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No. 7

GOVERNMENT OF MALAYSIA

[illegible] STUDY, MALAYSIA

[illegible] SOUTH JOHOR

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA

REGIONAL WATER RESOURCES STUDY OF SOUTH JOHOR

VOL. 6

ANNEX

H. ENGINEERING GEOLOGY

I. CONSTRUCTION MATERIAL

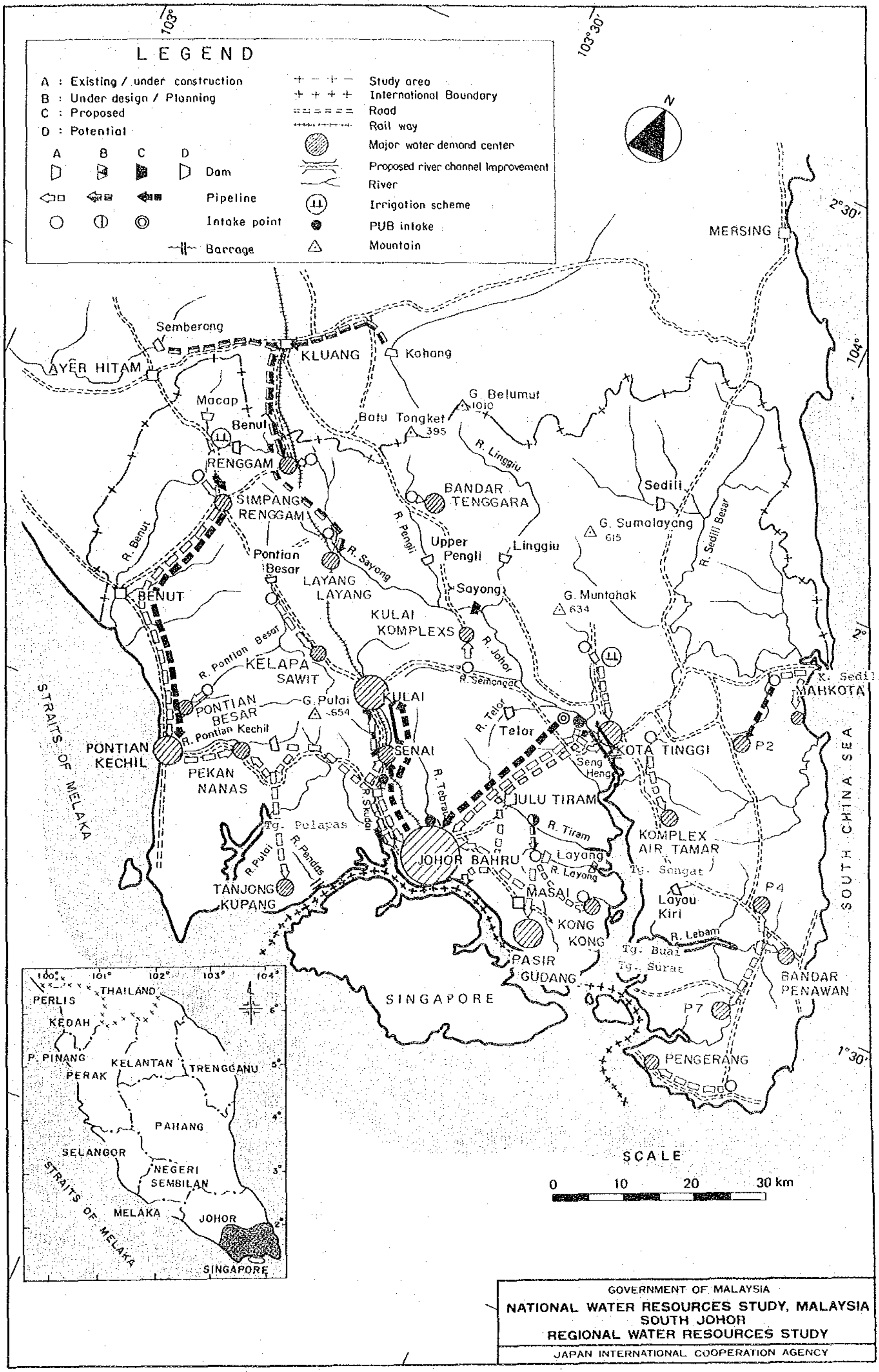
DECEMBER 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

NATIONAL WATER RESOURCES STUDY, MALAYSIA

REGIONAL WATER RESOURCES STUDY OF SOUTH JOHOR

LIST OF VOLUMES


LEGEND
A : Existing / under construction
B : Under design / Planning
C : Proposed
D : Potential
A B C D
Dam
Pipeline
Intake point
Barrage
Study area
International Boundary
Road
Rail way
Major water demand center
Proposed river channel Improvement
River
Irrigation scheme
PUB intake
Mountain
N
103°
103°30'
104°
2°30'
2°
1°30'
MERSING
Semberong
AYER HITAM
KLUANG
Kahang
Macap
Benut
G. Belumut 1010
Batu Tongket 395
RENGGAM
SIMPANG RENGGAM
BANDAR TENGGARA
Sedili
G. Sumalayang 615
R. Linggiu
R. Sedili Besar
R. Benut
R. Pengli
Upper Pengli
Linggiu
Pontian Besar
LAYANG LAYANG
R. Sayong
Sayong
G. Muntahak 634
BENUT
KULAI KOMPLEXS
R. Johor
R. Pontian Besar
KELAPA SAWIT
KULAI
R. Semanggar
K. Sedili
MAHKOTA
G. Pulai 654
PONTIAN BESAR
R. Pontian Kechil
R. Telor
Telor
PONTIAN KECHIL
SENAI
KOTA TINGGI
P2
Seng Heng
PEKAN NANAS
R. Tebrau
JULU TIRAM
R. Skudai
Tg. Pelapas
R. Tiram
KOMPLEX AIR TAMAR
R. Pulai
R. Pandas
JOHOR BAHRU
Layang
R. Layang
Tg. Sengat
TANJONG KUPANG
MASAI
Layau Kiri
P4
KONG KONG
R. Lebam
Tg. Buai
Tg. Surat
PASIR GUDANG
BANDAR PENAWAN
SINGAPORE
P7
PENGERANG
STRAITS OF MELAKA
SOUTH CHINA SEA
SCALE
0 10 20 30 km
100° 101° 102° 103° 104°
6° 5° 4° 3° 2°
THAILAND
PERLIS
KEDAH
P. PINANG
KELANTAN
TRENGGANU
PERAK
PAHANG
SELANGOR
NEGERI SEMBILAN
MELAKA
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STRAITS OF MELAKA
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NATIONAL WATER RESOURCES STUDY, MALAYSIA
SOUTH JOHOR
REGIONAL WATER RESOURCES STUDY
JAPAN INTERNATIONAL COOPERATION AGENCY

ABBREVIATIONS

(1) Oreganization/Plan

4MP (5MP)	:	Fourth (Fifth) Malaysia Plan
DID (JPT)	:	Drainage and Irrigation Department
DOA	:	Department of Agriculture
DOE	:	Department of Environment
EPU	:	Economic Planning Unit
FELCRA	:	Federal Land Consolidation and Rehabilitation Authority
FELDA	:	Federal Land Development Authority
GSD	:	Geological Survey Department
JICA	:	Japan International Cooperation Agency
KEJORA	:	Lembaga Kemajuan Johor Tenggara
MOA	:	Ministry of Agriculture
MOH	:	Ministry of Health
MTR	:	Mid-Term Review of 4MP
NEB	:	National Electricity Board
NWRS	:	National Water Resources Study
PUB	:	Public Utility Board (Singapore)
PWD (JKR)	:	Public Works Department
RESP	:	Rural Environmental Sanitation Program
RISDA	:	Rubber Industry Smallholders Development Authority
WHO	:	World Health Organization

(2) Others

B	:	Benefit
BOD	:	Biochemical Oxygen Demand
C	:	Cost
COD	:	Chemical Oxygen Demand
D & I	:	Domestic and Industrial
dia.	:	Diameter
DRC	:	Dry Rubber Content
EIRR	:	Economic Internal Rate of Return
EL.	:	Elevation Above Mean Sea Level
Eq.	:	Equation
FFB	:	Fresh Fruit Bunch
Fig.	:	Figure
GDP	:	Gross Domestic Project
GNP	:	Gross National Product
GRP	:	Gross Regional Project
HWL	:	Normal High Water Level
O & M	:	Operation and Maintenance
Q	:	Discharge
Ref.	:	Reference
SS	:	Suspended Solid
VA	:	Value Added

ABBREVIATIONS OF MEASUREMENT

Length

mm = millimeter
cm = centimeter
m = meter
km = kilometer
ft = foot

Area

cm^2 = square centimeter
m^2 = square meter
ha = hectare
km^2 = square kilometer

Volume

cm^3 = cubic centimeter
l = lit = liter
kl = kiloliter
m^3 = cubic meter

Weight

mg = milligram
g = gram
kg = kilogram
ton = metric ton

Time

s = second
min = minute
h = hour
d = day
y = year

Other Measures

% = percent
° = degree
' = minute
" = second
°C = degree in centigrade
10^3 = thousand
10^6 = million

Derived Measures

m^3/s = cubic meter per second
Mgd = million gallon per day
Mld = million litre per day

Money

M$ = Malaysian Ringgit
M¢ = Malaysian Cent

CONVERSION FACTORS

	From Metric System	To Metric System
Length	1 cm = 0.394 inch 1 m = 3.28 ft = 1.094 yd 1 km = 0.621 mile	1 inch = 2.54 cm 1 ft = 30.48 cm 1 yd = 91.44 cm 1 mile = 1.609 km
Area	1 cm^2 = 0.155 sq.in 1 m^2 = 10.76 sq.ft 1 ha = 2.471 acres 1 km^2 = 0.386 sq.mile	1 sq.ft = 0.0929 m^2 1 sq.yd = 0.835 m^2 1 acre = 0.4047 ha 1 sq.mile = 2.59 km^2
Volume	1 cm^3 = 0.0610 cu.in 1 lit = 0.220 gal.(imp.) 1 kl = 6.29 barrels 1 m^3 = 35.3 cu.ft 10^6 m^3 = 811 acre-ft	1 cu.ft = 28.32 lit 1 cu.yd = 0.765 m^3 1 gal.(imp.) = 4.55 lit 1 gal.(US) = 3.79 lit 1 acre-ft = 1,233.5 m^3
Weight	1 g = 0.0353 ounce 1 kg = 2.20 lb 1 ton = 0.984 long ton = 1.102 short ton	1 ounce = 28.35 g 1 lb = 0.4536 kg 1 long ton = 1.016 ton 1 short ton = 0.907 ton
Energy	1 kWh = 3,413 BTU	1 BTU = 0.293 Wh
Temperature	°C = (°F − 32)·5/9	°F = 1.8°C + 32
Derived Measures	1 m^3/s = 35.3 cusec 1 kg/cm^2 = 14.2 psi 1 ton/ha = 891 lb/acre 10^6 m^3 = 810.7 acre-ft 1 m^3/s = 19.0 mgd	1 cusec = 0.0283 m^3/s 1 psi = 0.703 kg/cm^2 1 lb/acre = 1.12 kg/ha 1 acre-ft = 1,233.5 m^3 1 mgd = 0.0526 m^3/s
Local Measures	1 lit = 0.220 gantang 1 kg = 1.65 kati 1 ton = 16.5 pikul	1 gantang = 4.55 lit 1 kati = 0.606 kg 1 pikul = 60.6 kg

Exchange Rate

(1985)

US$1 = M$2.41
¥100 = M$0.980

ANNEX H
ENGINEERING GEOLOGY

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1. INTRODUCTION

This study was performed as a part of the Regional Water Resources Study of South Johor for the purpose of obtaining the geological data for planning and preliminary design of dams and clarifying the geotechnical problems of the proposed damsites.

A geological investigation for this study was carried out in two stages. The first stage took 45 days between August and September 1984, when the following eight possible damsites were identified.

Benut site on the Benut river
Pontian Besar site on the Pontian Besar river
Linggiu, Sayong, Pengli, Telor and Layau Kiri sites in the Johor river basin
Sedili site on the Sedili Besar river

In the first stage surface geological investigation was carried out at the eight possible damsites and also the existing geological data were collected and studied for the Region including the possible reservoir area.

As the results of the above study, three damsites of Linggiu, Sayong and Sedili were given priority for further study not only from geological and topographical viewpoints but also from other study results. The drilling work to get the detailed geological data was planned for these three damsites.

The second stage investigation consisted mainly of the driling works of 11 holes and 426.5 m in total length financed by the Government of Malaysia. Summary of drilling work quantity is shown in Table 1.

This ANNEX reports the results of the geological study based on the data obtained in the first stage and the drilling results of the second stage.

2. REGIONAL GEOLOGY

2.1 Topography

The South Johor Region is located in the southernmost part of the Peninsular Malaysia. In this region the cordillera of the peninsula decreases its height gradually from northwest to southeast. Northeastern part of the Region is mountainous but south western part of the Region is flat with low hills.

The highest peak in the Region is G. Belmut (EL. 1009 m) in the northern mountainous area, where exist also the ridges ranging from 300 m to 600 m in altitude such as Bt. Jengeli, G. Sumalayang and Muntahak, etc. Chain of these mountains trend in the northwesternly direction, which are an extension of the G. Tahan Range in the central part of Peninsular Malaysia. On the other hand, the hills occupying the southern reaches hardly exceed 150 m to 200 m except G. Pulai (EL. 654 m). The high peaks such as G. Belumut and G. Pulai in the region are composed mainly of granite or adamellite with volcanic rocks.

In terms of river system, the South Johor Region is classified into four basins, they are, from west to east:

Benut Pontian basin containing the Benut and Pontian Besar rivers
Skudai basin containing the Pulai, Skudai and Tebrau reivers
Johor basin containing the Johor river and its tributaries
Sayong, Linggiu, Pengli, Semangar and Telor rivers etc
Layang, Tiram, Layau Kiri, Lebam rivers
Sedili basin containing the Sedili Besar river

Benut Pontian basin is located in the western part of the Region, and occupies the area in the west side of national railway linking Johor Bahru and Kluang. The rivers flowing southwestward in this basin empty into the Straits of Melaka. The basin is featured by low hills ranging from EL. 50 m to EL. 150 m composed of Jurassic to Triassic sedimentary rocks. Those hills are widely cultivated for oil palm and rubber fields. The middle to lower reacheds of the rivers are characterized by extensive swamp zone of 10 km to 20 km in width, which is developed on the alluvial deposit. The swamp area is generally not in high degree. It is utilized only partly for paddy and vegetable field where the drainage work has been completed.

The Skudai basin is located to the southeast of Benut Pontian basin. The river flows southward and empty into the Strait of Johor. Topography of the catchment area of this basin is characterized also by low mountains and hills, of which the ground height is ranging from EL. 50 m to EL. 100 m in the upper to middle reaches. The lower reaches of this basin where is a commercial and political center of Johor State forms widely developed terrace of 10 to 20 m in altitude and narrow belts of alluvial plains along the rivers.

The Johor basin occupying the central part of the Region contains the Johor river which flows south-southeast or southeast and empties itself the Strait of Johor. The northern area in the uppermost reaches of the Johor river is inflicted by many fauls trending northwest to southeast or north to south and right angle to them. These faults stretch to the lower reaches of the basin under thick surface deposits. Land use in this basin are mainly for oil palm and rubber plantation, especially at the middle reaches where undulating hills of 100 m to 200 m in altitude are developed.

The Sedili basin is located in the eastern part of the Region. The upper reaches are wholly in the mountainous zone ranging 300 m to 500 m in altitude and covered by jungle. Meandaring rivers in the middle reaches form moderately wide flood plains which are cultivated wholly for oil palm fields. Running through the coastal alluvial plain, the Sedili river empties finally into the South China Sea. Rock outcrops are scattered along the east coast line.

2.2 Geology

Geology of the Region is shown in Fig. 1 and Fig. 2 shows geological sequence. Outline of the geology is described as follows:

Permian meta-sedimentary rocks of Mersing Group which develops in the middle to eastern part of the region are mainly composed of phyllite and small scaled meta-quartzite, meta-siltstone, hornfels and slate.

Predominantly arenaceous and argillaceous meta-sedimentary rocks of marine origin associated with volcanic facies of Jurassic to Triassic Gemas formation are distributed in a belt of 5 km to 10 km in width extending from northern part of Ayer Hitam to the rivermouth of Pulai river.

Small scale patches of Mesozoic sedimentary rocks of Triassic Jurong Formation and Cretaceous Tebak Formation are distributed sporadically in the Johor and Skudai basin.

Small scale patches of Tertiary to Quarternary deposits of Layang-Layang Formation comprises semi-consolidated sand and clay.

In the vicinity of the Johor Bahru and Kota Tinggi, Quarternary Terrace deposits named Simpang Formation is developed in the low land and hilly area, covering the bed rocks of granite.

Alluvial deposits form an extensive plain with the width of some 20 km along the west coast. On the east coast, the alluvial plains are smaller and rather local. The river alluvial deposits fill the bottom of valleys and form wide flood plains in the middle to lower reaches of the rivers.

In the central part of the Region, there exists massive and widespread intrusive granite partly including adamellite. It is composed of coarse-grained quartz, feldspar, hornblend and biotite. Age of the granite intrusion varies from Permian to Tertiary.

Pre-granite basic rocks, consisting mainly of gabbro, occur in a part of the Skudai basin.

General trend of geological structure of Peninsula Malaysia veers in this region from north-northwesterly direction to north-westernly direction as shown in Fig. 1. The direction is controlled by the trend of old geosynclines.

Soils strongly laterilized occur generally in the low lands and undulating hills. Light reddish arkose soils including quartz grains are widely developed in the areas.

The alluvium contains sedimentary deposits of tin which originated in cassiterite included in the granites. Such sedimentary deposits are commonly distributed in the upper reaches of the Johor river and the Sedili river, which are situated among a granite area.

3. SITE GEOLOGY

3.1 Benut Dam and Reservoir Area

The proposed Benut damsite is located in the uppermost reaches of the Benut river and approximately 5 km upstream of the confluence of the Machap river, a left side tributary. The damsite is accessible by jeepable through a plantation road branching from the principal road between Simpang Rengam and Ayer Hitam.

The catchment area of the proposed dam is surrounded by the watershed of the Johor river and the Semberong river. Low hilly terrain with peakes at EL. 120 m to 150 m develops in the area. Chain of those peaks shows NW-SE trend reflecting the orientation of the regional geological structure. Oil palm fields are extensively developed in the catchment area.

The proposed reservoir area is geologically composed of Upper Triassic Blumut Granites in the northeast and sedimentary rocks of Upper to Middle Triassic Gemas Formation in the southwest.

The Benut river flows through a flat wide valley. Though the damsite was selected at the narrowest part of the valey, yet the inclination of the abutment slope is only 2 to 3 degrees from the horizontal on the left and 4 to 5 degrees on the right. Both the abutments are situated among rubber and oil palm plantations and easy to approach through unpaved roads.

Sedimentary rocks of Gemas Formation in the damsite are composed mainly of shale and sandstone, striking NW-SE and dipping 30 degrees to SW. Located at the distance of about 1 km from the contact zone with the Blumut granite, the Gemas Formation in the damsite does not seem to be seriously metamorphosed or schistose. There is no evidence of major faults causing serious problems upon the proposed dam plan. However, it should be confirmed in due course by means of core drilling and seismic exploration, as the bedrocks are widely covered by thick top soil and residual soil. The geological map of the proposed reservoir area is shown in Plate 1.

For the lack of appropriate rock material within a reasonable distance, earthfill type is recommended for the dam. Excavation of cut-off-trench for the earthfill dam will have to be extended to an approximate depth of 10 m below the ground surface, as roughly estimated from the thick weathering.

It seems preferable to lay out the intakes facilities for water supply on the right bank where the slope is steeper and the bedrock could be shallower than on the left bank.

The diversion waterway shall be designed in the type of open channel to meet the flat topography. The right bank is again more favourable for its layout to minimize its length due to the form of river course.

Permeability of the fresh bedrock is inferred to be for the most part within the range of 1 x 10^{-4} cm/sec or less. Grout curtain will be required up to the depth of some 15 m to 20 m from the bottom of the cut-off trench.

The area on the left side of the reservoir is expected for earth borrow for the embankment material. Detailed investigation should be conducted in the future.

3.2 Pontian Besar Dam and Reservoir Area

The proposed Pontian Besar damsite is located at the crossing of the Pontian Besar river and the principal road linking Ayer Hitam with Kulai.

The damsite is situated in the uppermost reaches of the Pontian Besar river which has about 35 km long river course. Low hills with ground height of EL. 30 m to 61 m develops in the catchment area of the proposed dam. There are no conspicuous peaks.

Small-scale plantations of rubber, coffee, pepper and oil palm are developed in the area. Private blick factories are scattered along the highway, collecting residual soil in the reservoir area for material of the blicks.

Bedrock of the reservoir area is mainly shale and sandstone of the Gemas Formation. The Blumut granite is distributed in the northeastern parts. The Gemas Formation is metamorphosed in parts along the contact with the intrusive granite.

While bedrocks are not cropped out in the damsite, covered by thick residual soil, they are deemed to consist of shale and sandstone of the Gemas Formation as judged from reddish to brownish colored cohesive soil of the residual soil. According to the regional geological map by Geological Survey, Malaysia, the trend of bedding in this area is NNW-SSE in strike and 30° to 50° SW in dip, that is approximately right angle with the dam axis. The geological map of the proposed reservoir area is shown in Plate 2.

Without good rock quarry site within a reasonable hauling distance, it is deemed economical to select a earthfill type for the dam. In the case of earthfill dam, it is recommendable to lay out the spillway on the right bank for the topographic reason.

A saddle dam will be necessitated at the head of a small tributary on the right side immediately upstream of the damsite.

Intensive weathering seems to develop up to the depths around 10 m. Cut-off trenches for the main dam and the saddles dam will accordingly have to be sunk to that depth. Further, the main dam will require curtain grouting from the bottom of the cut-off trench, of which depth shall be determined based on the results of detailed subsurface investigations in the future.

It seems that the thick residual soil on the left side of the reservoir provides good earth material for the dam embankment, which should also be a subject of the future investigations.

No sign of landslide was found out in the proposed reservoir area.

3.3 Linggiu Dam and Reservoir Area

Linggiu damsite and its reservoir area are located in the middle to lower reaches of the Linggiu river, which is confluent with the Johor river in its middle reaches at about 10 km downstream from the damsite. The Linggiu river flows southward through mountainous area in the northern part of the Johor river basin.

The reservoir area is wholly covered by jungle, where a logging project by KEJORA is under way. As the logging scheme is supposed to complete by 1990, the Linggiu dam project would not conflict with the KEJORA scheme. There exists a tin mine in small scale operated in the reservoir area.

The damsite and reservoir area is easy to access through a road constructed by the logging project on the left side of the Linggiu river. Both abutments on the dam axis form moderately steep slope, 17 degrees on the left abutment and 11 degrees on the right, which offers a favourable topography for dam construction.

Base rocks in the damsite and reservoir area consist mainly of sandstone and other kinds of sedimentary rocks, pyroclastics and lava, which belong to Upper Permian age.

Since there are five streaks of faults striking N-S and NW-SE in the reservoir and its vicinity, geology in the reservoir area and its vicinity is fractured and highly permeable.

It is inferred, however, that water leakage through the fractured bedrocks may scarecely be serious because they are covered with thick top soil and residual soil of low permeability. The geological map of the proposed reservoir area is shown in Plate 3.

Drilling at 3 holes with a total length of 137.5 m conducted at the damsite under financing by Government of Malaysia.

Geology in dam axis consists of fractured rhyolitic tuff and tuffaceous sandstone. Drilling core samples revealed that the bedrock is fractured and cracked in general.

The core samples of the borehole LG-2 indicate fractured zones probably caused by the faults through a whole depth.

The Drilling revealed also that the overburden such as top soil, residual soil and alluvial deposits are seen extensively throughout the damsite, reaching 15.7 m below ground level in the left abutment, 10 m in the river bed and 9 m in the right abutment.

Though the overburden is especially thick on the left bank, the N-values of standard penetration test shows more than 50 below the depth of only 3 m. On the other hand, in the river bed and the right bank such high N-values is encountered only at the top of the weathered bedrock at the depth of 9 m or 10 m. At the depth of 5 m, it shows 19 in the river bed and 10 on the right bank. To place the base of fill type dam upon the zone of high N-values, deep foundation excavation should be taken into account. However, it should be considered in the future to place the dam base in the zone of lower N-values by adjusting the inclination of the embankment slopes based on the results of more detailed subsurface investigations in the next stage of the project study.

Permeability of the bedrock, as measured in the borehole permeability test, shows high values ranging from 1×10^{-3} cm/sec to 1×10^{-4} cm/sec. Permeability of the overburden is around 1×10^{-3} cm/sec. The geologic profile along the proposed damaxis is shown in Plate 4.

Cut-off trench shall be sunk at least up to the top of the bedrock, and diaphragm wall will be required below the bottom of the trench in order to improve the high permeability of the bedrock. An alternative measures for under-seepage treatment will be construction of the upstream blanket, which could be less effective than diaphragm wall but still deserves examination.

Dam of concrete gravity type is unconceivable for this damsite because of the thick overburden and weakness of the weathered bedrock beneath it.

3.4 Upper Pengli Dam and Reservoir Area

The proposed Upper Pengli damsite is located on Pengli river at about 8 km upstream from its confluence to the Sayong river. The Sayong river is a major tributary of the Johor river in the middle to upper reaches of its basin.

Catchment area of the Upper Pengli dam is bordered in the north and northwest by the ridges with altitude of 300 m to 610 m which divide the Pengli river basin from the Linggiu and Semberong river basins. On the other hand, the southern and southeastern parts of the catchment area including the proposed reservoir area, are the terrain of mildly rolling hills, where the oil palm plantations are developed.

The watershed ridges of upper and in the Pengli river are composed mainly of the Blumut Granites of Triassic age, and are covered by jungle, while the southern hill area consists of sedimentary rocks of Lower Cretaceous Tebak Formation and semi-consolidated sand, silt and clay of Plio-Pleistocene Layang-Layang Formation. The outstanding contrast of the topography in the catchment area is deemed to reflect the difference in resistance against erosion between the granites and the sedimentary rock.

A saddle dam will be necessitated on the right bank ridge of the reservoir area.

Both the proposed main damsite and the saddle damsite are situated in the area of the Pli-Pleistocene sediments which are semi-consolidated and weak in strength. Further, a long stretched fault is inferred from topographic feature of straight linearment of the river course to run through the main damsite. With this problems in view, the final assessment of geotechnical conditions of this sites is yet to be made on the basis of more detailed subsurface investigations in the future. The geological map of the proposed reservoir area is shown in Plate 5.

An earthfill dam would be the most suitable type. The seepage control will have to be made by means of the upstream blanket, since ordinary curtain grouting is very likely to have little effects on this semi-consolidated deposits.

The right bank is preferable for layout of the spillway and diversion channel in order to economize their length, as the existing river channel is located close to the right bank among the 500 m wide valley bottom.

Embankment material for the earthfill dam will be obtainable in sufficient quantity on the right side of the reservoir area. The quality shall be examined by laboratory tests in the future.

3.5 Sayong Dam and Reservoir Area

The proposed Sayong damsite is located on the Sayong river at approximately 500 m upstream from the confluence of the Linggiu river. The area is situated in the middle reaches of the Johor river basin.

The Sayong dam, contemplated so far, will have its crest at EL. 25.5 m and H.W.L at EL. 18 m, while the present river bed is approximately at EL. 5 m. The town of Layang-Layang is located at the Upstream end of the reservoir. The reservoir area and its surroundings are well developed for oil palm plantation and other land uses.

The Sayong river flows among a wide flat valley in this vicinity. The abutments are on flat ridges with inclination of around 11 degrees on the right and 8 degrees on the left. The right abutment is occupied by oil palm field and the left abutment by the ressetlement houses of Kampong Sayong Pinnang.

The dam and reservoir area is geologically composed mainly of granites, locally associated with Mesozoic sandstones, Plio-Pleistocene sand and sandy clay and alluvial deposits in the river bed. The Mesozoic sediments are developed in a part of the left side of the reservoir.

The reservoir area is generally coated with strongly lateritized residual soil, of which thickness is often around 10 m. No particular passages for possible leakage from the reservoir are observed.

The existing regional geological map does not indicate major faults in the surroundings of the damsite. The geological map of the reservoir is shown in Plate 6.

Core drilling of 165 m in total length and at 5 spots was performed on the proposed dam axis under financing of the Government of Malaysia and under supervision of the JICA engineer. Standard penetration tests and borehole permeability tests were conducted along with the drilling.

The investigation to date has revealed that earth fill dam is suitable for this site and that excavation depth reaches 11 m from ground level in the right abutment, 10 m to 14 m in the river bed and 7 m in the left abutment.

Fresh granite, which shows low permeability ranging from $1x10^{-6}$ cm/sec to $1x10^{-7}$ cm/sec, occurs about 8 m deep from the ground surface in the left abutment.

It seems that the overburden is generally thinner in the left abutment. The geologic profile along the proposed damaxis is shown in Plate 7.

It is probable that rock materials for riprap and concrete aggregates for auxiliary structures become available on the left bank of the damsite by excavating intact fresh granite.

Embankment materials can easily be provided from the left bank.

Spillway and auxiliary structures is recommended to found on fresh granite in the left abutment.

3.6 Telor Dam and Reservoir Area

The Telor river is a right side tributary of the Johor river in the middle reaches of its basin. The proposed damsite on the Telor river is located about 4 km upstream from its confluence to the Johor river. A highway linking Kota Tinggi and Kulai passes 2 km north of the damsite.

While the damsite is situated favourably for water supply to such areas of big demand as Kota Tinggi, only 12 km away, and Johor Bahru at 30 km of distance, its topographic feature is too flat to construct a large scale reservoir. The reservoir and catchment areas are located among the mildly undulating hill region with ground height ranging from 15 m to 60 m. The highest terrain in these areas is Bukit 75 at EL. 134 m on the basin watershed. The catchment area of the dam is covered by jungle.

The Telor river valley is open wide with gentle slopes on both banks in general. The damsite was selected at the relatively narrow portion of the valley.

Bedrock in this area is composed mainly of granites of Lower Triassic age. Remnants of Upper to Middle Triassic Jurong Formation, consisting of shales, sandstones and conglomerates, are distributed in a narrow belt of NW-SE direction. The alluvial deposits are scattered along the river course.

It seems that intensive weathering is developed deep into the bedrocks, altering their superficial zones into the residual soil. Thickness of the residual soil and the other overburden is not confirmed but could be not less than 10 m, referring to the cases of the core drilling in the Linggiu sites which have more or less similar geologic facies and under the same climate to develop weathering. The geological map of the proposed reservoir area is shown in Plate 8.

Earthfill dam will be the most viable type for the dam in view of availability of the embankment material. Because of the thick weathering, no quarry sites that is economically exploitable are likely to exist within a reasonable hauling distance to the damsites. Earth embankment material will be obtained from the bed of the residual soil on the left side of the reservoir area.

To locate the spillway, the hill on the left abutment is more massive and stable than the right bank. The right bank side is deemed preferable for the diversion channel from the lineation of the meandering river channel.

3.7 Sedili Dam and Reservoir Area

The proposed damsite is located in the middle reaches of the Ulu Sedili Besar river and approximately 3 km upstream or west from the crossing of the highway from Kota Tinggi to Mersing. Both the abutments of the damsite are easy for access by car through logging roads. The contemplated reservoir is entirely included in the timber logging area of the Forest Department. There are no public inhabitants in this area.

There exists a tin mine of small scale in the reservoir area, which is exploiting the sedimentary deposit of cassiterite in the alluvial deposits.

Geological units in the dam and reservoir area are as follows:

Permian Mersing Group, mainly comprising phyllites and schists, developping in the downstream parts and the right side of the reservoir area including the damsite,

Upper Permian Sedili Volcanic Formation consisting of acidic to intermediate pyroclastic rocks and lavas, which is developed mainly in the upstream right rim of the reservoir, overlying unconformably the Mersing Group,

Triassic Lenggor Granite of which forms a large intrusive mass occupying widely the upstream left bank of the reservoir area and

Alluvial deposits in the river channel and swamps in the bottom of the valley.

A few faults trending N-S and NW-SE run through the reservoir area, but will not cause any substantial leakages from the reservoir since gentle sloped watersheds with the adjacent basins are so thick that hydraulic gradient for any leakage path would be very low. The geological map of the proposed reservoir area is shown in Plate 9.

The damsite was selected at a narrow portion of the valley with a wide open storage area immediately upstream. The river flows east-northeast through the 200 m wide flood plain at the level of approximately EL. 8 m. The width between both abutments shows 470 m at EL. 35 m, the contemplated height of the dam crest.

Core drilling of 124 m in total length at three spots was performed on the proposed dam axis under financing by the Government of Malaysia. The borehole US-1 on the left abutment revealed that the overburden of top soil and residual soil is 3.8 m thick and the underlying bedrock is moderately hard phyllite which is weathered. The borehold US-2 in the bottom of the river valley indicates that the phyllite is covered by the 14 m thick overburden of alluvial deposits and residual soil. The borehole US-3 on the right abutment revealed that the overburden of top soil and residual soil is 8.0 m thick. The N-values of standard penetration test exceed 30 below the depth of 7 m, while they are not higher than 6 in the upper zone. Foundation excavation should be made at least to the depth of 7 m for the entire base of the fill dam. In the right abutment, the overburden is 8 m in thickness, of which the lower 4 m section shows N-values higher than 40.

Permeability of the bedrock ranges from 1×10^{-4} cm/s to 1×10^{-5} cm/s. The geologic profile along the proposed damaxius is shown in Plate 10.

The residual soil on the left bank in the vicinity of the damsite is expected for an abundant source of earth embankment materials. The granite in the upstream area, which could be good rock material in fresh condition, is actually so deeply weathered and deteriorated that it does not seem to become a competent source of rock material. An earthfill dam is deemed to be the most economical type of dam in this site.

3.8 Layau Kiri Dam and Reservoir Area

Layau Kiri river is a left side tributary of the Johor river located in the lower reaches of the Johor basin. It joins the Lebam river from north, and the Lebam river is confluent to the Johor river in its estury. The proposed damsite on the Layau Kiri river is located about 10 km upstream of the confluence of the Layau Kiri with the Lebam river.

The reservoir area is highly developed for a oil palm plantation. A housing plan is also under way in this area.

The dam and reservoir area is situated among the terrain of low hills and wide open valleys with ground height ranging from 15 m to 60 m. The geomorphological trend of the hills shown NW-SE direction reflecting the regional geological structure.

The dam and reservoir area is located entirely in the real of Johor Lama Granite of Triassic age. Phyllites of Permian Mersing Group which compose the watershed on the northeast is developed to the upstream end of the reservoir area, where the phyllites show general strike NW-SE and dip 70 degrees NE according to the existing geological map. The bedrocks are covered by thick residual soil.

Thick and intensive weathering of the granite bedrock in the damsite should be taken into account, though it is yet to be confirmed in the future sub-surface investigations. The geological map of the proposed reservoir area is shown in Plate 11.

A sub dam will be necessitated at the head of Semenchu stream, a small tributary from the left side to the Layau Kiri river, which is located about 3.5 km east of the main damsite.

For the spillway, the left abutment will be preferable because of the river channel closer to it.

For the lack of good rock quarry site, an earthfill type is recommendable for the dam. Earth embankment material is to be taken from the thick residual soil bed on the left bank of the reservoir area.

4. RESULTS OF CORE DRILLING

Among the foresaid eight damsites, the Linggiu, Sayong and Sedili dams were selected as a first priority from the viewpoint of future water demand estimation, flood control, geological and topographical conditions, etc. And core drilling work was done in these three damsites from Nov. 1984 to Jan. 1985 under financing by the Government.

The geotechnical interpretation of the core drilling results is stated hereinafter, and Figures and Tables showing the core drilling results are attached as Appendix.

4.1 Linggiu Damsite

Drillings of 3 holes (LG-1, 2, 3 as shown in Figs. A2 to A7) and 137.5 m in total length was conducted along the dam axis.

<u>LG-1 the left bank)</u>

0-15.7 m: There extend a top and residual soils of very stiff to hard, reddish to yellowish brown silty clay with heavily weathered small gravels.

15.7-50 m: Weak to moderately strong, wholly fractured, brecciated rhyolite. Almost without cylindrical core, the core-recovery is 70 % in average. Rock Quality Designation (R.Q.D) is nearly zero, and almost all core samples are angular fragments with some clay. Rock classification in this section is mainly CL. The sections of 15.7-20.0, 30.3-34.7 and 40.0-42.0 m in depth are highly fractured with clay and show poor core-recovery of 10 to 20 % (D-CL class).

<u>LG-2 (the riverbed)</u>

0-8.3 m: Loose top soil consisting of light brown colored silty sand. Medium dense, brown colored alluvial deposit of medium to coarse sand with little gravels heavily weathered.

8.3-10.0 m: Hard, brown silty clay with some weathered gravels.

10.0-24.0 m: Mostly hard, grey clayey silt to sand with weathered rhyolite fragments derived from rhyolitic tuff. Almost clayey core of 90 % recovery, D-CL class.

24.0-42.0 m: Reddish to greyish, fractured and brecciated rhyolite, ryolitic tuff subjected to fault fracturing throughout the hole. Core-recovery of 70 % in average, mainly D-CL class. The section of 24.7-28.0 m is composed of many cylindrical cores, R.Q.D 40 % in average

LG-3 (the right bank)

0-9.0 m: Stiff, brown colored top and residual soil of silty clay

9.0-22.0 m: brown colored clay with some heavily weathered sandy gravel with 80 % recovery of mainly clayey core, D class.

22.0-27.8 m: Pale brown, fractured and brecciated rhyolite in the sheared zone by fault. Poor core-recovery of 30 % in average, no cylindrical core, CL class.

27.8-45.5 m: Moderately strong, grey to reddish brown colored rhyolite. Mainly brecciated core of 70 % recovery. The sections of 27.8-30.5 and 38.5-43.0 m have many cylindrical cores exception with R.W.D 50 % in average, CM class.

According to the above mentioned drilling results, the bedrock of rhyolitic tuff in the area is moderately to highly fractured due to fault along the river course. Rock materials for aggregates and rock fill is hardly obtained in and around the site. Accordingly an earthfill dam is deemed most economical.

N-values of the standard penetration test conducted in the unconsolidated deposits in each drill hole exceed 50 below the depth of 3 m at the borehole LG-1 on the left bank, 12 m at the borehole LG-2 in the riverbed and 10 m at LG-3 on the right bank.

With no gravels encountered, these N-value over 50 can taken as correctly reflecting the strength of the beds that is deemed sufficient to support the embankment of some 30 m height. It should be designed for the foundation excavation of the entire dam base to be made up to this zone. While this depth of excavation might be reducible by adjusting the slopes of the dam embankment to meet weaker subsoil with less N-value, it should be the matter to be discussed after more detailed investigation is performed for the foundation in the future stage of the project study.

The water pressure test in the boreholes were to be conducted in every five meter secton, under seven steps of different pumping pressures, that is, 1 kg/cm^2, 3 kg/cm^2, 7 kg/cm^2, 10 kg/cm^2, 7 kg/cm^2, 3 kg/cm^2 and 1 kg/cm^2 in order. Because of high leakage, however, the planned high pressures could not be attained within discharge capacity of the ordinary test pump in the Linggiu damsite and the tests were conducted under three or five steps of pressure. The results indicate considerably high permeability.

Results of the water pressure tests are shown in Tables B1 through B3, and the relation between the pressure head and the water intake are presented graphically in Fig. C1 through C9.

In the borehole LG-1 on the left bank, the residual soil up to the depth of 15.7 m shows Lugeon units ranging from 63 to 334. This means that if the mechanically stable zone with N-value higher than 50 is reached at the depth of only 3 m, a zone of high permeability ranging in the order of 10^{-3} cm/s is developed deeper. The bedrock shows permeability of 54 Lugeon unit in its top zone between the depth of 15.7 m and 25 m, and 28 to 30 Lugeon unit in the deeper zone.

All of the above mentioned Lugeon units are the values obtained from the test under the highest step of pressure in each test section. As seen in Fig. C1 to C3, the relation between the pressure head and the water intake is not always linear, sometimes showing salient breaks of the graphs which indicate unproportionate increments of the water intake at certain height of pressure. This does not always mean breakage or destructure of bedrock and subsoil by the high pressure but indicates elasic or partly plastic deformation of them resulting in opening of cracks or seepage paths. If the water intake in the course of reducing the pressure is similar to that in the course of raising the pressure, the deformation can be interpreted completely elastic.

In this respect the test results for the zone deeper than 25 m, in which the change of the water intake as against the head is reversible, indicate completely elastic deformation (See Fig. C3). The test results in this zone also indicate that the water intake increases sharply when the pressure head exceed 42 m, and the calculated Lugeon values for the head lower than 42 m are less than 5, while they are 28 to 30 for the higher head. For the presently contemplated dam height, the water head that is actually built up will be less than 30 m. Therefore, the permeability in this zone can be considered as less than 5 Lugeon unit or 7×10^{-5} cm/s for design of the dam. Compared with very high permeability in the upper zones, this may be deemed as virtually impervious.

On the other hand, the test in the section from 4 m to 5 m shows that the water intakes under the same head of 15 m are quite different between before and after the head has once been raised up to 30 m. The water intake after the raising of the head is more than five times that before. Deformation of the residual soil is partly irreversible, and cracks or seepage paths once opened by the high pressure head of 30 m closed only partly when the high pressure was removed. Such irreversible water intake is observed in the section from 7 m to 10 m, too. Below 10 m of depth, deformation of the residual soil and the bedrock is nearly or completely reversible. Magnitude of the irreversible water intake, or deformation, is roughly correlated with softness of the subsoil or bedrock.

In the borehole LG-2 in the riverbed, Lugeon value under the highest step of pressure shows 53 to 85 up to the depth of 3 m, without indicating much differences between the alluvial deposit and the bedrock. It is reduced to 31 only in the bottom section of 35 m to 40 m. In most cases in this borehole, the water intake shows less increase under the higher heads, contrary to the cases in LG-1. In the other words, the water intake increases rapidly as the pressure rise from zero to a certain height, but does not increase so much after that. It is deemed that some irreversible or plastic deformations take place to consolidate the rocks surrounding the water-filled cracks in the initial steps of pressure, and after the consolidation the deformation becomes more elastic and resisting. In this case, the calculated permeability is higher under the lower head. Under the head of 15 m, the calculated Lugeon values show often around 100 or more. The relation between the water intake and the head is generally reversible in the zone deeper than 20 m.

In the borehole LG-3 on the right bank the permeability is 108 and 71 Lugeon unit in the residual soil, less than 70 Lugeon unit with only one exceptional case out of five in the bedrock from 10 m to 35 m of depth and 38 in the section from 35 m to 40 m. The increase rate of water intake is less in higher heads in some sections and reverse in the other sections. The relation between the water intake and the head is reversible in the bedrock deeper than 15 m.

Groundwater level is located around EL. 16 m in all the three borehole, that is, nearly the same level as the river water. This also is deemed to indicate high permeability in the both abutmens.

The under-seepage treatment for the dam foundation should be made by means of a concrete diaphragm wall. As grouting does not seem to be effective for the residual soil, even if the cut-off trench should be sunk to reach the bedrock.

An alternative measure for the under-seepage treatment would be an upstream blanket, which would be lower in cost than a concrete diaphragm wall but less effective in reducing seepage quantity.

Test grouting is recommended for the future study in order to assess the effect of grouting in order to save the cost for the dam foundation treatment.

4.2 Sayong Damsite

Drillings of 5 holes (SY-1 to SY-5 as shown in Figs. A8 to A15) and 165 m in total length was conducted along the dam axis.

SY-1 (the left bank)

0 -2.6 m: Top soil. Brown, sandy or silty clay including some organic contents.

2.6-8.4 m: Residual soil derived from weathered granite. Stiff, brown, sandy clayey silt with little gravels intensively weathered.

8.4-35.0 m: Mainly strong and fresh biotite granite with almost 100 % core-recovery. With all cylindrical cores, R.Q.D is nearly 100 %. Slightly weathered in 9 m. Rock classification is CH to B.

SY-2 (the riverbed)

0 -3.5 m: Top soil and alluvial deposit. Stiff, light brown, silty clay..

3.5-11.5 m: Soft to medium dense, grey, fine alluvial sand with poor core-recovery of 20 % in average.

11.5-13.9 m: Residual soil from decomposed granite. Medium dense, greenish silty and including coarse grain quartz. 50 % core-recovery.

13.9-30.0 m: Mainly strong fresh biotite granite with 100 % core-recovery and 90 % R.Q.D in average, CH to B class.

SY-3 (the riverbed)

0 -30.0 m: Top soil and alluvial deposit. Medium stiff, light brown silty clay.

3.0-9.0 m: Medium dense, light brown alluvial sand with 20 % core-recovery

9.0-10.5 m: Residual soil or decomposed granite. Medium dense, light grey coarse arkose sand, mainly consisting quartz grain. 40 % core-recovery.

10.5-35.0 m: Mainly strong fresh biotite granite. All cylindrical core 100 %, R.Q.D of nearly 90 %, CH to B class. Cracky at 16.5-18.0 m, 27.5 m and 29 m.

SY-4 (the foot of the right bank)

0 ~ 7.5 m: Top soil, alluvial deposits, mostly composed of moderately stiff, light brown, silty clay.

7.5-9.0 m: Medium dense, grey, fine to medium alluvial sand with 20 % core recovery.

9.0-11.4 m: Residual soil and decomposed granite. Reddish brown, silty clay and gravelly sand with completely weathered granite fragments. 80 % core-recovery.

11.4-35 m: Hard, fresh biotite granite, 100 % core-recovery and 90 % R.Q.D in average. Cracky cores at 14.3, 15.8, 19.5-20.5, 21.8 and 28.5-29.5 m.

SY-5 (the right bank)

0 -1.5 m: Top soil including organic contents, light brown silty clay.

1.5-9.5 m: Residual soil. Stiff, reddish brown silty clay.

9.5-16.0 m: Soil of completely weathered and decomposed granite, or residual soil subjected to strong lateritization. Hard, reddish brown, silty clay 80 % core-recovery.

16.0-21.5 m: Completely weathered and decomposed granite. Almost soil condition. Hard, light brown, mainly silty clay with some gravelly sand. 90 % core-recovery.

21.5-35.0 m: Strong fresh biotite granite, 100 % core-recovery, all cylindrical core. R.Q.D 70 % in average. Cracky cores with joints dipping 60 degrees at 21.5-24.0, 28.7, 30.0 and 32.5-33.5 m.

Core drilling shows that fresh granite is encountered at the depth of 8.4 m in the left bank, 10.5 to 11.5 m in the riverbed and 21.5 m in the right bank.

N-value of the standard penetration test exceeds 50 at the depth of 7 m on the left abutment, while it is less than 12 in the upper layers. In the boreholes SY-2 to SY-5 in the river bed and on the right abutment, N-value exceeds 20 at the depths around 10 m. This to be considered as the depth of foundation excavation for the entire base of the fill dam. Cut-off trench shall be further excavated to the interface of the underlying fresh granite.

The results of borehole permeability tests are shown in Table B4 through B8 and Fig. C10 through C20. Clear contrast is seen between the permeabilities of the fresh granite and the overburden.

The borehole permeability tests in constant head method in the top soil, residual soil and alluvial deposit give high permeability ranging from 4.0×10^{-4} cm/s to 9.1×10^{-3} cm/s. The decomposed granite in the borehole SY-5 on the right abutment also indicate the permeability in this range. On the other hand, the permeability is generally in the order of 10^{-5} or 10^{-6} cm/s in the fresh granite, which is encountered at the depth of 8.5 m to 11 m in SY-1, SY-3 and SY-4, and 13.5 m to 21.5 m in SY-2 and SY-5.

The treatment against the under-seepage will be required only for the overburden and the decomposed granite. As grouting does not seem effective for those zones, the treatment will have to be made by means of cut-off trench to reach the fresh granite or by means of upstream blanket.

4.3 Sedili Damsite

Drillings with 3 holes (US-1, 2, 3 as shown in Fig. A16 to A21) and 124 m in total length was conducted along the dam axis.

US-1 (the left bank)

0 -3.8 m: Top and residual soil. Stiff, light brown, silty clay including little gravelly sand.

3.8-13.0 m: Moderately weak phyllite. Brownish grey, friable. Mainly brecciated cores of D class, with poor core-recovery of 60 % in average.

13.0-20.0 m: Brownish grey moderately weathered phyllite, cracky, occationary iron oxide stains and quartz veins. CM to CL class, partly fractured. 90 % core-recovery.

20.0-40.0 m: Dark grey phyllite. Moderately hard, slightly friable. Trace fine pyritization, occasionary with quartz veins. CM class, almost 100 % core-recovery, R.Q.D 10 to 20 %.

US-2 (the riverbed)

0 -5.5 m: Top soil and colluvium. Loose, yellowish brown clayey silt to fine sand.

5.5-11.0 m: Alluvium. Medium dense and stiff, light yellowish brown coarse sand.

11.0-14.0 m: Residual soil or completely deteriorated phyllite. Dark grey, clayey silt with sub-round rock fragments. D class, 50 % core-recovery.

14.0-16.5 m: Completely weathered phyllite. Weak, dark grey, fractured, with quartz veins. CL to D class, poor core-recovery of 10 % in average.

16.5-23.0 m: Moderately weak, dark grey cracky phyllite. Occasionally with fine quartz veins and trace pyritization. CL class, 80% core-recovery in average. R.Q.D nearly zero.

23.0-45.0 m: Moderately hard, dark grey phyllite with quartz veins, with frequent cracks partly fractured CM class, 100 % core-recovery and 20 % R.Q.D in average.

US-3 (the right bank)

0 - 2.0 m: Top soil. Reddish brown silty clay.

2.0-8.0 m: Residual soil. Stiff to hard, reddish brown silty clay.

8.0-16.0 m: Heavily weathered, weak, dark grey, friable phyllite partly with iron oxide stains, pyritization and quartz veins. CL to CM class, poor core-recovery of 20 % in average, R.Q.D 0 %.

16.0-39.0 m: Moderately hard, partly fractured, dark grey phyllite with quartz veins and pyritization. CM class, almost 100 % core-recovery, R.Q.D 10 % in average.

Substantial bedrock of slightly weathered phyllite, classified in CL to CM due to many cracks, is reached at the depth of 13 m on the left bank, 16.5 m in the riverbed and 16 m on the right bank, dipping 30 to 60 degrees and probably striking NNW-SSE, and accompanied with pyritization and quartz veins.

In the borehole US-1 on the left abutment, residual soil is terminated at the depth of 3.8 m, underlain by intensively weathered phyllite. N-value of the standard penetration test rises to 30 at the depth of 3.5 m and more than 50 in the intensively weathered phyllite.

In the borehole US-2 in the river, the alluvial deposits are 11 m thick, and below the 3 m thick residual soil the intensively weathered phyllite is encountered at the depth of 14 m. N-value rises sharply from 6 to 87 at the depth of 7.5 m. Though the N-value shows lower in some parts below this depth, it does not drop under 25.

In the borehole US-3 on the right abutment, residual soil is 8 m thick and shows rather high N-values. While the N-value is only 7 at the depth of 2.5 m, it rises to 20 at 3.5 m and then up to 43 at 4.5 m. Below this level is shows more than 40.

From the above appropriate depths of excavation for the base of a fill type dam are 3.8 m for US-1, 7.5 m for US-2 and 4.5 m for US-3.

Due to the deep weathering and insufficient strength of the bedrock, concrete gravity type is not suitable for this site.

Permeability is generally low in the phyllite. In the borehole US-1 the results of the water pressure test in the phyllite shows for the most part less than 5 Lugeon unit, with only one exception of 11 Lugeon unit in the section from 25 m to 30 m. In US-2 in the river bed, the upper zone of phyllite in the depth of 15 m to 30 m shows 11 to 29 Lugeon unit, while the deeper zone indicates only 3 to 6. Permeability of the phyllite in US-3 ranges from 1 to 8 Lugeon unit, except for the section from 20 to 25 m where it shows 16.

Relatively high permeability of 17 to 52 is occasionally observed in the overburden. This should be rested by cut-off trench sunk to the top of the phyllite in CL to CM class.

Though the phyllite bedrock would not take much grout in general, it is yet recommendable to plan a certain extent of curtain grouting in order to pick up the part of higher permeability and improve them.

Further confirmation of the foundation permeability will be required for the future study.

5. SEISMICITY

Peninsular Malaysia is situated in the zone of low seismicity, which is about 400 km far distant from the Trans-Asiatic Belt which is known as one of the most active seismic zones in the world. It is considered that almost all the earthquakes felt at the proposed damsites in the past time had their epicenters in the western part of Sumatra Island and its vicinities. Historical epicenters of large scale earthquakes in the Sumatra is shown in Fig. 3 and Table 2.

The estimation of seismicity is made for the Sayong damsite which is located at the shorter distance to the seismic zone than the other two damsites of first priority.

Seismic intensity at the proposed damsite is computed using the following formula (Kawasumi's Formula).

$$Ij = Mk - 0.00183(d-100) - 4.605 \log d/100 \quad (\text{if } d>100\text{km}) \qquad (1)$$

$$Ij = Mk + 4.605 \log Do/D + 2k(D-Do) \log e \quad (\text{if } D<100\text{km}) \qquad (2)$$

where, Ij: the intensity in JMA(Japan Meteorological Agency) scale at the project site

Mk: the intensity in JMA scale at the distance of 100km from the epicenter*

d : the distance from the epicenter to the project site (km)

D : the distance from the focus to the project site (km)

Do: the distance from the focus to the point of d=100km (km)

k : the damping ratio of S-wave (0.0192/km)

*The relation between Mk and the magnitude in Richter scale (M), is presented by the formula:

$$M = 4.85 + 0.5Mk \quad (\text{after Kawasumi}) \qquad (3)$$

The relation between the intensity "Ij" and the peak ground acceleration "a" of the earthquake mortion is very closely approximated by the following equation (by Kawasumi, 1951),

a = 0.45 x E 0.5Ij (in gal) (4)

Where a is the geometrical mean value of the peak ground accelerations observed emprically.

Accordingly, the expected maximum acceleration with recurrence period of 100 years was estimated at 126 gal or 0.13G. However this value was not adopted to the design. Because this is the same magnitude as the earthquake of Magnitude 8.0 occurs in the Straits of Melaka 200 km from the proposed damsite, judging from the past record, such a scale of earthquake might not take place in the project area.

It is recommended to take 0.10 for the design coefficient of ground acceleration by earthquake at the proposed damsites.

6. PROPOSAL OF FUTURE GEOLOGIC INVESTIGATION

For the future study in the stages of Feasibility and Detailed Design, the following investigation is recommended in the proposed sites.

Proposed Geologic Investigation for Future Stage

Site	Geological Mapping	Seismic Exploration		Core Drilling	
Linggiu	Scale 1:1,000	6 lines	7,200 m	11 holes	570 m
Sayong	Scale 1:1,000	9 lines	6,400 m	18 holes	635 m
Sedili	Scale 1:1,000	5 lines	4,400 m	11 holes	550 m

For the confirmation of the fault location, its width and for the interpretation of the geological structure, it is necessary to carry out a geological mapping with trench work by the map (scale 1/1,000) provided in this time.

It is recommendable that the seismic exploration shall be carried out prior to the drilling and each proposed core drilling point shall be reviewed based on its results. Further, test grouting of 6 holes to the depth of 35m will be necessary for the detailed design in each proposed damsite of Linggiu, Sayong and Sedili.

Besides the core drilling for the relocation roads in the proposed reservoir areas should be planned in the next stage.

The future investigation plan map of each proposed damsite of Linggiu, Sayong and Sedili is illustrated in Plate 12.

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TABLES

Table 1 QUANTITIES OF CORE DRILLING

Damsite	Drill Hole No.	Drill Length (m)	Standard Penetration Test Nos.	Permeability Test: Constant & Falling Head Test Nos.	Permeability Test: Water Pressure Nos.
Linggiu	LG-1	50	15	0	8
	LG-2	42	25	0	8
	LG-3	45.5	15	0	8
Sayong	SY-1	35	7	1	5
	SY-2	30	13	1	3
	SY-3	35	7	1	5
	SY-4	30	11	1	5
	SY-5	35	15	1	6
Sedili	US-1	40	14	1	7
	US-2	45	15	2	7
	US-3	39	9	1	7
Total	11	426.5	146	9	69

Table 2 LIST OF HISTORICAL LARGE SCALE EARTHQUAKES

YEAR	E P I C E N T E R			DISTANCE	DAMSITE
	LONGITUDE	LATITUDE	MAGNITUDE	(Km)	INTENSITY(Ij)
1907	96.30	2.00	7.8	834.4	0.3
1909	102.00	-2.00	7.7	488.3	1.8
1914	99.00	-4.50	8.1	899.2	0.6
1926	100.50	-0.50	7.9	460.8	2.4
1935	98.25	0.00	7.9	656.6	1.3
1936	99.50	0.00	7.0	527.8	0.2
1943	101.00	-1.00	7.4	456.8	1.4
1943	101.00	-1.00	7.6	456.8	1.8
1946	99.50	0.00	7.1	527.8	0.4
1953	100.00	1.00	6.8	437.3	0.2
1956	101.80	0.00	6.4	314.8	0.4
1967	101.50	-1.00	6.8	420.8	0.3

FIGURES

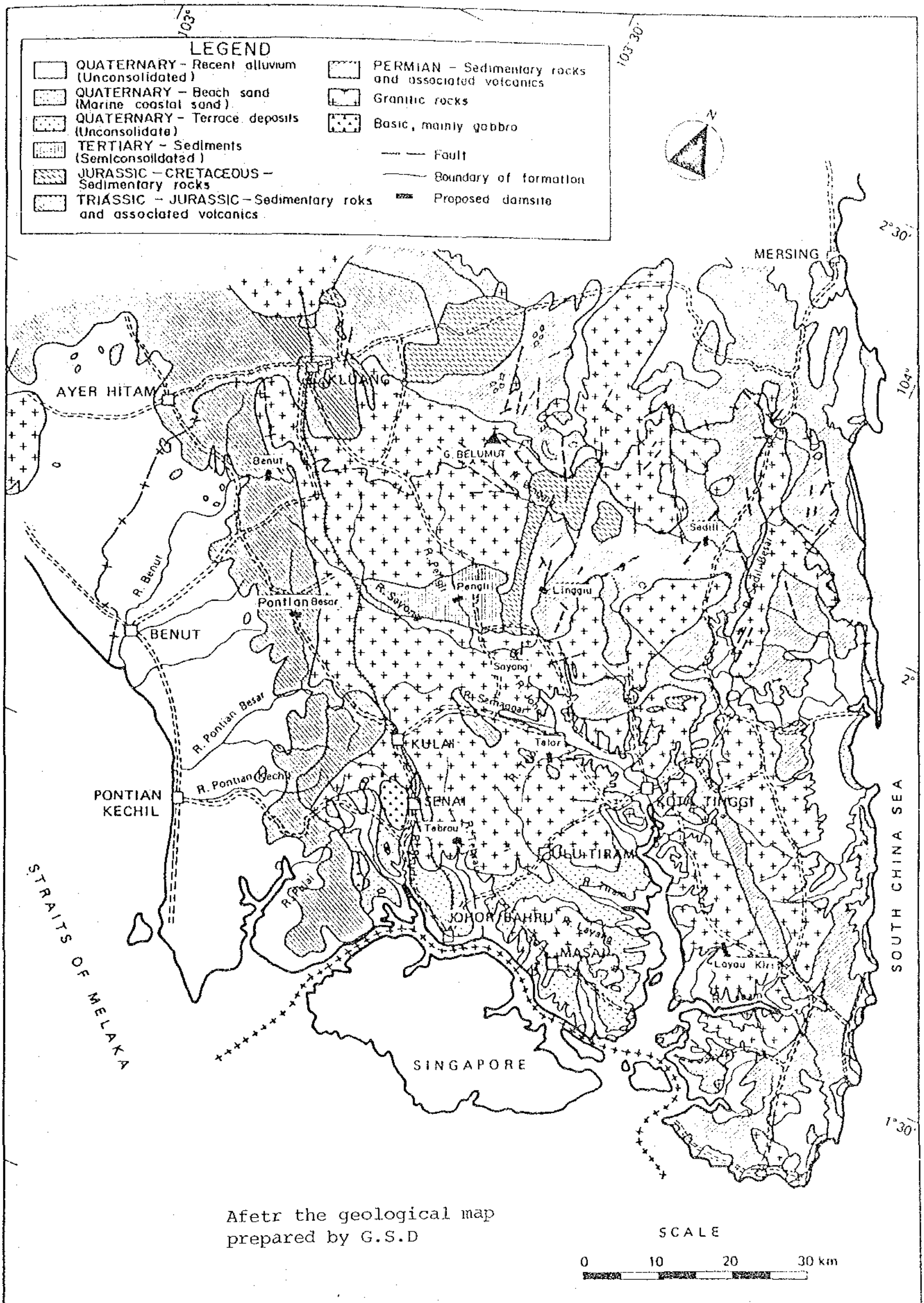

Fig. I Geological Map of the Region

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Geological stage			Geological Condition: Geology	Geological Condition: Lithology
Cenozoic	Quaternary	Holocene	Recent Alluvium (the raised sand beach) Gula Formation (marine deposits) Beruao Formation (Inland freshwater deposits)	Alluvium, swamp, eluvial soils sand dune, peatly clay clay, clayey sand & gravel
Cenozoic	Quaternary	Pleistocene	Simpang Formation (Terrestrial deposits)	Angular quartz sand with rounded quartz. Boulder sand, clay, gravel with weathered layer.
Cenozoic	Tertiary		Layang-Layang Formation Pengeli Sands Members Badak Shale Members	Unconsolidated white cream or pale gray arkosic sand with minor argillaceous layers Dove gray to brown and black clay shale with plant remains.
Mesozoic	Cretaceous		Panti Sandstone Formation (Tobak Formation)	Mainly coarse, cross-bedded quartzsandstone with conglomerate layers. Typically massive, thick bedded and flat-lying.
Mesozoic	Jurassic			
Mesozoic	Triassic		Tenarg Formation Blumut Granite Formation	Tuffaceous Conglomerate, Sandstone shale and interbedded tuffs Granite,
Paleozoic	Permian		Sedili volcanic Formation Linggiu Formation Mersing Group	Prominent flows,andestic crystal tuffs,ignimbrite. Mainly calcareous sandstone minor argillaceous strongly folded mainly psaminitic low-grade metasediments, with some pelitic and acid metavolcanic bands

Fig. 2 Chart of Geological Sequence

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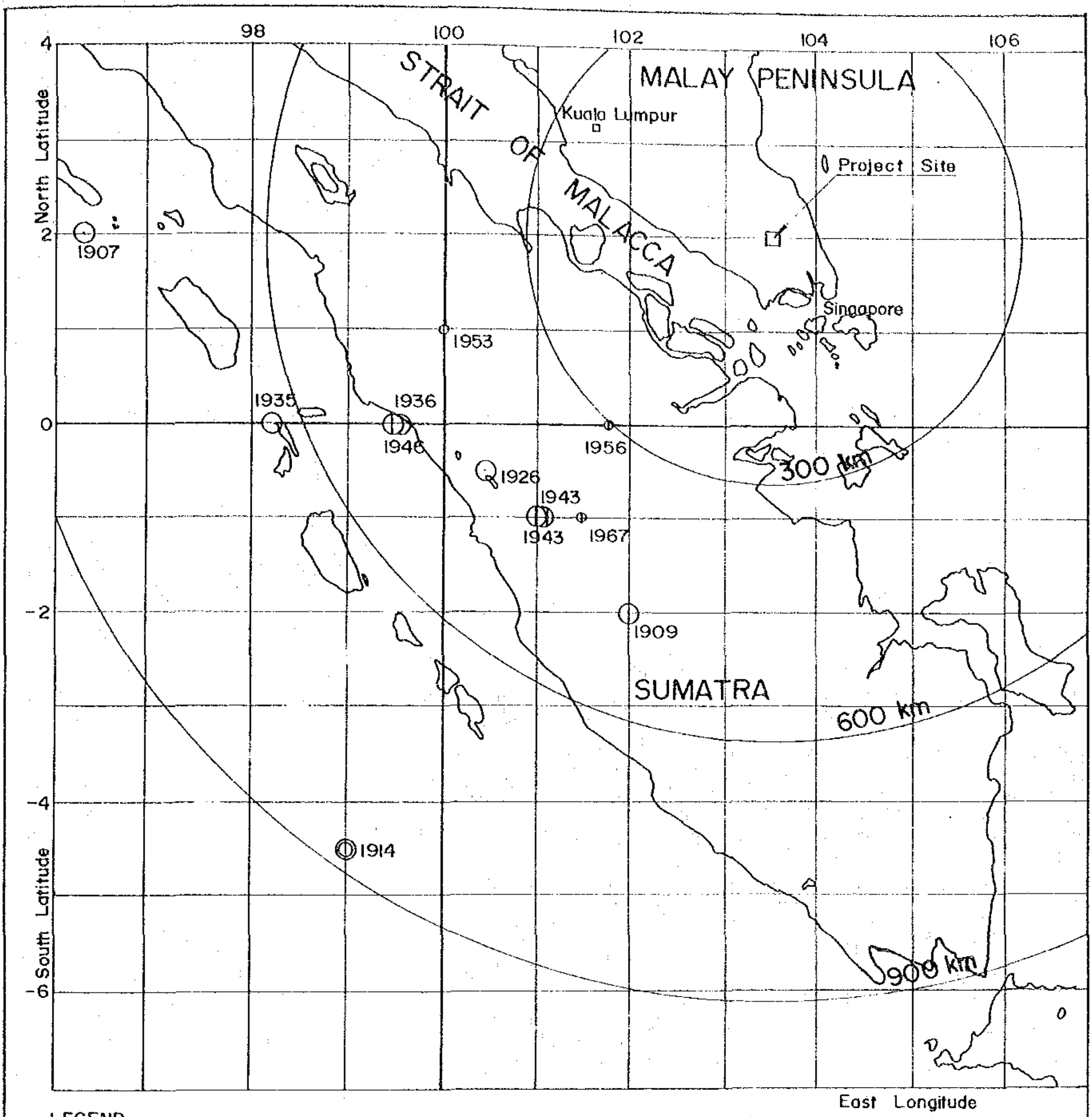

LEGEND

1) Magnitude Of Earthquake Is Expressed As Follows:

◎ 8 ≤ M

○ 7 ≤ M < 8

o 6 ≤ M < 7

0 SCALE 300km

2) Depth Of Earthquake Is Expressed As Follows:

⦶ Depth 50km To 300km

○ Shallow Earthquake

3) Year Of Earthquake Occuring

○ 1956

Fig. 3 Historical Epicentres of Large Scale Earthquakes in the Northern Sumatra

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PLATES

LEGEND

GEOLOGIC AGE	FORMATION	SYMBOL	DESCRIPTION
HOLLOCENE	ALLUVIUM		River and swamp alluvium. Mainly sand, silt and clay with some gravel.
UPPER TRIASSIC	BLUMUT GRANITE	+ + +	Porphyritic and non-porphyritic biotite granite, minor hornblende-bearing granite, granodiorite and diorite.
UPPER TRIASSIC TO MIDDLE TRIASSIC	GEMAS FORMATION		Shale, mudstone, tuff with minor siltstone, sandstone, phyllite and meta-tuff.

Boundary of Formation

Strike and dip of Bedding

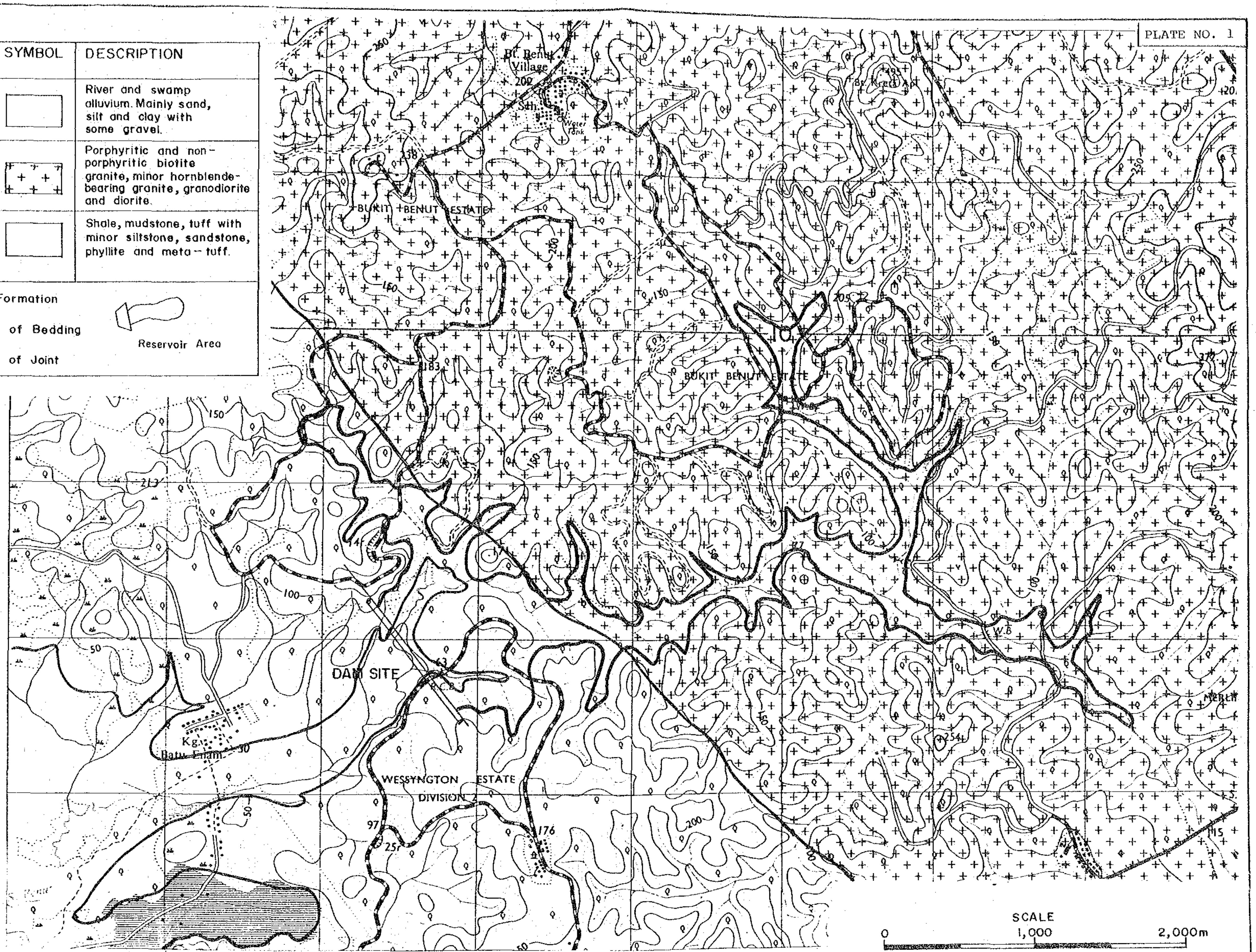
Strike and dip of Joint

Reservoir Area

PLATE NO. 1

N

(After the geological map prepared by G.S.D)



SCALE

0 1,000 2,000m

Altitude in feet

Geological Map of the Proposed Benut Reservoir Area

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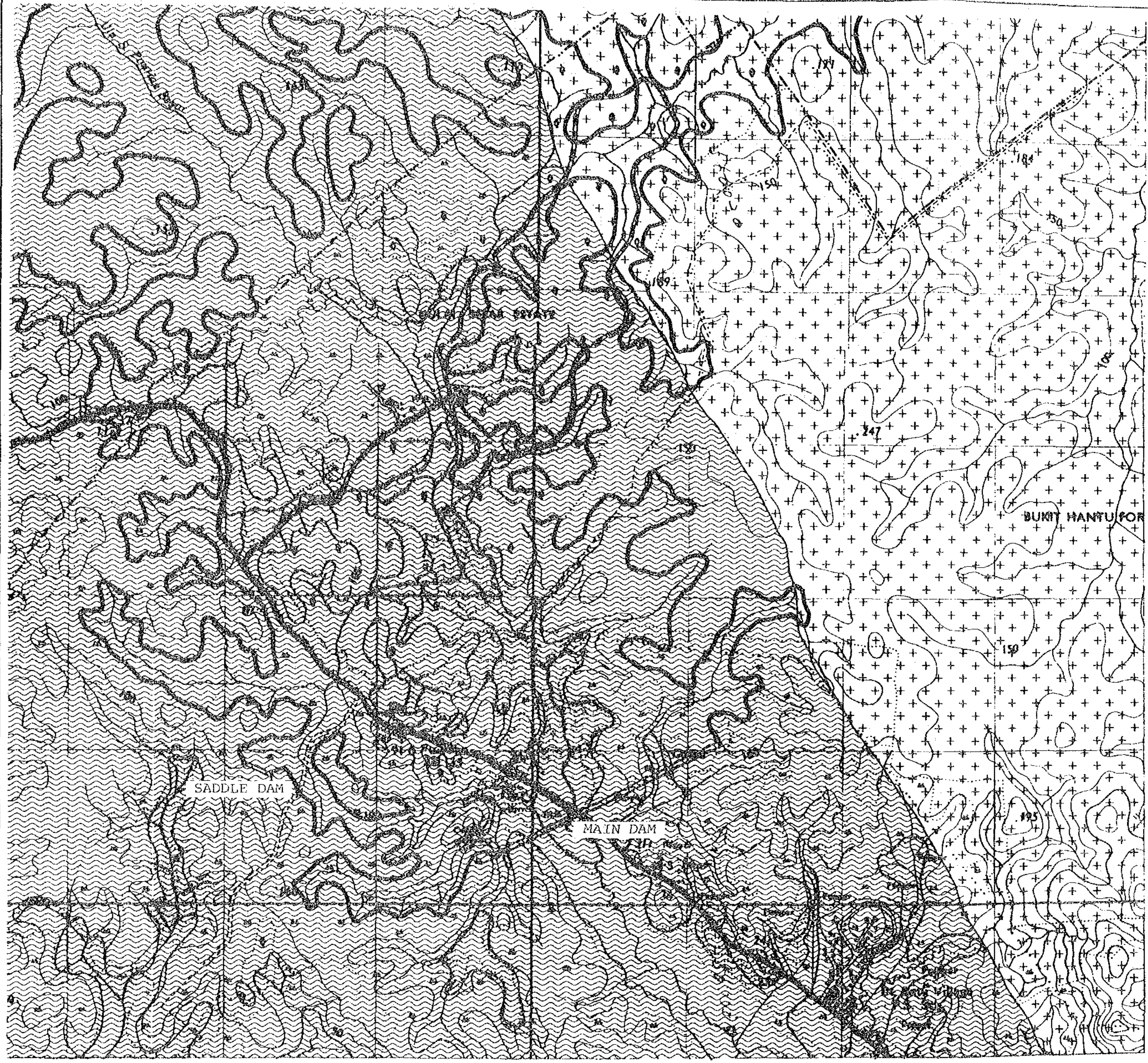
PLATE No 2



N

LEGEND

GEOLOGIC AGE	FORMATION	SYMBOL	DESCRIPTION
HOLOCENE	ALLUVIUM		River and swamp alluvium. Mainly sand, silt and clay with some gravel.
UPPER TRIASSIC	BLUMUT GRANITE	+ + +	Porphyritic and non-porphyritic biotite granite, minor hornblende-bearing granite, granodiorite and diorite.
UPPER TRIASSIC TO MIDDLE TRIASSIC	GEMAS FORMATION		Shale, mudstone tuff with minor siltstone, phyllite and meta-tuff

Boundary of Formation

Strike and dip of Bedding

Strike and dip of Joint

Reservoir Area

(After the geological map prepared by G.S.D)

SCALE

0 1,000 2,000m

Altitude in feet

Belukar

Rubber Plantation

Pepper Plantation

Geological Map of the Proposed Pontian Besar Reservoir Area

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