercalated with thin beds of shale from left abutment to right abutment below elevation 135 meters near the riverbed, while the area above elevation 135 meters of right abutment is underlain by shale. Boundary of the sandstone and shale in the area is the fault contact between sandstone and shale. The faulting plane about 1 to 2 centimeters wide, dipping 75 degrees towards the upstream reaches of right bank. Small scale faults were discovered in both banks (see Fig. I-7, Geological Profile of Dam Axis).

The sandstone dips 30 to 40 degrees towards downstream reaches of right bank and the shale strikes to the northeast direction, and dips 30 to 40 degrees towards the upstream reaches of the right bank because of the bend of the river.

The sandstone intercalated with thin beds of shale is massive, hard and jointy. The cleavages in shale are commonly slickensided, fresh and hard.

Joints in the sandstone consist of many vertical or flat-lying ones dipped with 25 to 40 degree towards downstream reaches with few millimeters to 2 centimeters opening. Spaces of flat-lying joints are in the range of 15 to 25 and 25 to 40 centimeters, while vertical joints are in the range of 30 to 70 centimeters. In general, flat-lying joints are well developed in the left bank side than the right bank.

Foundation rock of the damsite based on these matters, consists of sandstone intercalated with thin beds of shale. It will be adequate as foundation of dam. However, sandstone has flat-lying joints dipping downstream, the nature and distribution of which are still unknown. It can , however, be said that those zones have high permeability. Further survey to confirm the permeability and stability of the dam will be needed in the detailed design stage.

Powerhouse with 30 meters in width and about 100 meters in length is planned on the gentle slope of right bank along the Medamit River. The slope is commonly covered with terrace and slope wash deposits. The thickness of terrace and slope wash deposit is unknown. However, total thickness of these deposits at the proposed powerhouse site is in the range of 5 to 6 meters, estimated from the topographic map and observation of outcrops along the river. Therefore, the sandstone and shale at the site are estimated adequate for the foundation of the powerhouse.

5.2 Alternative-2 plan

Powerhouse of this Alternative plan is located on the left bank of about 850 meters downstream side from the damsite along the river. Geology of damsite is described in the preceding Section, 5.1.1 Damsite.

5.2.1 Waterway

Waterway consists of intake, headrace tunnel and penstock line.

(1) Intake

Intake is located at the left bank of immediately upstream side of the dam. Geology of the intake area is underlain by sandstone intercalated with thin beds of shale. From the field investigation results, the sandstone will have no serious problem for the foundation rock of intake structure.

(2) Headrace tunnel

Headrace tunnel is about 380 meters long from the intake (EL.123 m) to surge tank which is located on the slope of left bank. This tunnel changes its direction from north-south to northeast-southwest at about 120 meters from the intake. Thickness of rock mass covering the tunnel is estimated at about 110 meters at the top of ridge from the map of scale 1:5,000.

Geology of the section from intake to 50 meters of the tunnel is sandstone intercalated with thin beds of shale and the remaining place is underlain by shale.

The tunnel would pass through two faults : One of them is a small scale fault, forming a boundary between sandstone and shale. The other is cutting the sandstone unit, striking northwestly. The latter is observed to have few meters in width from the outcrop at the logging road near the damsite, which runs in parallel to or at the acute angle to the tunnel where shale is distributed. It is found that the shale is fractured. It is highly possible that water will appear inside the tunnel of sandstone area during construction.

(3) Surge tank and penstock line

Surge tank and penstock line will be placed on the slope with a gradient of 30 degree. Geology of the surge tank and penstock line is shale which is similar to that of tunnel.

Weathered zone of shale would be thick because of weathering and faulting. Foundation of surge tank and anchor blocks would base on the weathered shale zone and moderately weathered shale zone, respectively.

5.2.2 Powerhouse

Powerhouse is located on the riverside of the left bank. Geology at the powerhouse site is shale which is similar to that of tunnel. Foundation of the powerhouse site would be based on the moderately weathered shale.

5.3 Alternative-3 plan

Powerhouse of the Alternative-3 plan is located on the right bank of the Limbang River. Geology of damsite is described in the preceding Section, 5.1.1 damsite.

5.3.1 Waterway

Waterway consists of intake, headrace tunnel and penstock line. Geology of the intake is sandstone which is similar to that of damsite.

(1) Headrace tunnel

Headrace is about 4.5 kilometers long from portal of tunnel (EL.123 m) to surge tank (EL.118.5 m) at the right bank of the Limbang River. The tunnel changes its course from north-south to northeast-southwest at about 220 meters from the intake. This tunnel will pass through valleys and streams. Rock mass covering the tunnel is estimated in the range of 100 to 300 meters in thickness from the map of 1:5,000 scale.

According to the results of geological reconnaissance, mountains are covered with vegetation, however, highly weathered shale, sandstone and some minor faults are exposed along logging road and high elevation area.

Geology along the tunnel consists of sandstone and shale (see Fig. I-8 Geological Profile along the Headrace). The section from intake to 50 meters in tunnel consists of sandstone intercalated with thin shales. The remaining part consists of shale interbedded with two units of sandstone bed. These rocks along the tunnel except sandstone near the damsite will be hard and tight due to the fresh rock cover of 100 to 300 meter above the tunnel. However, sandstone near the damsite, section from the intake to 50 meters in the tunnel, forms the fractured zones. Furthermore, the displacement of the sandstone is caused by one of the main faults at the point of about 110 meters from the intake. Therefore, there is a possibility to meet groundwater during construction.

(2) Surge tank and penstock

Surge tank and penstock are planned on the mountain slope located at the right bank of the Limbang River.

Surge tank is located on the small ridge of elevation 160 meters and penstock line is located on the slope with a gradient of 30 to 40 degree from the surge tank to alluvial terrace.

Two boreholes, BMe-5 and BMk-6, were drilled at the surge tank and penstock line. A summary of these drilling and field tests is as follows:

<u>BMe-5</u> : Vertical hole, 30 meters in length, surge tank

0 to 22.5 meters	Top soil and residual soil of weathered shale. Stiff to very stiff clayey silt. N-value : 9 to 27
22.5 to 25.8 meters	Highly weathered sandy silt. Hard. N-value : over 50

25.8 to 30 meters	Slightly weathered fresh shale. Cracky. Bedding 45 degree. Core recovery : 100% RQD : 30 to 40%

<u>BMe-6</u> : Vertical hole, 20.3 meters in length, penstock line

0 to 14 meters	Top soil and residual soil of weathered shale. Very stiff clayey silt with lateritic gravels. N-value : 26 to 39
14 to 20.30 meters	Highly weathered shale. Clayey silt with lateritic gravels. N-value : over 50

According to results of seismic prospecting, the geology of this site can be classified into four layers by its velocity as shown below:

1st layer	250 m/s	(0.5 to 2 meters in thickness)
2nd layer	500, 600 m/s	(2 to 8 meters in thickness)
3rd layer	1,000, 1,300 m/s	(4 to 12 meters in thickness)
4th layer	3,500 to 3,700 m/s	

Note : Low velocity of 1,600 m/s, 70 meters wide, is recognized in the central part of penstock.

Judging from three seismic velocities of MEF line, first layer is corresponding to top soil, second layer is completely weathered shale and residual soil, third layer is highly weathered shale and the fourth layer is moderately to slightly weathered or even fresh shale. Low velocity layer is due to unconformity, sheared zone and soluble cavities near the uncomformity.

Foundation rock at the surge tank and penstock line area is underlain by shale and limestone having the uncomformity and sheared zone between them (see Fig I-9 Geological Profile from Surge Tank to Powerhouse). These structure site is covered with highly weathered lateritic hard clayey to soft shale and limestone extending 10 to 20 meters in thickness. Foundation of the surge tank is expected to base on the slightly weathered to fresh shale, while anchor blocks of penstock line would be based on the soft shale, over 50 blows in N-value of SPT test.

5.3.2 Powerhouse

Powerhouse is located on an alluvial terrace at the right bank of the Limbang River.

Core drilling of one borehole (BMe-7) and seismic prospecting at two lines, MEF and MEG, were performed at the powerhouse site. A summary of this borehole and field tests are as follows:

<u>BMe-7</u> : Vertical hole, 10.4 meters in length

0 to 6 meters	Terrace deposit including top soil. Clayey fine sand, very loose. N-value : 1 to 4
6 to 7.15 meters	Terrace deposit Sand, gravel and boulders N-value : over 50
7.15 to 10.4 meters	Limestone Slightly weathered rock, hard. Leakage along fissures Core recovery : 100% RQD : 65 - 90% Lu-value : 37.9

According to results of seismic prospecting, the geology of the powerhouse can be classified into four layers by its velocity as follows:

<u>MEG line</u> : Along the Limbang River

1st layer	250 m/s	(1 to 2 meters in thickness)
2nd layer	600 m/s	(4 to 7 meters in thickness)
3rd layer	1,300 m/s	(10 to 15 meters in thickness)
4th layer	3,500 m/s	

From the four seismic velocities of MEG line, first layer is corresponding to top soil or residual soils. Second layer are the slope wash and terrace deposits and completely weather rock. Third layer is the terrace deposit and limestone with cavities along joints, and fourth layer is slightly weathered to fresh limestone.

Geology of the powerhouse site is underlain by limestone covered with terrace deposit of about 7 meters in thickness. The deposit consisted of silty-fine sand and gravels is exposed in terrace scarp along the river, furthermore, two springs were found at the scarp during field investigation.

The values of standard penetration test at terrace deposits showing over 50 blows in N-value at 6 meters in depth is an excessive value because of hitting on a boulder.

The result of water pressure test in limestone does not indicate any problem on bearing force, even if it has a high permeability. Thus, limestone at the powerhouse site is adequate as the foundation rock by removing terrace deposits.

CHAPTER 6. RECOMMENDATION FOR FURTHER WORK

The following are the recommendations for the foundation rock of Alternative-3 plan based on the interpretations and evaluations of the geological data obtained.

(1) Sandstone intercalated with thin beds of shales is known to have enough bearing force to construct the concrete dam. However, flat-lying joints dipping downstream in the rock mass of sandstone are developed. Furthermore, the sandstone has permeability of 1 to 32.5 Lugeons, while shale has 1 to 2.4 Lugeons.

Reinforcement such as grouting and rock bolts to lower permeability and to increase shearing force would be required when the dam is built. However, it is still unknown where zones of high permeability extend. It is therefore recommended that the stability and permeability condition of the area are confirmed during the detailed design stage.

(2) The surge tank and penstock line site are covered with highly weathered lateritic hard clayey to soft shale and limestone, extending 10 to 20 meters thick. Foundation of surge tank is expected to base on the slightly weathered to fresh shale, while anchor blocks of penstock line are based on the soft shale, over 50 blows in N-value.

It is recommended that more detailed field investigation to confirm the modulus of elasticity and deformation by means of Borehole Jack Test and so on should be carried out during the detailed design stage.

(3) The material for concrete aggregates will be obtained from a quarry. The potential site used as the quarry is sandstone area formed a protrusion at about 100 meters downstream side from the dam axis on the left bank of the Medamit River. It is recommended that more detailed field investigation is carried out by drillings and seismic prospecting to confirm the condition of the sandstone.

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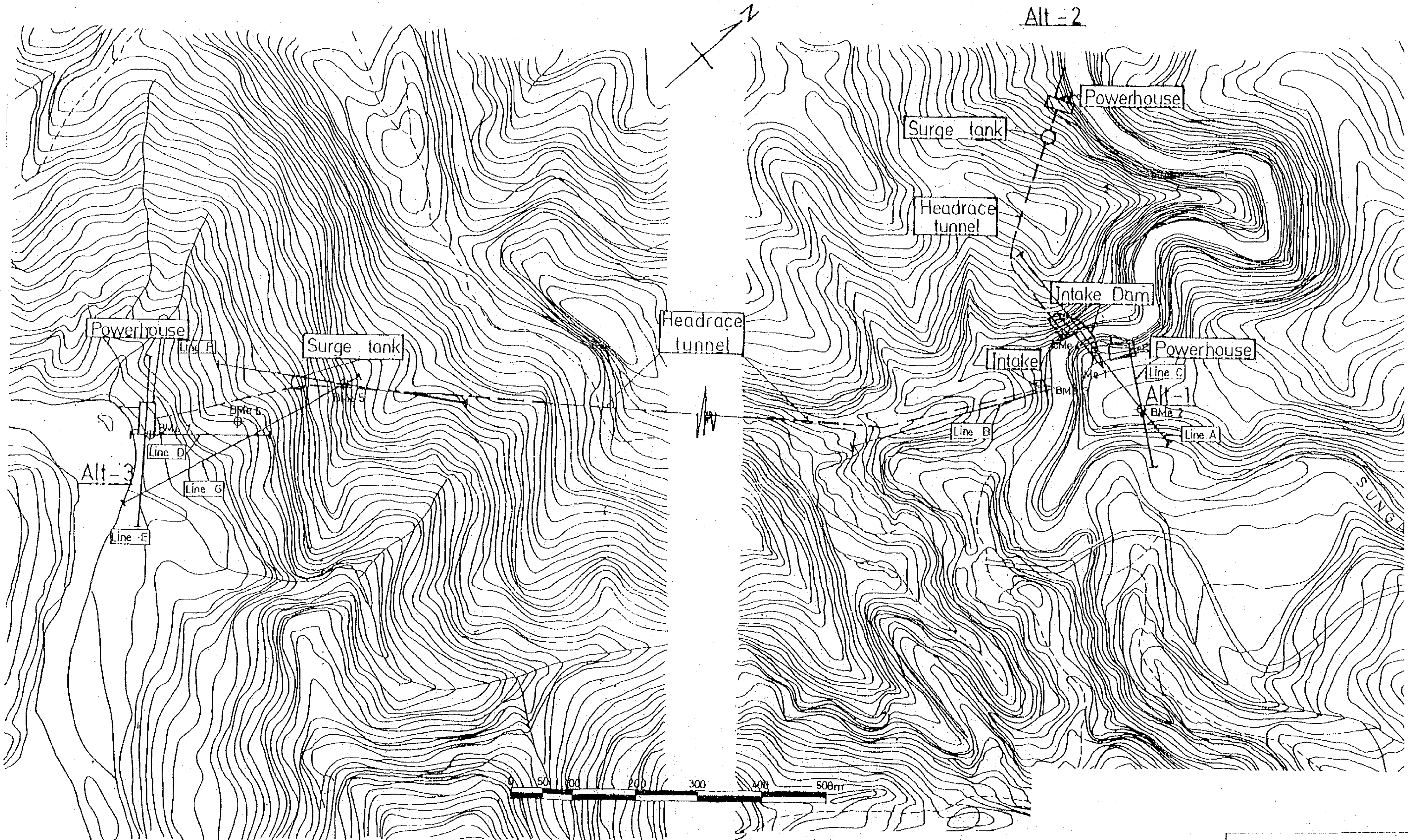

Fig. I-1 Location Map of Geotechnical Investigation

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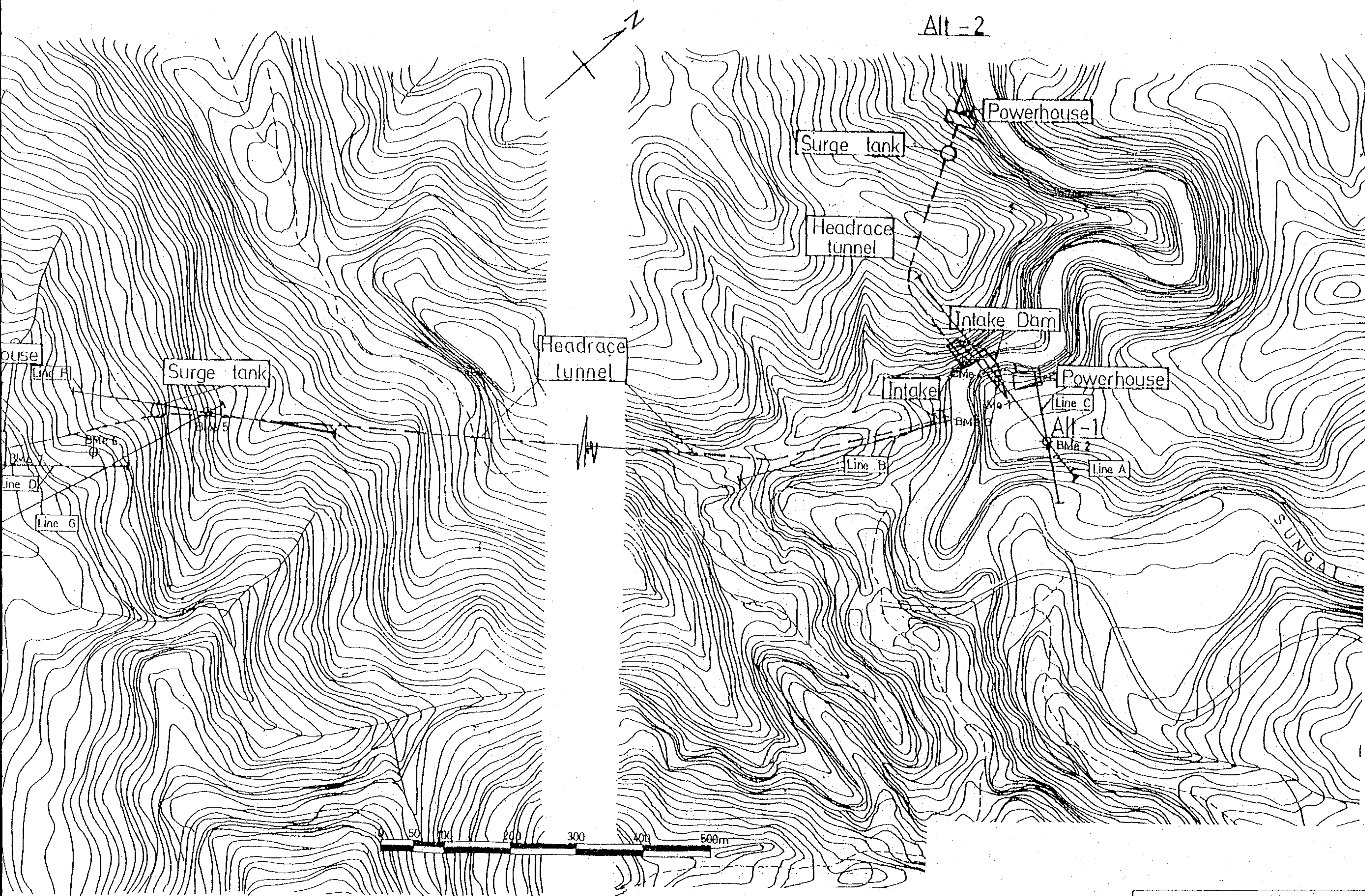

Fig. I-1 Location Map of Geotechnical Investigation

GOVERNMENT OF MALAYSIA
FEASIBILITY STUDY
SMALL SCALE HYDROELECTRIC POWER PROJECT IN SARAWAK
JAPAN INTERNATIONAL COOPERATION AGENCY