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NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG
REGIONAL WATER RESOURCES STUDY
PART 2
BERIS DAM FEASIBILITY STUDY

VOL. 5
ANNEX

G. ENGINEERING GEOLOGY
H. CONSTRUCTION MATERIAL

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JAPAN INTERNATIONAL COOPERATION AGENCY

NATIONAL WATER RESOURCES STUDY, MALAYSIA

PERLIS - KEDAH - PULAU PINANG

REGIONAL WATER RESOURCES STUDY

PART 2

LIST OF VOLUMES

ABBREVIATIONS

(1) Organization/Plan

4MP (5MP)	:	Fourth (Fifth) Malaysia Plan
DID (JPT)	:	Drainage and Irrigation Department
EPU	:	Economic Planning Unit
FELCRA	:	Federal Land Consolidation and Rehabilitation Authority
FELDA	:	Federal Land Development Authority
IBRD	:	The World Bank
JICA	:	Japan International Cooperation Agency
MADA	:	Muda Agricultural Development Authority
MOH	:	Ministry of Health
MTR	:	Mid-Term Review of 4MP
NEB (LLN)	:	National Electricity Board
NWRS	:	National Water Resources Study
PWA	:	Pulau Pinang Water Authority
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
EIRR	:	Economic Internal Rate of Return
El.	:	Elevation Above Mean Sea Level
Eq.	:	Equation
Fig.	:	Figure
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
H	:	Height, or Water Head
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
yd = yard

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
gal. = gallon

Weight

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

Time

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

Electrical Measures

V = Volt
A = Ampere
Hz = Hertz (cycle)
W = Watt
kW = Kilowatt
MW = Megawatt
GW = Gigawatt

Other Measures

% = percent
HP = horsepower
° = degree
' = minute
" = second
°C = degree in centigrade
10^3 = thousand
10^6 = million
10^9 = billion (milliard)

Derived Measures

m^3/s = cubic meter per second
cusec = cubic feet per second
mgd = million gallon per day
kWh = kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
kWh/y = kilowatt hour per year
kVA = kilovolt ampere
BTU = British thermal unit
psi = pound per square inch

Money

M$ = Malaysian ringgit
US$ = US dollar
¥ = Japanese Yen

CONVERSION FACTORS

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

Exchange Rate

(at the end of 1983)

US$1 = M$2.312

¥100 = M$0.998

ANNEX G

ENGINEERING GEOLOGY

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1. INTRODUCTION

This Annex presents the results of a geological investigation which was performed between December 1983 and March 1984 for the feasibility study of the Beris dam.

A geological investigation for the Beris dam and reservoir area was carried out between December 1982 and March 1983, as a part of pre-feasibility study for proposed six dams under Part 1 Study. A surface exploration was performed over the proposed damsites and reservoir areas and 200 m of core boring was conducted in the Beris area among others; 3 holes of 30 m each at the Beris Damsite 1, 3 holes of 30 m each at the Beris Damsite 2 and 1 hole of 20 m at the Beris Suddle Damsite. The results of the investigation compiled in Annex J of the final report of Part 1 Study show that the Beris Damsite 2 should be selected to the Beris Damsite 1, where a fault was detected. Drill logs resulted from Part 1 Study are incorporated herein.

The objective of the geological investigation under Part 2 Study is to examine the foundation geology of the proposed Beris Damsite 2, Beris Saddle Damsite and quarry site in sufficient detail for the feasibility design and cost estimate by conducting a surface exploration, geological drilling and seismic exploration. Out of 18 holes of 520 m in total length of drilling, 11 holes of 310 m in total length for the main dam site and an alternative quarry site were financed by the Government of Malaysia and the remaining 9 holes of 210 m of drilling and 2,100 m of seismic exploration were undertaken by JICA.

Further, drill logs, seismic exploration results, and results of water pressure test and water head falling test are shown in Appendices A to D attached to this Annex.

2. OUTLINE OF FIELD INVESTIGATION

2.1 General Description of the Damsite and Reservoir Area

The proposed Beris damsite is located in a narrow valley of the Beris river, a left tributary of the Muda river, 1.6 km upstream of the confluence of the Muda river and the Beris river.

A paved road linking Alor Setar, Nami, Sik and Gurun crosses the Muda river near Nami. An unsealed all-weather road branching off the abovementioned road near Nami travels on the left bank of the Muda river and leads to Kg. Kuala Beris, which is located near the confluence of the Muda river and the Beris river. The right abutment of the proposed Beris dam is accessible from Kg. Kuala Beris through a jeepable road on the right bank of the Beris river.

The reservoir area extends on a hilly region on the southeast of the damsite with peaks ranging from El. 200 m to El. 450 m. Upstream area of the proposed reservoir is featured by mildly undulating terrain of low reliefs, involving a eastern part of the Alor Setar - Nami - Sik - Gurun road.

The damsite and reservoir areas are situated in the geological province of Triassic Semanggol Formation, which consists of sandstones, shales, gritty sandstones and conglomerates. Intrusive rock of granite is encountered in the upstream end of the reservoir area. A geological map of the proposed damsite and reservoir area is shown in Plate 2.

The sandstones are light grey, grey and bluish grey coloured, fine to medium grained hard rock in fresh condition. Some are highly siliceous. If weathered it is discoloured to yellowish brown, white, and sometimes purple.

The shales are grey to dark grey coloured and moderately hard in fresh condition. They bear latent cleavages in common in similar orientations as the bedding plane and are apt to break along those cleavages when shocked. However, as a mass, they are fairly strong and not very flaky. They are weakened and discoloured to yellowish brown, reddish brown and white by weathering.

The gritty sandstones and conglomerates are rather minor members in extent, but they are well developed in the vicinity of the dam site. The gritty sandstone is largely composed of angular to sub-angular particles of rock fragments, grey coloured in general, medium grained and very hard. The conglomerate is made of angular, sub-angular and round fragments of chert, argillaceous rock and quartz, ordinarily of granule and pebble size, with the gritty sandstone as matrix. It is characteristic that the aggregate of many angular to sub-angular rock fragments are in small size and in various colours. While conglomerate is the term of customary usage for this member, the term of polymictic lithrudite has been given appropriately by Teoh Lay Hock, Geological Survey of Malaysia (1974). Relation between the gritty sandstone and the conglomerate is very often gradual transition.

Sandstone and shale alternation covers widely the reservoir area. The lenses of the gritty sandstone and conglomerate are exposed in the vicinity of the damsite and on the right bank of the Charok river, a right tributary. Mt. Dada Ayam (El. 447 m) on the right bank is composed of the same member.

Geological structure of the reservoir area shows roughly north to south trend as presented in general strike of the bedding planes, though considerable deviations are observed. Dip of the strata varies in gradient and direction. It is believed that the boundary between the upstream granite zone and the Semanggol Formation is a fault contact of northeasterly and east-west trends. Also, a probable fault runs northwesterly through the saddle dam site at 500 m north of the main damsite.

Although the slopes in the reservoir area appear to be covered with thick residual soil, these slopes are generally of mild inclination. It seems not probable that any rapid land slidings of large scale may jeopardize the safety of dam and reservoir. No evidences are observed for possibility of leakages through bedrock in the reservoir rim, which is sufficiently thick.

2.2 Surface Exploration

A geological surface exploration resulted a geological map in scale of 1/10,000 covering the mainsite, saddle damsite and alternatives of quarry site, and one in a scale of 1/1,000 covering the main damsite and one in a scale of 1/1,000 covering the saddle damsite. Plates 3, 4 and 8 are reduced compilations of the maps.

2.3 Core Drilling

In Part 1 Study, two alternative damsites were proposed; the present main damsite was called the Damsite No. 2 and the other site located 750 m upstream of the present main damsite was named the Damsite No. 1. Three holes each 30 m deep were drilled at each damsite; one in the left abutment slope, one in the bottom of valley and one in the right abutment slope. One hole of 20 m in depth was located at the bottom of the saddle. The results of core drilling showed that there is a quite probable fault which passes Damsite No. 1 and the saddle damsite. It was then judged that the Damsite No. 2 (+ saddle dam) should be selected to be Damsite No. 1, because the treatment of the fault, though it is not difficult, is supposed to be easier for a lower saddle dam than for a higher No. 1 dam.

In starting the core drilling in Part 2 Study, it was planned that the whole drilling of 250 m for the main damsite would be undertaken by the Government and that of 90 m for the saddle damsite and 120 m for a quarry site would be undertaken by JICA.

The proposed quarry site (Quarry 1) was located on the upper slope of the left abutment of the main dam. Bore holes in this site, however, showed that the rocks are heavily weathered to a depth of 40 m or more.

The holes of 57 m in total length only were drilled in this Quarry Q1 and two holes of 63 m in total length were drilled in Quarry Q3, which was selected 200 m downstream of Quarry Q1.

A possible quarry site was found on the top of the hill between the main and saddle damsites. This site is named Quarry Q2 and two holes of 30 m each were drilled as an additional undertaking by the Government.

All the bore holes except those at Damsite No. 1 are listed in Table 1 and their locations are shown in Plate 1. Table 2 shows the work quantities performed for core drillings, standard penetration tests, permeability tests and installation of perforated PVC pipes. In Part 2 Study, 18 holes of 520 m in total length were drilled. Out of these, 11 holes of 310 m in total length were undertaken by the Government and 7 holes of 210 m in total length were undertaken by JICA.

Drill logs obtained in Part 1 and Part 2 except those for Damsite No. 1 are compiled in Figs. A-1 to A-32.

2.4 Seismic Exploration

Seismic exploration was carried out at the main damsite, saddle damsite and Quarry Q1, as summarized in Table 3. The seismic exploration lines were 10 in number and 2,100 m in total length. Their locations are shown in Plate 1.

The results of seismic exploration are shown as travel time-distance curves and velocity zone profiles in Plates B-1 to B-11.

3. THE MAIN DAMSITE

3.1 Surface Geology

The river channel of 20 m in width adjoins mountain slopes of 30° on both banks. It frequently exposes bedrocks such as gritty sandstones and conglomerate, while river deposit is thin on a rapid slope of about 1/100. No sign of fault is found out.

There are small scale talus deposits near the brooks which are located 50 m upstream and 250 m downstream of the proposed dam axis on the left bank. On the other hand, there is no brook but gritty sandstones and conglomerate crop out to a great extent on the right bank.

Triassic Semanggol Formation of gritty sandstones and conglomerate, sandstones, alternations of shales and fine grained sandstones is overlain by Alluvial deposits in the riverbed.

Gritty sandstones and conglomerates are dominant in the main damsite containing many fragments of slate and quartzite of less than 2 cm in diameter. They are highly resistant to weathering because their matrices and fragments are hard and well cemented. Sandstones are also hard and resistant to weathering, derived from coarse grained quartzite. Shales occur in far remote area from the main damsite (for geological map, refer to Plate 4).

Bedding plane strikes N45E and dips 20NW, approximately parallel with the left bank slope. Joints develop at intervals of 2 m to 3 m in parallel with and perpendicular to the bedding plane.

3.2 Subsurface Geology of Main Dam

Geological profile of main damsite is shown on Plates 5 and 6.

There are six p-wave velocity layers in the main damsite, according to the results of seismic exploration. They can be correlated with density of materials in general. The density is closely related to the weathering conditions of rocks. The p-wave velocity represents average density condition of the subsurface materials. Accordingly there are some parts where the velocity cannot be related with boring core samples.

The velocity layer of 0.3 km/s corresponds to the topsoil of extremely soft, unsaturated clay containing rock fragments. It covers top 1 m in depth of slopes, tending thicker in higher part of slopes. Riverbed and other areas of outcrops of sandstone and conglomerate lack this layer. The velocity layer of 0.6 km/s corresponds to the residual soils of very stiff clay containing many rock fragments. It is located under the topsoil in a thickness of 1 m to 2 m. The velocity layer of 1.5 km/s corresponds to 1 m to 3 m thick upper weathered zone of strongly weathered rocks accompanied by frequent cracks and joints, or saturated sand and gravel layer on the riverbed. The velocity layer of 2.0 km/s to 2.5 km/s corresponds to the lower weathered zone, in which rocks appear fresh but they are weathered to involve many latent cracks.

This layer is thin of 1 m but thickness increases to 10 m to upper portion of slopes. The velocity layers of 3.5 km/s to 4.0 km/s correspond to fresh rock zone of alternation of sandstone, conglomerate and gritty sandstone involved joints rather frequently. The p-wave velocity of 4.0 km/s is limited to the right bank, where gritty sandstones are almost monolithic with joints tightly closed.

Line E of seismic exploration was placed on the proposed dam axis, on which 3 boreholes were drilled and 3 holes of Part 1 Study are also closely located. The number of holes are BS-3, BM-10, BS-2, BM-8, BM-5 and BS-1, from the left to the right (BS: drilled Part 1 and BM in Part 2).

Rocks in BS-3 are solid, hard and almost fresh conglomerate intercalated with thin sandstone layers. Top 2.7 m in depth consists of topsoil and completely weathered soft conglomerate, underlain by intensively weathered layer of conglomerate to 3.65 m. Below these sections hard conglomerate and sandstone are recovered except weathered zones of 8.0 m to 14.2 m, 15.5 m to 17.5 m, and 25.6 m to 28.1 m. In BM-10 topsoil and residual soil are in the section of 0.0 m to 2.16 m. Below 2.16 m hard consolidated conglomerate and sandstone are recovered. BS-2 near the riverbed confirmed thin soil layer for 1.05 m below the ground surface. There obtained fresh conglomerate, sandstone, and gritty sandstone below the above section. BM-8 in the riverbed confirmed fresh conglomerate and gritty sandstone in the whole drilled sections except thin river deposits. Topsoil and residual soil are recovered from the section of 0.0 m to 2.45 m in BM-5. Below 2.45 m, hard conglomerate and sandstone are recovered. Thin residual soil for 0.9 m is confirmed in BS-1. The section below 0.9 m is predominantly hard conglomerate zones.

Subsurface condition along the dam axis is summarized from the result of seismic exploration and core boring as follows. The foundation rock of the proposed dam is composed of the layers of conglomerate and gritty sandstone (Ch-Cl based in Table 4), sandstone and gritty sandstone (Ch-Cl), and alternation of conglomerate and gritty sandstone (Ch-Cm). These formations have a monoclinal structure, dipping 10° to 15° from the left abutment to the right abutment.

The right abutment is dominated by the conglomerate and gritty sandstone. Conglomerates, gritty sandstones and sandstones are developed alternatingly along the river channel and in the left abutment.

Depth of weathered zones increases with height of the abutment slope. The weathered zone is thinner near river channel in general. The total depth of overburden, topsoil and residual soil, ranges between 0.6 m and 2.2 m on the left abutment and between 0.9 m and 2.5 m on the right abutment.

The bore holes BM-7, BM-8, BM-9, and BM-12 are located along the river channel. River deposits are confirmed in these bore holes, ranging in depth between 0.3 m and 1.5 m. The conglomerate and sandstone below the riverbed are fresh and hard except for partial fractured zones.

3.3 Subsurface Geology of Other Main Structures

Geological profile of other main stracture is shown on Plate 6.

The seismic exploration line A is along the assumed diversion tunnel. The velocity of p-wave is classified into five layers like along the main dam axis, as shown in Table 5. On this seismic exploration line three bore holes, BM-4, BM-5, and BM-6, were drilled. The recovered core samples from these bore holes are mostly hard consolidated conglomerate and hard sandstone with 100% of core recovery and nearly 100% of RQD. (RQD is defined in Page GA-1.)

The seismic exploration line D crosses the toe portion of the main dam. The p-wave velocity is also classified into five layers like the main dam axis. Three bore holes of BM-9, BM-11, and BM-12 were drilled at the toe portion of the main dam. From these bore holes the formations of conglomerate, sandstone, gritty sandstone, and alternation of sandstone and conglomerate are recovered. The recovered core samples show 100% of core recovery an more than 50% of RQD. There are some poor RQD portions partly because of fracturing of the bedrocks. However, as the fracturing is limited into small parts, the general condition of the foundation rocks is judged to be stable.

The seismic exploration line C is located on the slope of the left abutment. This line is to detect general subsurface condition on the left abutment, assuming an alternative alignment of the diversion tunnel. The p-wave velocity along line C is also classified into five layers as other exploration lines.

On the seismic line C, only one bore hole (BM-10) is located. The recovered bedrocks from this bore hole are conglomerate, and alternation of sandstone and gritty sandstone. The core recovery of this bore hole is 100% and RQD is more than 70-80% in general. Although the recovered cores are fractured partly, general core condition in fresh, hard, and well consolidated.

3.4 Permeability of the Foundation Rock in the Main Damsite

Distribution of permeability along the main dam axis is shown in Plate 7. Rather high Lugeon of 25-26 and 20 are confirmed in the sections between 17 m and 25 m and between 30 m and 35 m in BM-8. The other high Lugeon values of 530 and 400 are measured in a shallow zone, which is fractured and weathered, in BM-10. Except these high Lugeon units, the remaining units are small being mostly below 10. Consequently the permeability of the foundation rocks on the dam axis is generally very small, but the relatively pervious zones are detected in BM-8.

On the other hand, the distribution of permeability of the foundation rocks along the river channel is changeable. High Lugeon values of more than 100 are measured in the sections between 15 m and 20 m in BM-9 and between 20 m and 30 m in BM-12, corresponding to fractured zones.

Along the seismic exploration line A, there are three bore holes BM-4, BM-5, and BM-6. Lugeon values measured by packer method in these bore holes are less than 8 except the zones of loose shallow zones. Bedrocks are in impervious condition generally.

Along the seismic exploration line D, there are three borehole, BM-9, BM-11, and BM-12. The measured Lugeon values are less than 10 generally. However, Lugeon values in the sections between 15 m and 25 m in BM-9, 15 m and 20 m in BM-11, and 15 m and 30 m in BM-12 exceed 20. Especially, in the sections of 15-20 m in BM-9 and 20-30 m in BM-12 Lugeon values exceed 100. These sections of high Lugeon values correspond to heavily weathered and fractured bedrock zones. Spring water was observed at the depth of 25 m in BM-12. This spring water probably implies disturbed zones; faults or fractured zones, through which water leakage pose high Lugeon values.

Along the seismic line C, there is only one bore hole, BM-10. Permeability of the bedrocks is small of less than 10 in Lugeon unit except that the zones shallower than 10 m in depth have Lugeon units more than 100 because of loosened condition by weathering. The bedrock deeper than 10 m seems to be very hard and stable.

3.5 Engineering Interpretation

Surface and subsurface geological conditions are investigated by means of surface exploration, core drilling accompanied by bore hole permeability tests, and seismic exploration.

The foundation rocks of the main dam are alternation of conglomerate, sandstone and gritty sandstone, which have gentle dipping from the left abutment to the right abutment and from the upstream side to the downstream side.

Topsoils and residual soils are thin of 1 m to 3 m in general. Weathering also does not develop deeply into the foundation rocks; less than 10 m in general.

Judging from the obtained results, a concrete gravity dam should be built on the top of lower weathered zone. The required average excavation depth will be 7 m in the left abutment, 5 m in the right abutment, and 4 m in the riverbed section respectively.

If a fill type dam is selected, the foundation of impervious core also should be the top of lower weathered zone, but the shell zone can be placed on the top of upper weathered zone.

Permeability of the foundation rocks is small generally, and the zones of relatively high Lugeon values can be improved by ordinary cement grouting.

As for consolidation grouting, ordinary method and quantity of grouting will be sufficient for the foundation rocks.

4. SADDLE DAMSITE

4.1 Surface Geology

The proposed saddle damsite is located 700 m northeast of the main damsite. The height of the saddle dam is about 15 m above the ground surface. The slopes on both abutments are mildly inclined and covered by topsoil and residual soil with thickness of 4 m to 10 m.

The bedrock is composed of areno-argillaceous sedimentary rocks of Semanggol Formation. Sandstone is largely developed on the left abutment, while alternation of shales and fine sandstones predominates on the right abutment (for geological map, refer to Plate 8).

4.2 Subsurface Geology

Geological profile of saddle damsite is shown on Plate 9.

Seismic exploration along the saddle dam axis distinguished five velocity layers under the ground, as shown in Table 6. Competently solid foundation rock zone is represented by the layers with seismic wave velocity not less than 2.0 km/sec. The other layers overlying the above are correlated with badly deteriorated rock zone and soil overburden.

Four core borings, BSS-2, BSS-3, BRS-1 (PART 1), and BSS-4 from the left bank to the right bank, were carried out along the assumed saddle dam axis. Alternations of sandstone, conglomerate, and shale are recovered from the bore holes BSS-2 and BSS-3, which are located on the left abutment and central part of the dam axis. Only alternation of shale and fine sandstone is confirmed in the bore hole BSS-4, on the right abutment.

The recovered core samples are in poor condition in general: RQD is almost zero and the core recovery is often very low, especially in the section below 10 m in the bore holes BSS-3 and BRS-1. Very weak shale and sandstone are recovered from this section.

Low velocity zone is not found out at the middle part of the dam axis on the time-distance curves; however, the recovered core samples from the bore holes BSS-3 and BRS-1 are very weak and very likely to suggest the presence of a fault zone. On the other hand, a low velocity zone was identified in the left abutment, suggesting the presence of another fault.

4.3 Permeability of the Foundation Rock in the Saddle Damsite

Results of the bore hole permeability test are presented in Lugeon Map in Plate 10. Permeability shows rather low values in general; lower than 15 Lugeon unit in the most test sections. Only three sections out of twenty one indicate higher value ranging from 28 to 56 Lugeon unit, of which two sections are located deeper than 20 m in the sandstone on the left abutment and one is in the depth of 15 m to 20 m in the shale and sandstone alternation on the right abutment. The inferred fault zone and the superficial weathered zone indicate rather low permeability, presumably because of clayey material included.

The high permeability in the deep zone is deemed due to open cracks in fresh hard rock, which can be treated rather easily with cement grouting.

4.4 Engineering Interpretation

Intensive weathering is developed to the depth of 5 m to 12 m on the left abutment and 5 m to 8 m on the right abutment. Foundation excavation for impervious core zone of the rockfill dam should be performed up to the above depth, below which lies solid bedrock of the lower weathered zone. Excavation for shell zone of the dam will be required to the depth of only 3 m on an average, or to the top of the upper weathered zone.

Relatively pervious sections were found out in the permeability test in the bore holes BSS-2 and BSS-4. The maximum permeability is 56 Lugeon unit in the depth of 25 m to 30 m in BSS-2. These high permeability through open cracks in hard rocks can be improved rather easily by means of conventional cement grouting.

Though the bore hole permeability tests indicate low Lugeon values in the lower weathered zone on which the impervious core of the fill-type dam will be placed, it is still possible that some water passages exist at places. Blanket grouting with short group holes at few-meter intervals is recommended to protect the impervious core base.

The fault zone encountered by the bore holes BSS-3 and BRS-1 should be treated by concrete plugging and grouting. This zone could consist of several minor faults, considering that it was not caught by the seismic exploration. The similar treatment shall be applied to the inferred fault on the right abutment, too, which was identified as a low velocity zone in the seismic exploration.

5. QUARRY SITE

The quarry Q1 site is located on the upper half of the left abutment slope of the main damsite. Seismic exploration of 2 lines and 400 m in total length and core drillings at two spots were conducted in this quarry site. The quarry Q1 site consists of conglomerates and sandstone which are thicker than 40 m and intensively weathered. The seismic wave velocity of the weathered rock zone is 1.5 to 1.9 km/s.

The Rock Quality Designation (RQD) of core drilling was only 20 to 30% for both BQ-2 and BQ-3 bore holes. The core samples taken from these bore holes show that the rocks are very cracky and badly deteriorated by subsurface weathering.

Consequently, it was judged that the rock materials in the quarry Q1 site were not suitable for concrete aggregate materials (refer to Plate 11).

The quarry Q2 site is located on the ridge of El. 130 m to 150 m between the main damsite and the saddle damsite. It is about 200 m distance from the saddle damsite and 500 m from the main damsite. Core drilling was conducted at two spots in this quarry site.

The Q2 site consists of mainly conglomerates while a sandstone layer with 5 m in thickness is located about 20 m beneath the ground surface. The results of core drilling show that the thickness of topsoil is as thin as only 3 meters and hard fresh bedrocks are encountered immediately beneath the topsoil. The core samples of bedrocks in the bore holes BQS-5 and BQS-6 were cylindric with almost 100% of core recovery and high RQD.

The quality and quantity of the bedrocks at the quarry Q2 site are judged to be satisfactory both for concrete aggregate materials of the main dam and its appurtenant structures and for embankment materials of the saddle dam. Consequently, the quarry Q2 site would be given with the first priority as the quarry site for the construction of the Beris dam (refer to Plate 12).

The quarry Q3 site is located on the left bank slope of the Beris river about 200 m downstream of the quarry Q1 site. Core drilling was conducted at two spots in the area at about El. 90 m in height. Geology of the site consists of two bedrock zones, sandstones with thickness of 20 m from the ground surface and conglomerates developing beneath the sandstone zone. The thickness of topsoil is about 3 m.

The quality of sandstones is relatively hard and less cracky compared with that of the quarry Q1 site. The conglomerates are, however, so cracky that cylindric core samples were hardly obtained. The efficiency of excavation in the quarry Q3 site will be poor, though the quality of rock materials is much better than that of the quarry Q1. The quarry Q3 site is, therefore, given with the second priority following to the quarry Q2 (refer to Plate 13).

6. FUTURE INVESTIGATION

Now that the general conditions of geology and geotechnics for the Project have been clarified, additional investigations for the detailed design in the future should be made only for confirmations of geotechnical details and check on the spot to meet a final layout of the structures. Items and quantities for the future investigations are proposed as follows:

(1) Core drilling

Saddle damsite: 4 vertical holes, each 30 m deep
2 inclined hole, 60 m long

In view of varied geological conditions in this site; rather frequent changes in rock faces and existance of faults, drilling at shorter intervals are recommendable.

Quarry 2 and 3 sites: 6 vertical holes, each 30 m deep for further confirmation

Bridge sites for relocated road:
8 vertical holes, each 20 m deep

(2) Test trenching

Saddle damsite: 2 trenches, each 30 m long, depth up to the top of weathered bedrock

This shall be performed for in situ observation of the faults, as well as observation of weathered rock and overburden.

(3) Test grouting

Main damsite: 6 vertical grout holes, each 30 m deep

Saddle damsite: 6 vertical grout holes, each 30 m deep

(4) Adit excavation and in situ rock test

Main damsite: Adit: 2 adits, each 30 m long
Rock test: Block shear test 4 blocks
Modulus of elasticity 4 spots

These tests are made for confirmation of design values for shearing strength, modulus of elasticity and modulus of deformation of the foundation rock, that are critical for design of concrete gravity dam.

(5) Sampling and laboratory test

Laboratory rock tests for drill core samples from the main damsite and quarry site, including density test, absorption test, compression test, measurement of Young's modulus and Poisson's ratio, tensile strength test and abrasion test.

Laboratory soil tests for undisturbed samples of overburden in the saddle damsite taken from the test trench, including grain size analysis. Atterberg limit test, unit weight test, triaxial test, consolidation test, permeability test.

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TABLES

Table 1 LIST OF BORE HOLES

Boring No. (drilling length) (m)	Ground Height (El. m)	Coordinate X	Coordinate Y
o Main Dam			
BS - 1 (30)	94.76	19,444.97	37,027.68
2 (30)	51.92	19,349.33	37,027.20
3 (30)	92.90	19,279.60	37,027.15
BM - 4 (15)	58.93	19,411.14	37,073.08
5 (30)	76.73	19,400.88	37,017.38
6 (15)	57.95	19,350.94	36,944.93
7 (20)	50.75	19,372.08	37,048.08
8 (50)	50.27	19,369.01	37,027.99
9 (30)	51.29	19,358.44	36,999.38
10 (30)	70.87	19,323.60	37,041.92
11 (30)	51.52	19,336.91	37,005.79
12 (30)	50.67	19,341.79	36,983.58
o Saddle			
BRS - 1 (20)	69.76	19,910.88	37,428.13
BSS - 2 (30)	87.93	19,861.98	37,372.40
BSS - 3 (30)	71.14	19,903.48	37,405.01
BSS - 4 (30)	91.33	19,964.41	37,482.39
o Quarry			
BQ - 1 (33)	89.28	19,191.96	36,910.68
2 (22)	195.44	19,045.51	37,065.50
3 (35)	192.71	19,043.23	37,015.54
4 (30)	77.21	19,196.49	36,815.43
5 (30)	133.33	19,698.69	37,199.36
6 (30)	143.51	19,813.77	37,227.80

Table 2 QUANTITIES OF CORE DRILLING

	Boring No. (nos.)	Drilling Length (m)	*1 S.P.T. (times)	Permeability Test *2 (nos.)	Perforated P.V.C. Pipe (m)
Main dam site	(BS 1)*3	(30)*3	(1)*3	(6)*3	(30)*3
	(BS 2)*3	(30)*3	(1)*3	(5)*3	-
	(BS 3)*3	(30)*3	(2)*3	(6)*3	(30)*3
	** BM 4	15	1	3	-
	** BM 5	30	2	6	30
	** BM 6	15	1	3	15
	** BM 7	20	-	4	-
	** BM 8	50	-	10	-
	** BM 9	30	1	6	-
	** BM 10	30	1	6	30
	** BM 11	30	1	6	-
	** BM 12	30	-	6	-
Sub-total	9	250	7	50	75
Saddle dam	(BRS 1)*3	(20)*3	(3)*3	(3)*3	-
	BSS 2	30	3	6	30
	BSS 3	30	3	6	30
	BSS 4	30	3	6	30
Sub-total	3	90	9	18	90
Quarry site	BQ 1	33	-	-	-
	BQ 2	22	1	-	-
	BQ 3	35	1	-	-
	BQ 4	30	1	-	-
	** BQ 5	30	1	-	-
	** BQ 6	30	1	-	-
Sub-total	6	180	5		
Total of Part 2 drilling	18	520	21	68	165
Total of Part 1 (1983), Part 2 (1984)	22	630	28	88	225

Remarks:
*1: S.P.T. = Standard Penetration Test
*2: Water Pressure Test of Water Falling Head Test
*3: (Part 1 Boring work in 1983)
**: Financed by the Government of Malaysia

Table 3 SUMMARY OF SEISMIC EXPLORATION LINES

Location	Line	Start of Line Coordinate		End of Line Coordinate		Length/ (m)	Intersection Point	Boring Point Located on the Line Coordinated		
		X	Y	X	Y			Boring No.	X	Y
Main Dam Site	A	19,449.214	37,087.275	19,335.727	36,922.596	200	A85xE190 A138xD85	BS5 BS6	19,400.88 19,350.94	37,017.38 36,944.93
	B	19,379.100	37,117.871	19,332.410	36,923.394	200	B141xD59			
	C	19,289.160	36,922.141	19,349.303	37,122.885	200	C115xE109 C69xD20	BS10	19,323.60	37,041.92
	D	19,290.706	37,003.300	19,482.476	39,946.497	200	D20xC69 D59xB141 D85xA88	BS12	19,341.79	36,983.58
	E	19,219.897	37,074.793	19,505.828	36,983.999	300	E109xC-115 E145xB90 E190xA85	BS10 BS8 BS5	19,323.60 19,369.01 19,400.88	37,041.92 37,027.99 37,017.38
Saddle Dam Site	S1	19,814.666	37,319.612	20,016.449	37,541.612	300	S1,150xS3.80	BRS2 BRS4	19,861.98 19,964.41	37,372.40 37,482.39
	S2	19,888.997	37,319.618	20,023.519	37,467.616	200	S2,100xS3,135			
	S3	19,856.359	37,484.420	20,004.357	37,349.897	200	S380xS1,150 S3,135xS2,100			
Quarry Site	QS1	19,449.391	37,150.404	19,040.260	36,950.613	200	QS1,101xQs2,100	BQ2 BQ3	19,045.511 19,043.228	37,065.501 37,015.543
	QS2	18,944.931	37,055.075	19,144.722	37,045.943	200	QS2,100xQS1,101			

Table 4 CRITERIA FOR ROCK GRADE CLASSIFICATION*

Grade	Description	RQD (%)	Core Recovery (%)	Remarks
A	Very fresh in lithologic character. Constituent minerals are not weathered and altered at all. The rocks as a whole are very solid and densely hard. Few cracks are seen.	probably more than 70	100	Very good property as concrete dam foundation (height 60 m+) and rock fill dam core foundation (height 60 m+)
B	Fresh in lithologic character. Constituent minerals are little weathered and altered. The rocks as a whole are solid and densely hard. Cracks are sparsely seen, with close adhesion.	more than 50	100	Very good (the same as the above)
C_H	Almost fresh, solid and hard in lithologic character. Among constituent minerals, feldspars and colored minerals are slightly weathered and altered. Cracks are seen considerably. Crack walls are mostly colored, but closed adhesion. Long cylindric cores.	more than 30	100	Almost good (the same as the above)
C_M	Generally a little weathered and altered in lithologic character. Constituent minerals, feldspars and colored minerals are weathered, often being brown. Cracks are open with thin materials. Short cylindric cores. Rocks often collapse by a strong hammer blow.	20-30	more than 80	Almost durable property as rock fill dam core foundation (height 60 m+) and concrete dam foundation
C_L	Constituent minerals are considerably weathered. Rocks are as a whole brown or reddish brown. Cracks are open and contain clay or weathered materials. Rocks often collapse by a light hammer blow. Almost fragment cores.	zero	about 50 or less	Not appropriate but sometimes durable property as rock fill dam foundation abutment
D	Constituent minerals are considerably weathered or altered and sandy or clayey portions are often seen. Cracks are unclear. Generally rocks are soft and friable. Often drilled by no water drill.	zero	Often drilled by no-water	Bad

Remark; *: By the standards of the Central Research Institute of Electric Power Industry of Japan.

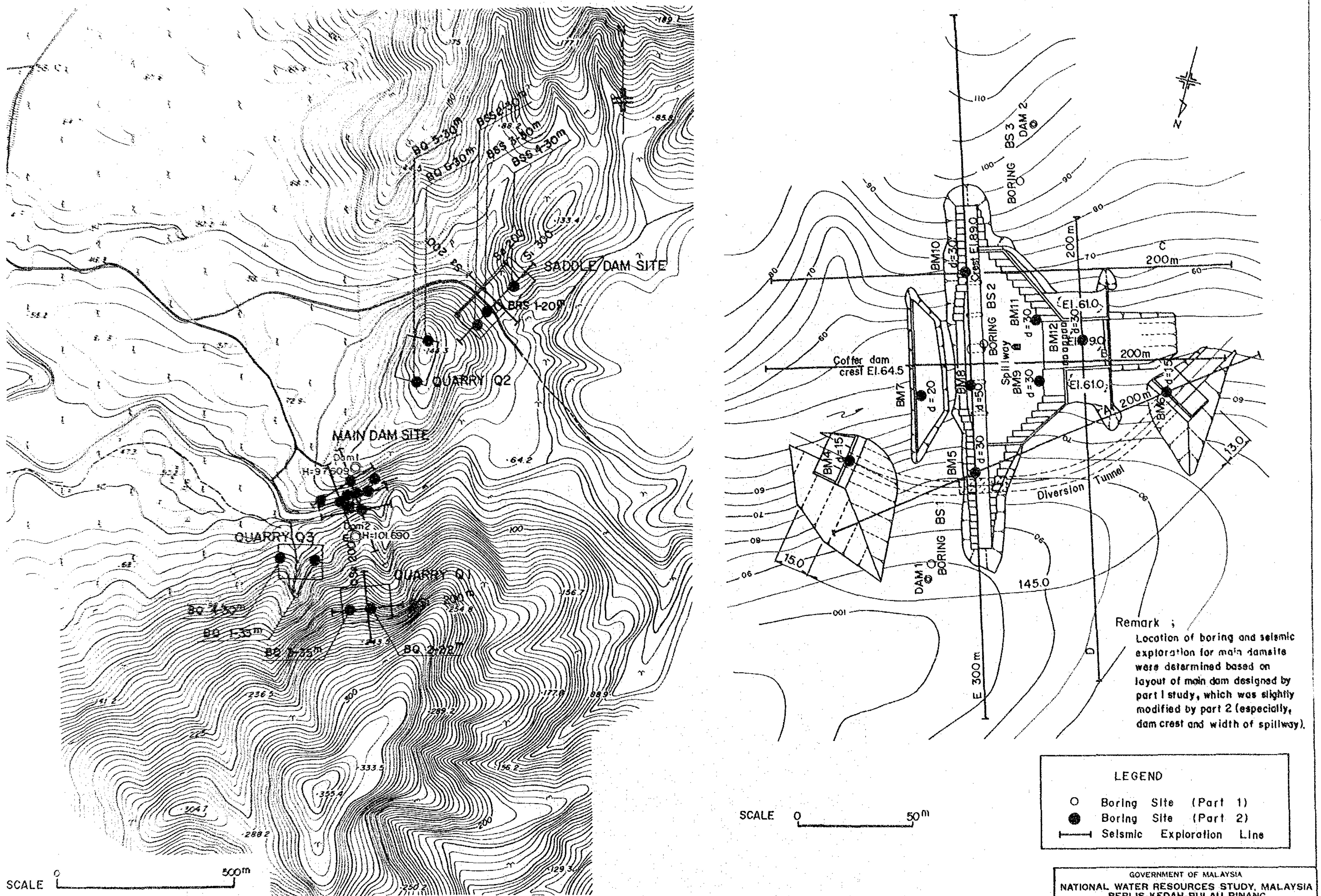
Table 5 RELATION OF SEISMIC VELOCITY LAYERS AND GEOLOGY AT MAIN DAMSITE

Layers (km/s)	Geological Condition	Thickness (m)	Description
0.3	Topsoil	= 1	Not existing in the riverbed. Widely distributed in higher parts of the slopes. Extremely soft, unsatulated clay including rock fragments.
0.6	Residual soil	1 - 2	Not existing in the riverbed. Very stiff clay including many rock fragments.
1.5	Upper weathered zone or Alluvial at the river bed	1 - 3	Water saturated sand and gravel on the river. Strongly weathered rock with clay along cracks.
2.0 - 2.5	Lower weathered zone	2 - 10	Very thin layer beneath the river beds. Widely distributed beneath the higher parts of the slopes. Apparently similar to fresh rock, but developing the latently cracks by weathering.
3.5 4.0	Fresh rock zone	-	3.5 km/s layer extends from the left bank and nearly to the river. 4.0 km/s layer develop at the right bank. Fresh rock.

Table 6 RELATION OF SEISMIC VELOCITY LAYERS AND GEOLOGY AT SADDLE DAMSITE

Layers (km/s)	Geological Condition	Thickness (m)	Description
0.3 - 0.35	Topsoil	1 ~ 3	Thickly developed on the left bank and rather thin on the right bank. Extremely soft and unsaturated clay including rock fragments.
0.6	Residual soil	1 - 4	Thickly developed in the left bank, while thickness is 1 - 2 m in the right bank. Very stiff clay including many rock fragments.
1.5	Residual soil and Upper weathered zone	2 - 10	Extremely stiff clay including many rock fragments. Strongly weathered rock including clayey zone along cracks.
2.0	Lower weathered zone	5 - 15	Thickly distributed in the left bank, while 5 - 10 m in the right bank. Apparently similar to the fresh rock, but developing the latently cracks by weathering.
2.5 3.5	Fresh rock zone	-	The 2.5 km/s layer is wide-spread. The 3.5 km/s layer developes only in higher parts of the slopes in the right abutment. Fresh rock includes many cracks.

PLATES



Location of Boring and Seismic Exploration

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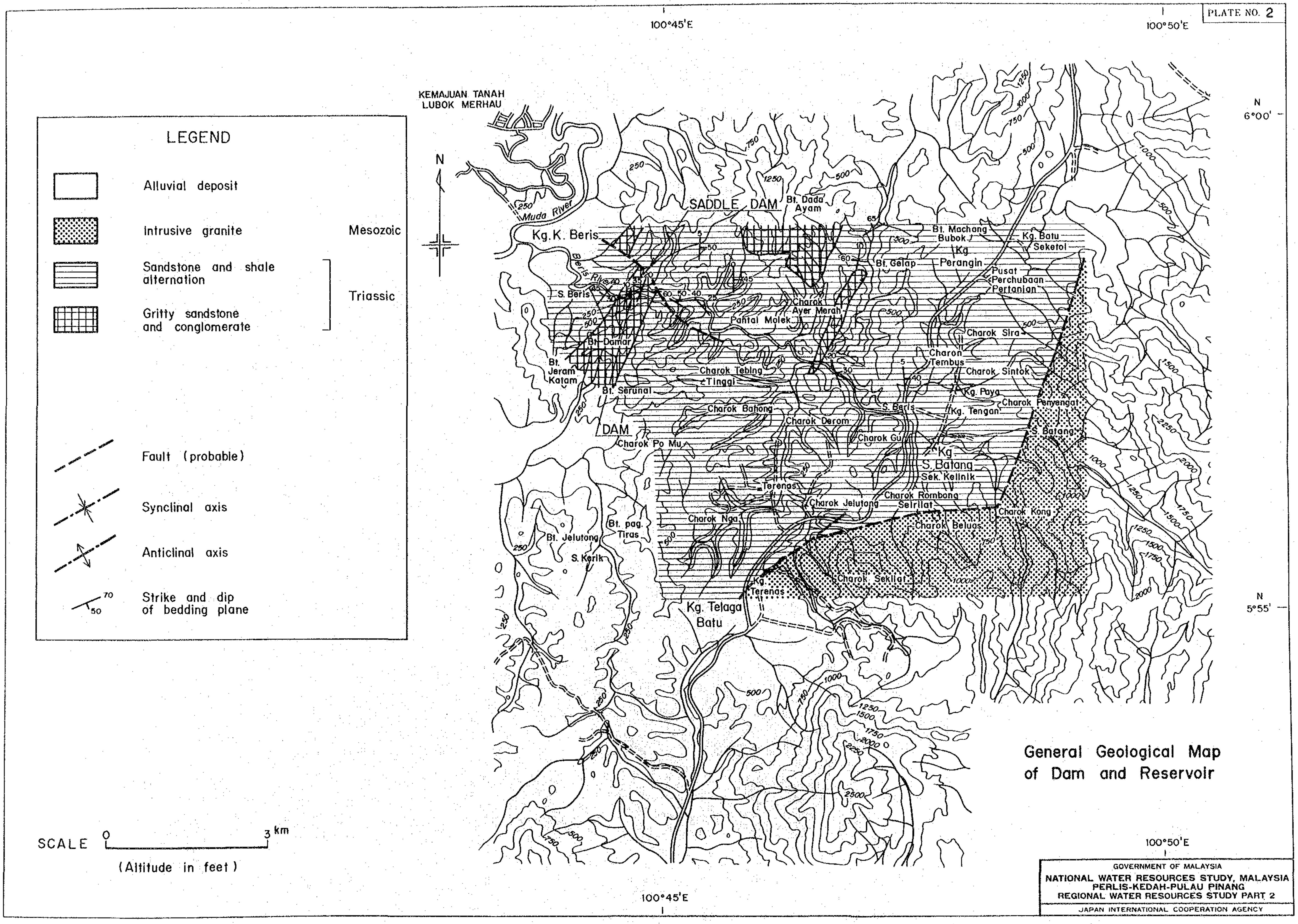
PLATE NO. 2



General Geological Map of Dam and Reservoir

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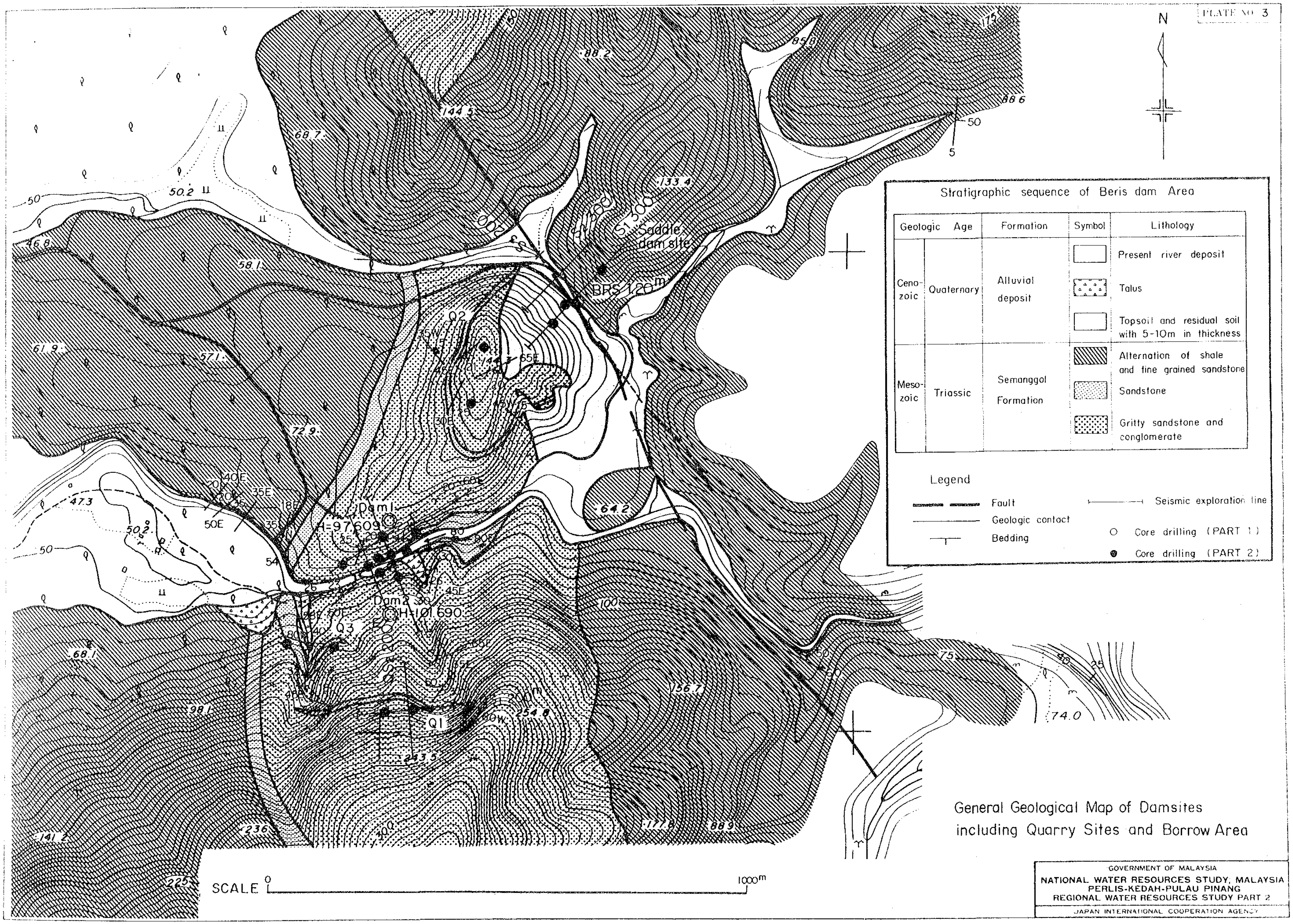

Stratigraphic sequence of Beris dam Area

Geologic Age		Formation	Symbol	Lithology
Cenozoic	Quaternary	Alluvial deposit		Present river deposit
				Talus
				Topsoil and residual soil with 5-10m in thickness
Mesozoic	Triassic	Semanggol Formation		Alternation of shale and fine grained sandstone
				Sandstone
				Gritty sandstone and conglomerate

General Geological Map of Damsites including Quarry Sites and Borrow Area

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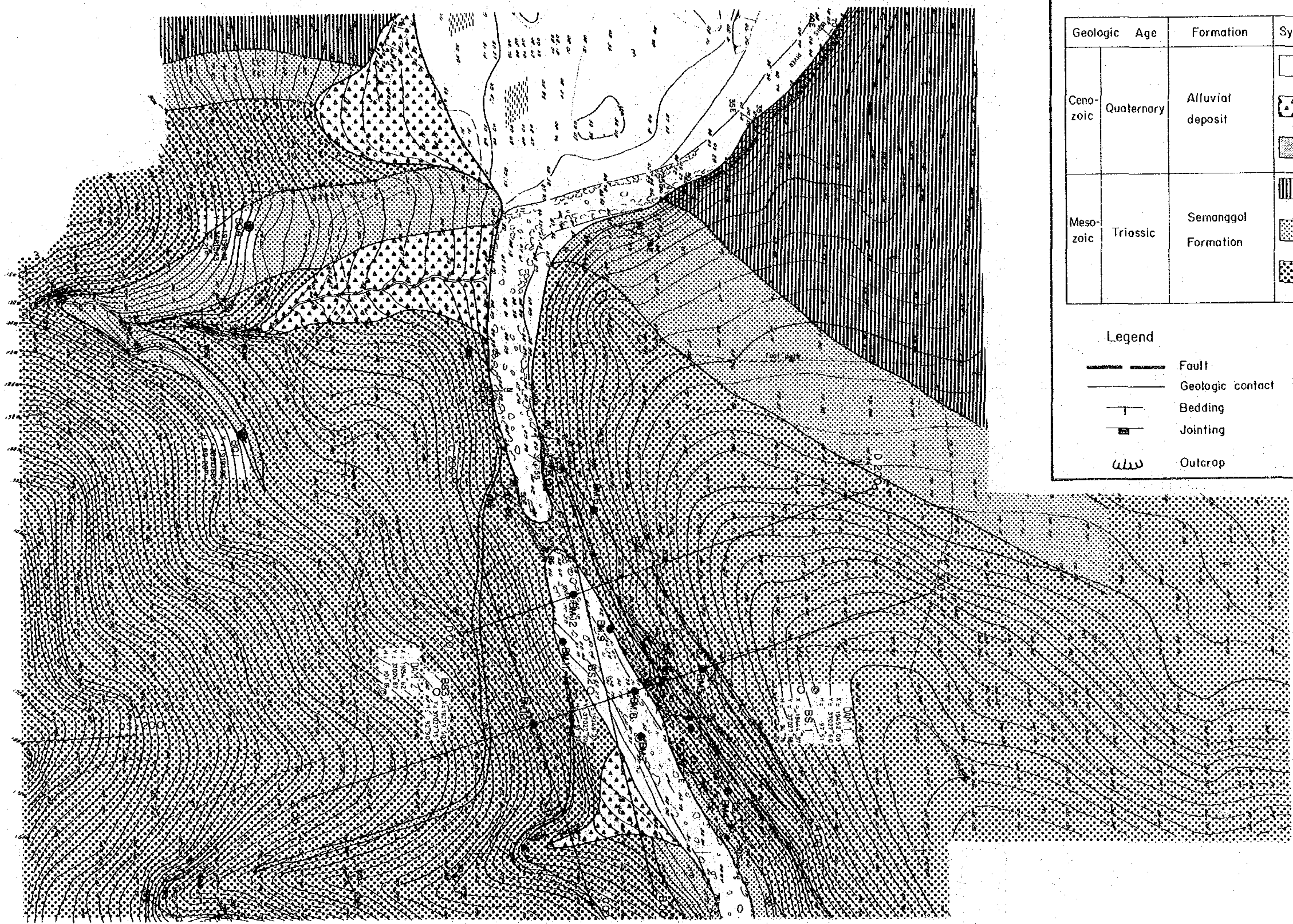
PLATE NO. 4



Stratigraphic sequence of Beris dam Area

Geologic Age		Formation	Symbol	Lithology
Cenozoic	Quaternary	Alluvial deposit		Present river deposit
				Talus
				Topsoil and residual soil with 5-10m in thickness
Mesozoic	Triassic	Semanggol Formation		Alternation of shale and fine grained sandstone
				Sandstone
				Gritty sandstone and conglomerate

Legend

- Fault
- Geologic contact
- Bedding
- Jointing
- Outcrop
- Seismic exploration line
- ○ *Core drilling (PART 1)*
- ● Core drilling (PART 2)

SCALE 0 — 150m

Detailed Geological Map of Main Damsite including Quarry Q3 Site

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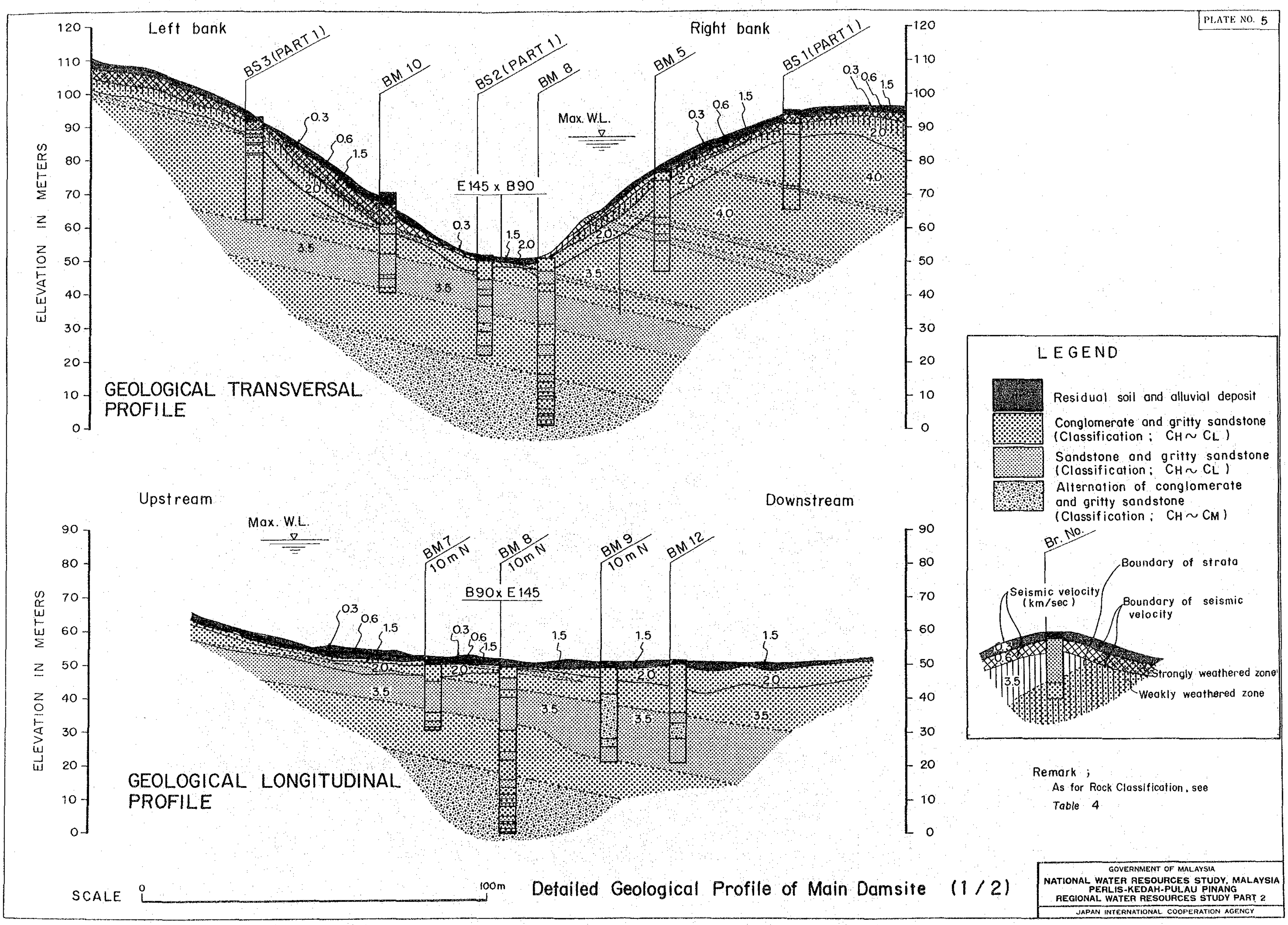
PLATE NO. 5
Left bank
Right bank
BS3(PART 1)
BM 10
BS2(PART 1)
BM 8
BM 5
BS1(PART 1)
Max. W.L.
E145 x B90
ELEVATION IN METERS
GEOLOGICAL TRANSVERSAL PROFILE
Upstream
Downstream
BM7 10m N
BM 8 10m N
BM 9 10m N
BM 12
B90x E145
GEOLOGICAL LONGITUDINAL PROFILE
LEGEND
Residual soil and alluvial deposit
Conglomerate and gritty sandstone (Classification ; CH ~ CL)
Sandstone and gritty sandstone (Classification ; CH ~ CL)
Alternation of conglomerate and gritty sandstone (Classification ; CH ~ CM)
Br. No.
Seismic velocity (km/sec)
Boundary of strata
Boundary of seismic velocity
Strongly weathered zone
Weakly weathered zone
Remark ;
As for Rock Classification, see Table 4
SCALE 0 100m
Detailed Geological Profile of Main Damsite (1/2)
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