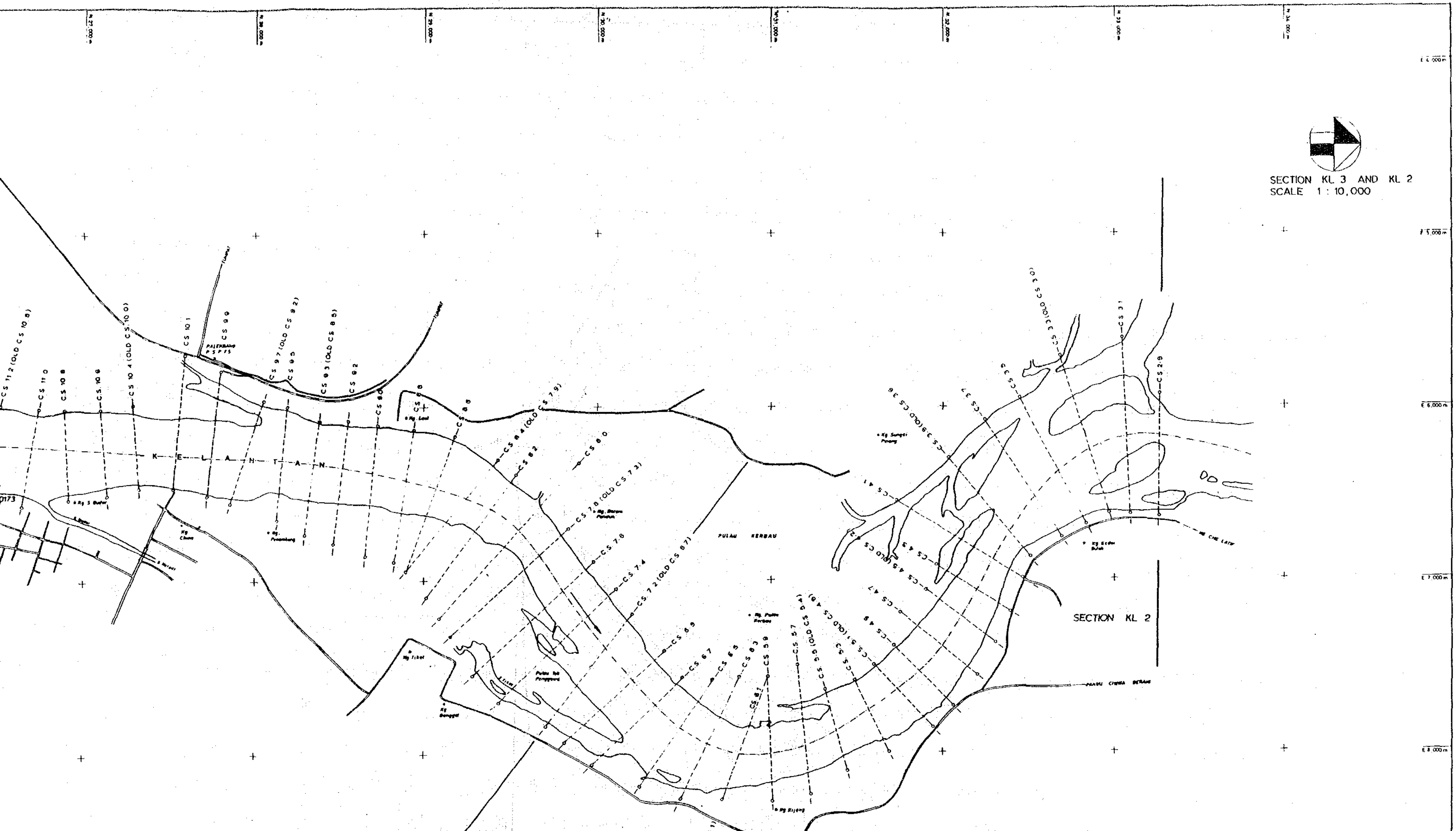

Fig.I.4.1
Index of River Cross Sections(1/4)
(Kota Bharu)

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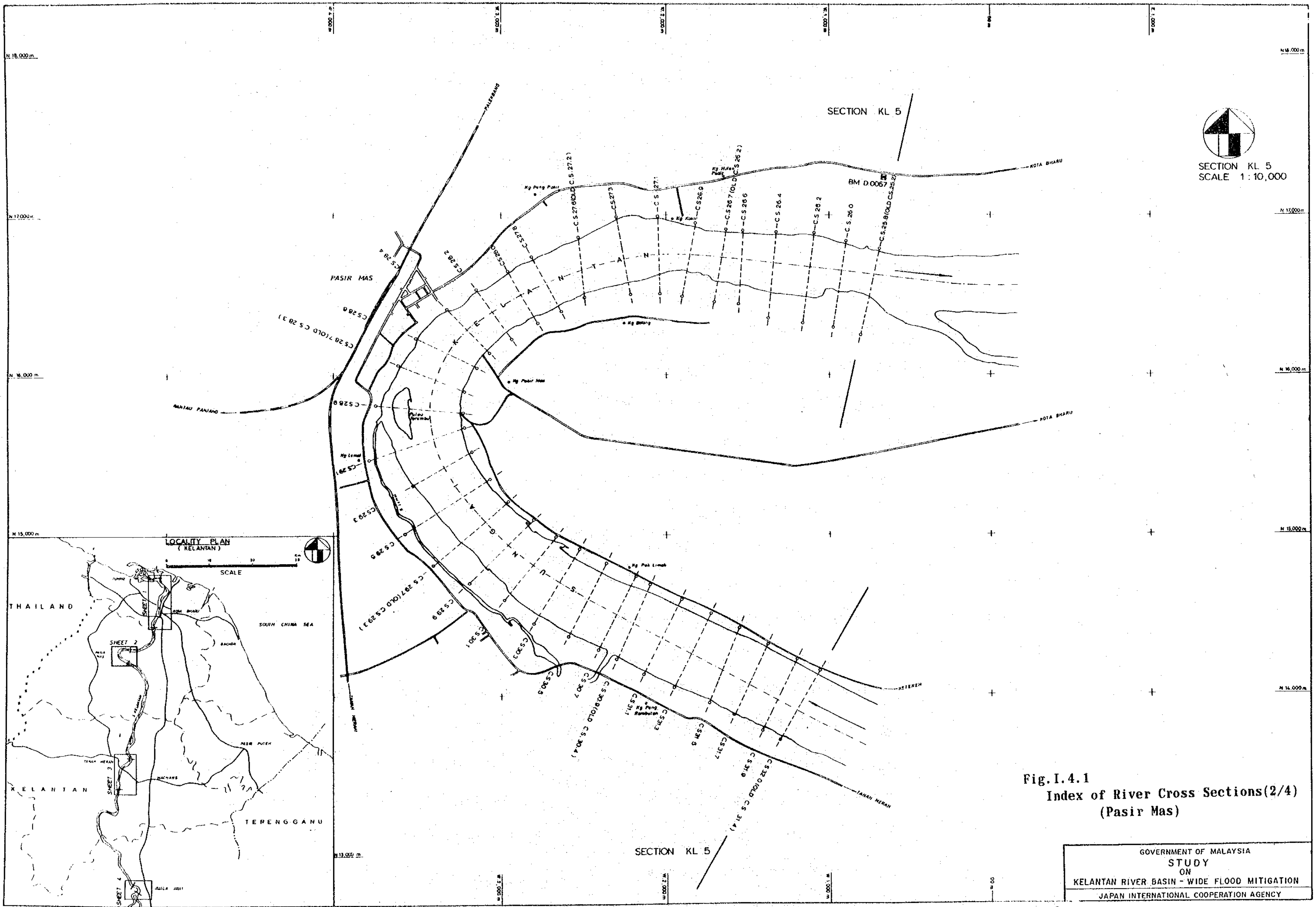

Fig.I.4.1
Index of River Cross Sections(2/4)
(Pasir Mas)

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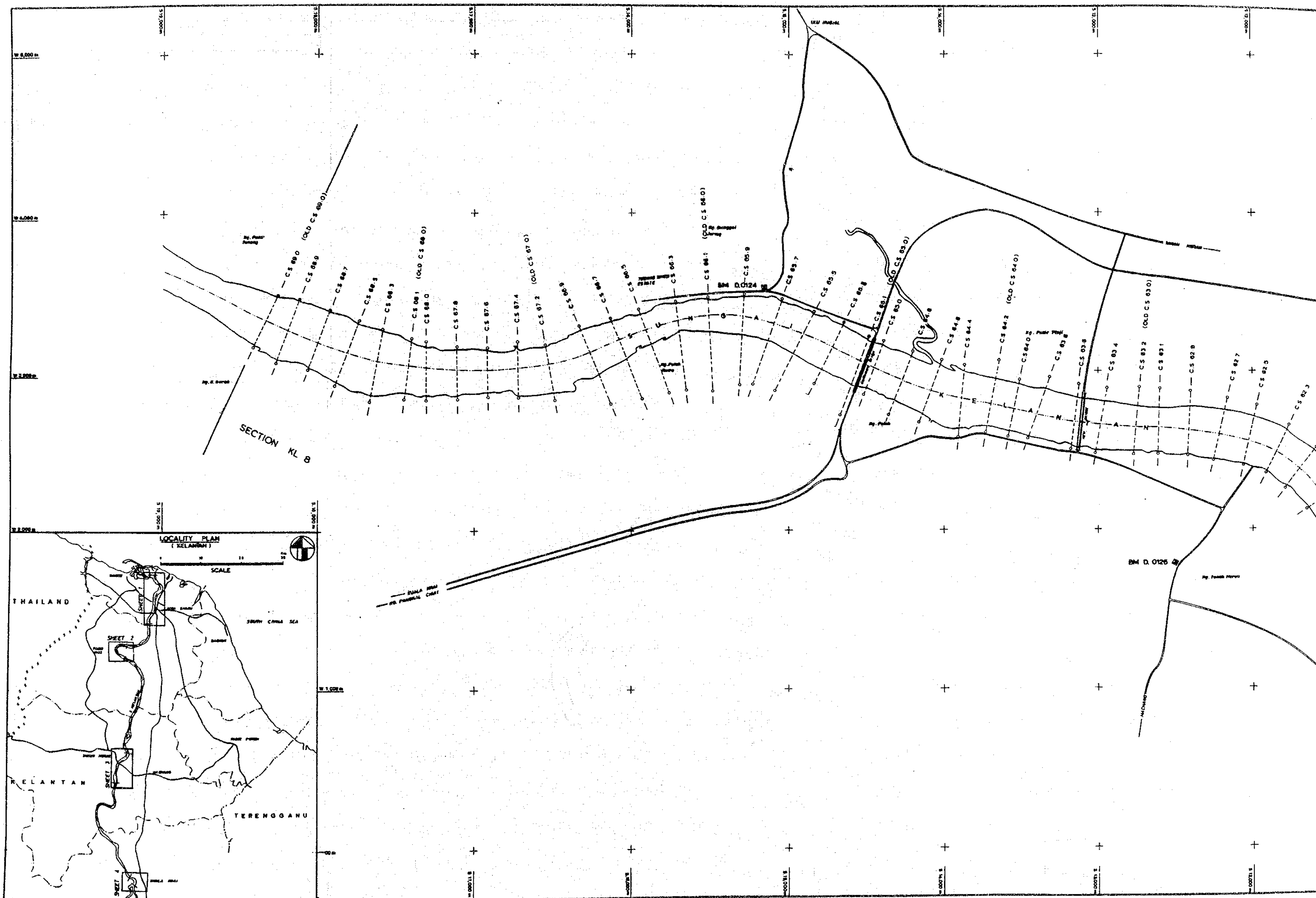

SECTION KL 8
S U N G A I
K E L A N T A N
BM D.0124
BM D. 0126
(OLD C S 69.0)
C S 69.0
C S 68.9
C S 68.7
C S 68.5
C S 68.3
(OLD C S 68.0)
C S 68.1
C S 68.0
C S 67.8
C S 67.6
C S 67.4
(OLD C S 67.0)
C S 67.2
(OLD C S 66.0)
C S 66.3
C S 66.1
C S 65.9
C S 65.7
C S 65.5
(OLD C S 65.0)
C S 65.1
C S 65.0
(OLD C S 64.0)
C S 64.4
C S 64.2
C S 64.0
C S 63.8
C S 63.4
(OLD C S 63.0)
C S 63.2
C S 63.1
C S 62.9
C S 62.7
C S 62.5
C S 62.3
LOCALITY PLAN
(KELANTAN)
SCALE
THAILAND
SOUTH CHINA SEA
SHEET 1
SHEET 2
SHEET 3
SHEET 4
KELANTAN
TERENGGANU

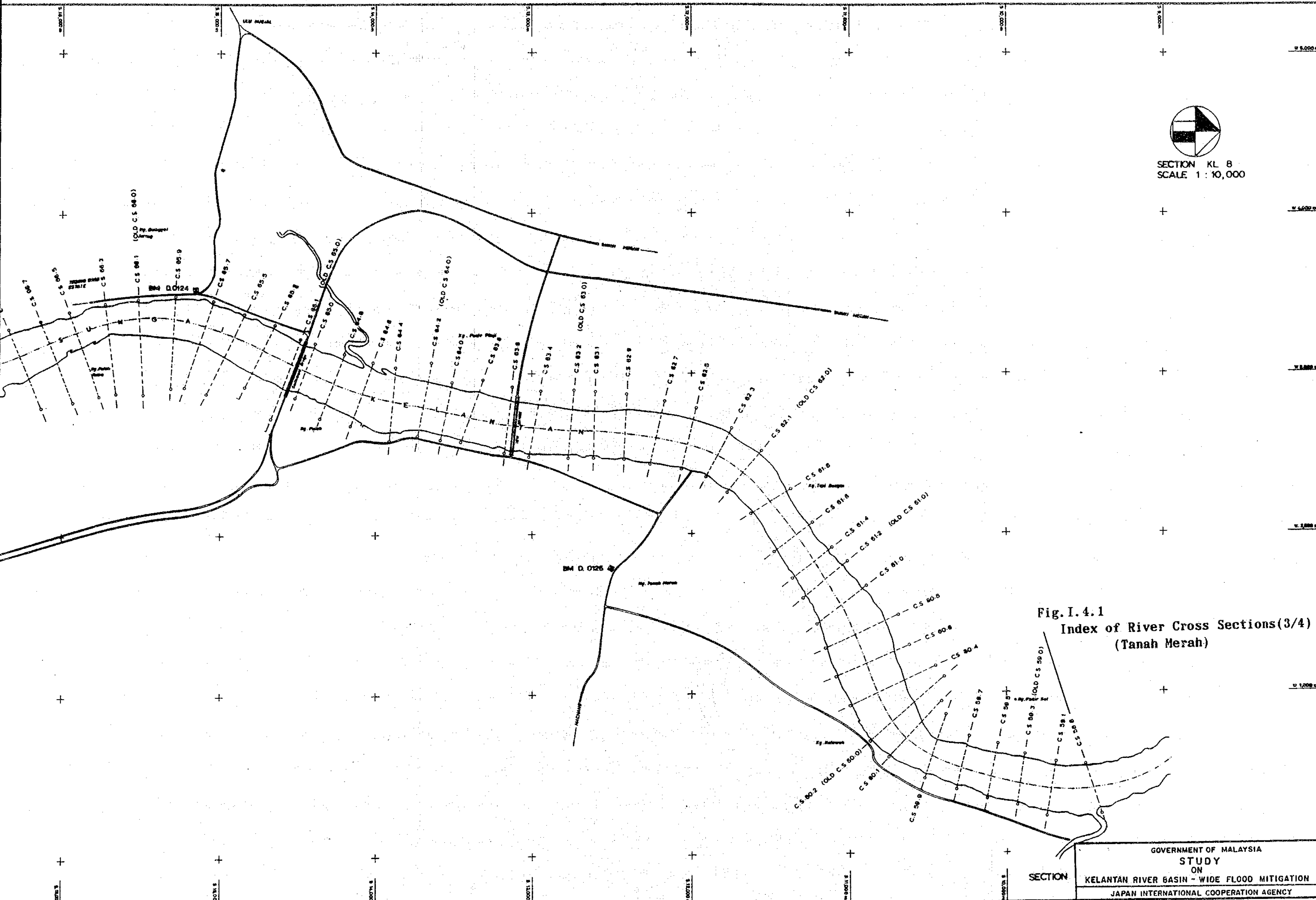

Fig. I.4.1
Index of River Cross Sections(3/4)
(Tanah Merah)

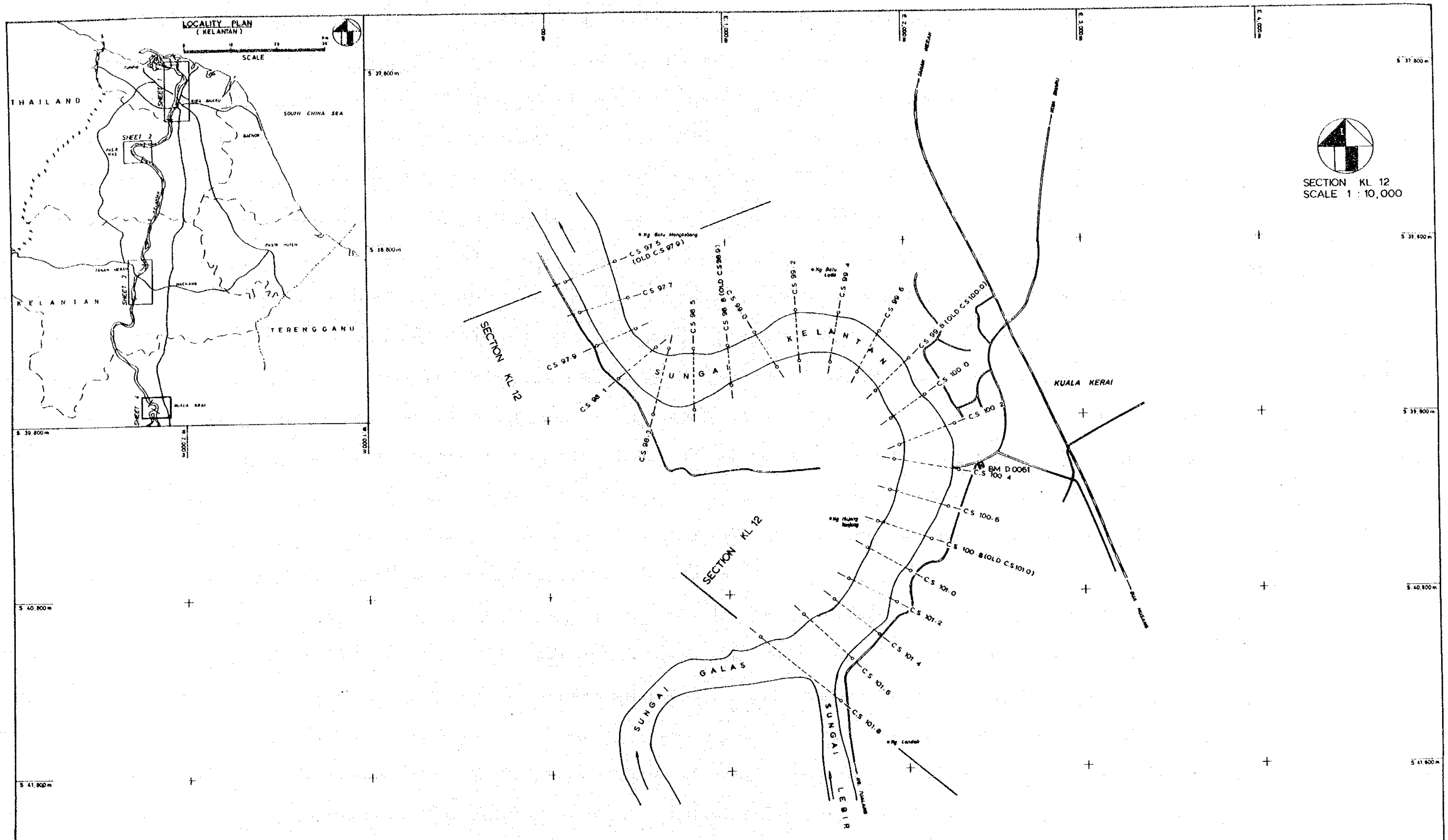

Fig. I.4.1
Index of River Cross Sections(4/4)
(Kuala Krai)

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ANNEX II

GEOTECHNICAL INVESTIGATION

TABLE OF CONTENTS

LIST OF FIGURES

II. GEOTECHNICAL INVESTIGATION

1. INTRODUCTION

Combination of Kemubu and Lebir dam schemes together with river improvement works in the downstream reach of the Kelantan River, one of case studies carried out in the course of master plan study, was selected to proceed in the pre-feasibility study stage.

Geological investigations such as geological mapping, core drilling and test pilling including in-situ permeability test and laboratory test were carried out for the Kemubu dam scheme. (refer to Part IV).

Geological and geotechnical investigations of Lebir dam and its reservoir were carried out by means of surface inspections together with aero-photo interpretations. Meanwhile, previous studies including the Feasibility Study of Lebir dam scheme (by JICA, March 1989) have been carried out.

Hence, geological and geotechnical conditions of the site are mentioned based on the findings during our site visit and those made by previous studies.

Figures such as geological maps and profiles of Feasibility Study Report on Lebir Dam Project by JICA (1989) are used in this report.

2. REGIONAL GEOLOGY

2.1 General

The Kelantan River is located in the north-eastern part of Peninsular Malaysia and originates from the mountain ridge which is the border with the State of Perak. Meandering in the hilly areas of the middle reaches and in flat plains of the downstream reaches northwardly, the Kelantan River drains into the South China Sea. A total catchment area of the Kelantan River basin is 13,100 km^2, which is 85% of the Kelantan State. A location map of the Kelantan River basin is shown in Fig.II.2.1.

The topographic features of the Kelantan River basin are characterized by geological strata running from south to north. High mountain ranges located at the eastern, western and southern sides of the basin make a border with the State of Terengganu and the State of Perak and Thailand, respectively.

A geological map of the Kelantan River basin is given in Fig.II.2.2. High mountains running from east to west through the southern part of the basin consist mainly of granites which are intruded at the Palaeozoic-Tertiary age. The granites, being massive and sound, form the steep mountain slopes.

The hilly areas extended in the middle reaches are predominated by the Palaeozoic-Mesozoic rocks comprising sandstones, shales, limestones, tuffs and volcanics, which are very often metamorphosed regionally into phyllites and slates and further into crystalline schists. Thermal metamorphism due to the granite intrusion is often observed in the formation of hornfels. Particularly, phyllites, slates and schists are deeply weathered because of plenty of cracks and foliations.

Limestones having strong resistance to weathering form the high pinnacles with some caves in these bodies. Granitic masses intruded sporadically in the hilly areas are generally small in size and without tendency to expand.

Geological structure runs north-south or northwest-southwest. The axes of folding and major faults also orients these directions, but are sometimes intersected by other groups of faults tending northeast to southwest.

The flat areas of downstream reaches situated in about 40 km long endmost river stretch consist of the alluvial deposits comprising mainly sand, silt and clayey soil, and form the soft ground. Dunes formed with coarse sands carried by the westward littoral current are developed with the 10 km wide band from the coastline, especially at the estuary of the Kelantan River.

2.2 Upstream

Most parts of the upstream reaches forming high mountainous ranges (refer to Figs. II.2.1 and II.2.2) consist mainly of granites except for the southern part dominated by the Palaeozoic-Mesozoic rocks. As mentioned in the preceding Section 2.1, these granites are massive and sound, shaping the steep mountain slopes with waterfalls and rapids.

Granitic activities have been indicated in four periods at least by Rb/Sr radiometric datings. The earliest one is in the Lata Carboniferous (300-285 million years), followed by two granite emplacements occurred in the Triassic; the Early Triassic (230 ± 6 million years) and Late Triassic (199 ± 2 million years). The latest granites intruded at the beginning of the Tertiary (75 ± 1 million years) occur as isolated stocks and dykes.

The granite is often sheared and gneissic, particularly near its contact with the adjoining rocks. Sheared planes generally strike in a northerly direction. On the other hand, weathering of the granites is not supposed to develop intensively except for the gentle slopes around the border with the hilly areas.

2.3 Mid-stream Reaches

Proposed dam schemes, such as Kemubu and Lebir dam schemes are located in the hilly area as shown in Figs. II.2.1 and II.2.2. Regional geological map of damsite is shown on Fig.II.2.3.

The hilly area consists mainly of the Permian and Triassic rocks, comprising phyllite, slate, shale, limestone, tuff, volcanics and metamorphic rocks. Due to metamorphism widely spreaded in the region, most of the Permian and Triassic rocks are deformed slightly to moderately. In general, the older rocks show a greater degree of metamorphism than the younger ones.

The distribution of Permian and Triassic rocks is complicated. These strata, however, have almost same direction of north-south or northwest-southwest.

The Permian rocks are classified into four groups; arenaceous rocks, argillaceous rocks, volcanic rocks, and metamorphic rocks. Metamorphic rocks consisting mainly of schists with developed foliation are distributed in the strip area from the vicinity of Terowong at 20 km southeast of Dabong to Tanah Merah at 30 km downstream of Kuala Krai. These schists named "Taku schists" comprise of mica-garnet schist, quartz schists and amphibole schists.

Volcanic consists of acid volcanics and basic volcanics. Acid volcanics comprises tuffs, agglomerates and rhyolites together with subordinately intercalated shale and quartzite predominate in the southeastern part of mid-stream reaches. Basic volcanics consisting mainly of tuffs, andesite and agglomerate with minor interbedded shale are distributed in the western part of hilly area and form long and narrow strips.

Argillaceous and arenaceous rocks occur mainly in the centre of hilly areas with limestones. These rocks due to metamorphism develop many foliations.

Limestones predominating in the area between the Lebir and Galas rivers form spectacular cliffs standing vertically or overhanged. Near the contact with granite masses, limestones are changed to crystalline marbles showing considerable variation in the grain size.

On the other hand, the Triassic rocks consist mainly of shales with mudstones. Sandstones/metasandstones, conglomerates, tuffaceous varieties and limestones are sporadically included in these Triassic rocks. The shales with grey to black colour are generally thinly laminated and strongly fissile.

Dykes formed from quartz porphry, aplite, pegmatite and microgranite sporadically occur in the schists and sedimentary rocks, being massive and sound in general. Faulting is common in all rocks.

Major faults strongly trend in the north-south or northwest-southeast direction, but are sometimes intersected by other groups of faults trending in the northwest to southwest direction. One of long-ranged major faults with north-northwesterly trend is located on the right bank of the Lebir River, running parallel to the river course. Minor faults are commonly found in association with folding.

2.4 Downstream Reaches

The downstream reaches shown in Figs. II.2.1 and II.2.2 are characterized by lower hilly area from Kuala Krai to Kg. Kemubu and flat alluvial plain area from Kg. Kemubu to the river mouth. The lower hilly area consists of Permian-Triassic sedimentary rocks and granites which have same geological conditions as the rocks distributed in the mid-stream reaches.

Flat alluvial plain area consists of alluvial deposits classified into marine deposits and fluviatile deposits, although it is not always possible to demarcate two types of deposits. The underlying bedrock consists mainly of the Permian sedimentary rocks and granites. The depth from the ground surface to the bedrocks is in 100 to 200 metres at the estuary of the Kelantan River and gradually shallow towards the upstream of the river.

3. KEMUBU DAM SCHEME

3.1 General

The pre-feasibility study of the Kemubu dam scheme has been carried out by JICA during the period from the middle of September, 1988 to the beginning of April, 1989.

The Kemubu damsite is located about 18 km upstream from the railway bridge in Kemubu village as shown in Fig. II.3.1. At the damsite, the Galas River, passing through a narrow gorge, changes its direction from west to northwest.

The Kemubu dam is proposed as a concrete gravity type dam for flood control with a crest height of EL.80.0 m in maximum.

3.2 Topography and Geology

The riverbed at the damsite is about 40 m wide and around EL. 37 m high. The slope on the left bank rises at a gradient of about 45° to 50° up to 15 m in height from the river brink and ends up about 40° above it.

On the other hand, the slope on the right bank rises at a gradient of about 20° up to 10 m in height from the river brink and changes gradient to 40° above it.

The bedrock, massive and comparatively sound, consists mainly of schist which is foliated due to metamorphism. The rock is exposed along the river brink and slopes of both banks, up to 15 - 20 m above the riverbed.

Schistosity, parallel to the bedding plane, strikes and dips N60° - 80°/70° - 80°W. The existence of small-scale faults is estimated by the aerophotograph interpretation and the field mapping but no major fault is found at the damsite.

3.3 Engineering Geology

3.3.1 Main dam

Geotechnical consideration is described for the Kemubu dam scheme based on the geological data obtained from the geological investigations. (refer to Figs.II.3.2 and II.3.3).

(1) Geological condition of damsite

The bedrock consists of calcareous quartz-mica schist which clearly exposes in series along the both banks of the damsite. On the other hand, the overburden of 2 m to 5 m thick is present on the left bank slope.

Weathered and decomposed zones are estimated to be 5 m to 10 m at the left bank and 10 m to 15 m at the right bank.

Generally, the bedrock of the damsite strikes in the N-S direction which intersects the river at the nearly right angle and dips 70^{o} to 85^{o} toward the west.

Main group of joints runs in parallel with the schistocity plane at an interval of 0.5 m to 1 m.

No major fault is found at the damsite by the investigation but several minor faults parallel to the schistocity locally appear in the bedrock.

(2) Strength of bedrock

From the view point of engineering geology, the foundation strength of the bedrocks is estimated as listed below:

Rock classification		Shear strength	
Rock class	Characteristic	Cohesion (kgf/cm)	Internal angle (degree)
CL	Weathered zone or 'cracky' zone	less than 5	30 to 35
CM	Slightly weathered, sound, massive	10 to 15	40 to 45
CH	Sound, massive	20	45 to 50

The bedrocks at the damsite, showing rock class of CM or CH, are evaluated to be sufficient for the construction of a 50 m high class concrete gravity dam. No serious deformation is expected since the foundation is massive and sound.

(3) Permeability of bedrock

According to the Lugeon test, the weathered zone is in high permeability. On the other hand, the sound rock which lies below 15 m in depth shows impermeability. However, there may be some possibility to encounter the places with high permeability due to crack zone of schist in relation to schistocity.

Grouting is considered as an effective measure for the improvement of high permeability.

3.4 Construction Materials

3.4.1 Concrete aggregates

Limestone is suitable for the concrete aggregate. Probable rock quarry of limestone is situated in 5 km south-west of the damsite. The geomorphology shows cliffs which are useful for taking the aggregate.

On the other hand, schist which is the major rock type in the project area is judged to be unsuitable for the aggregate due to the flaky condition with schistosity.

While, sand and sand/gravel, present as river deposits at the river bars around the Kemubu damsite are found to be suitable for fine concrete aggregates in quality but its amount is limited. Potential quantity of the river bar deposits shall be examined by the detailed investigation such as sounding and laboratory test.

4. LEBIR DAM SCHEME

4.1 General

The Lebir dam scheme, for which the feasibility study has been executed by JICA for the purpose of hydropower generation, is developed as the single-purpose scheme for flood mitigation. The main structures for this dam project comprise a 77 m high rockfill type dam, two saddle dams, spillway and so on as shown in Fig.II.4.1.

The Lebir damsite is located at about 3 km upstream from existing Tualang Bridge. The Lebir River forms an incised meander around the damsite, turning its direction from north to south and then returning to north. The geotechnical conditions reviewed for the pre-feasibility study and also based on this field survey are as follows:

4.2 Topography and Geology

The riverbed at the damsite is about 150 m wide and El. 26 m high. There exist rapids in the reaches where the dam sits.

River terraces are developed on both banks, the top of which is El. 45 m. The terrace on the left bank is narrow, behind which decomposed rocks rise at the gradient of about 16 to 18°. On the right bank, the river terrace is approximately 50 m wide, and the slope above it rises at the gradient of 20°.

Bedrocks underlying the damsite consist mainly of green tuffs, purple tuffs, green tuffaceous sandstones and shales with thin layers of tuffaceous conglomerates. These bedrocks, which are slightly metamorphosed and non-foliated, are hard and massive. Bedding is monoclinic with fairly consistent strike and dip of N40°E/34°E on an average.

4.3 Engineering Geology

4.3.1 Main dam

Irregular joints having main strike and dip of NW-SE/40° - 70°NE or SW occur in the bedrocks of damsite (Figs. II.4.2 and II.4.3). It is, however, found by field survey of core drilling and seismic explanation that there is little possibility of the existence of large-scale faults at the main damsite.

Intensive weathering develops on both banks of the damsite. The decomposed zones are 5 to 7 m thick on both slopes, and show high permeability of more than 20 Lugeon. To reach the fresh rocks, it will be necessary to excavate by 5 m at the riverbed, 10 m at the left bank and about 20 m at the right bank. While, the pervious rock zones, indicating more than 20 Lugeon, are 20 m deep in the riverbed, 15 m in the left bank and 25 m in the right bank.

It is considered from review result and site survey that JICA study result to adopt a 77 m high rockfill type dam is acceptable.

It is judged that a large scale landslide does not occur in the reservoir area since the bank slope of the reservoir area is fairly gentle.

4.3.2 Saddle dams

Two saddle dams have been proposed to keep the reservoir water level higher than El. 60 m (Fig. II.4.4). They are located on the right bank of the river; 1.8 and 2.0 km north-east from the proposed main dam, respectively. Both saddle dams with a rockfill type are about 70 and 45 m in height.

The bedrocks underlying saddle dam I consist mainly of tuffaceous conglomerates and tuffaceous sandstones with consistent strikes and dips of NNW-SSE/70 - 90°S. Heavily and deeply weathered zones are developed on both banks. Decomposed rocks with high permeability of more than 30 Lugeon are 5 to 10 m thick in the bottom, 25 to 30 m in the left bank and 5 to 20 m in the right bank. To reach the fresh rocks, it will be necessary to excavate 15 m in the bottom, more than 30 m in the left bank and 10 to 30 m in the right bank. The zones showing high permeability correspond to the weathered zones exceeding 30 Lugeon.

The bedrocks underlying saddle dam II are comprised mainly of tuffs, tuffaceous sandstones and intruded meta-dacites. Tuffs and tuffaceous sandstones alternate closely and strike generally NNW-SSE. Hard meta-dacites probably with some dozen metres in width are distributed on the right bank of the damsite. Weathering will be as shallow as about 7 m at most. The left bank of this damsite which corresponds to the right bank of the saddle dam I is weathered by around 25 m in depth.

It is concluded from the review result and site survey that JICA study result to adopt the rockfill type dam for two saddle dams is acceptable.

4.4 Construction Material

4.4.1 Rock materials and concrete aggregates

River deposits suitable for concrete aggregates and rock materials are insufficient in volume.

A proposed quarry site is located at 1.5 km north of the proposed main damsite. It consists of tuffs, tuffaceous breccias and rounded conglomerates. However, its surface layer with 10 to 15 m in depth is weathered and not suitable for rock materials and concrete aggregate. The available amount beneath the weathered zone is enough for dam construction, and suitability of quality as rock materials and concrete aggregates has been confirmed by the laboratory test.

4.4.2 Core materials

The borrow site for core materials is situated in the granite area near the boundary with the Mesozoic sedimentary rocks, 4 km east-northeast from the proposed main damsite. The granite mass is heavily weathered by 15 to 20 m in depth. This weathered granite is adequate for core materials in quality since the material tests show that the materials contain the natural water content of 15 to 20% and are well graded. A sufficient amount of the core material is supposed to obtain from the proposed borrow area.

It is considered that the JICA study result for rock materials, concrete aggregate and core material is reasonable.

4.4.3 Filter material

There are no descriptions for filter material in the feasibility study report. The result of field survey in this time clarified that the suitable filter materials have not been found around the proposed damsite, and then it is proposed to obtain them by crushing the rock material at the proposed quarry site.

4.5 Risk of Faulting and Seismicity

Any major fault lines have not been confirmed near the project area and it is also confirmed by the feasibility study of Lebir dam carried out by JICA in 1989.

Peninsular Malaysia is seismologically stable and the nearest possible epicenter of earthquake is expected in central and northern part of Sumatra. Therefore, no serious seismic damage is expected.

In consideration of damsite geology and dam design as well as past and ongoing dam construction in Peninsular Malaysia, K = 0.1 is proposed as seismic design coefficient.

5. RIVER IMPROVEMENT WORKS

5.1 General

Structural measures for the flood mitigation plans include dams in the mid-stream reaches and river improvement such as levee, revetment and enlargement of the river channel in the downstream reaches. Geological investigation for the dam scheme was performed for the conceivable river improvement works on the basis of geological data collected from DID and GSD as well as the result of field survey and interpretation of aerial photographs.

5.2 Topography and Geology

5.2.1 Low hilly area

Low hilly areas, from Kuala Krai to Kg. Gondang, consist mainly of Permian sedimentary rocks covered with river terrace deposits.

Terrace deposits on both banks of the river are composed mainly of sand and silt, occasionally gravel and clay. Thickness is estimated to be less than 5 m. The Permian sedimentary rocks deeply weathered expose on the brinks of the river sporadically.

5.2.2 Alluvial plain

The alluvial plain forming flat areas consists of fluvial and marine deposits. The fluvial deposits are composed mainly of sand, silt, clay, gravel and their alternation. On the other hand, marine deposits consist of medium-coarse sand and organic clayey soil behind rised beaches and dunes.

Both banks of the Kelantan River are mainly covered with silt, clay and their alternation of 5 m to 10 m deep, being soft and loose. Medium-coarse sands with gravels transported by floods remain on the riverbed, river bar and some parts of the riverside.

Marine deposits comprising coastal medium-coarse sand and organic clayey soil are distributed at and around the river mouth. Organic clayey soil such as peat is expected to form a soft foundation.

5.3 Engineering Geology

5.3.1 Low hilly area

(a) Foundation

It is judged that both terrace deposits and sedimentary rocks are suitable for the foundation of embankment less than 5 m. In the case of concrete structures, spread foundation is recommended to place on sedimentary rocks by stripping terrace deposits which is estimated to be thin.

(b) Slope stability

The sedimentary rocks which are intensively weathered will be required to be excavated at the slope of 0.8 to 1 H to 1 V by the depth less than 10 m. On the other hand, terrace deposits will be excavated at 1 to 1.2 H to 1 V by the depth less than 5 m and 1.2 to 1.5 H to 1 V for the depth of 5 to 10 m.

5.3.2 Alluvial plain

(a) Foundation

It is estimated that both fluvial and marine deposits are suitable for the foundation of embankment with a height lower than 5 m except for organic clayey soil. If organic clayey soil indicates 0 to 4 in N-value of the standard penetration test, foundation improvement will be necessary for consolidation settlement and sliding.

(b) Slope stability

In case that the foundation is excavated by the depth of less than 5 m at the sites consisting of fluvial or marine deposits, the slope will require to be cut at 1 to 1.2 H to 1 V, while 1.2 to 1.5 H to 1 V for the depth of 5 to 10 m. The slope will be required to be gentler, in case the foundation is organic clayey soil.

5.4 Embankment Materials

5.4.1 Low hilly area

Residual soil and decomposed rocks are suitable for embankment materials. These available in the vicinity of embankment areas will be suitable for embankment materials, and embankment slope will be 1.8 to 2 H to 1 V for the height less than 5 m.

5.4.2 Alluvial plain

Residual soils and decomposed rocks on the right bank around Machang and on the left bank at Tanah Merah are available for embankment materials. The slope will be 1.8 to 2 H to 1 V at the height of around 5 m.

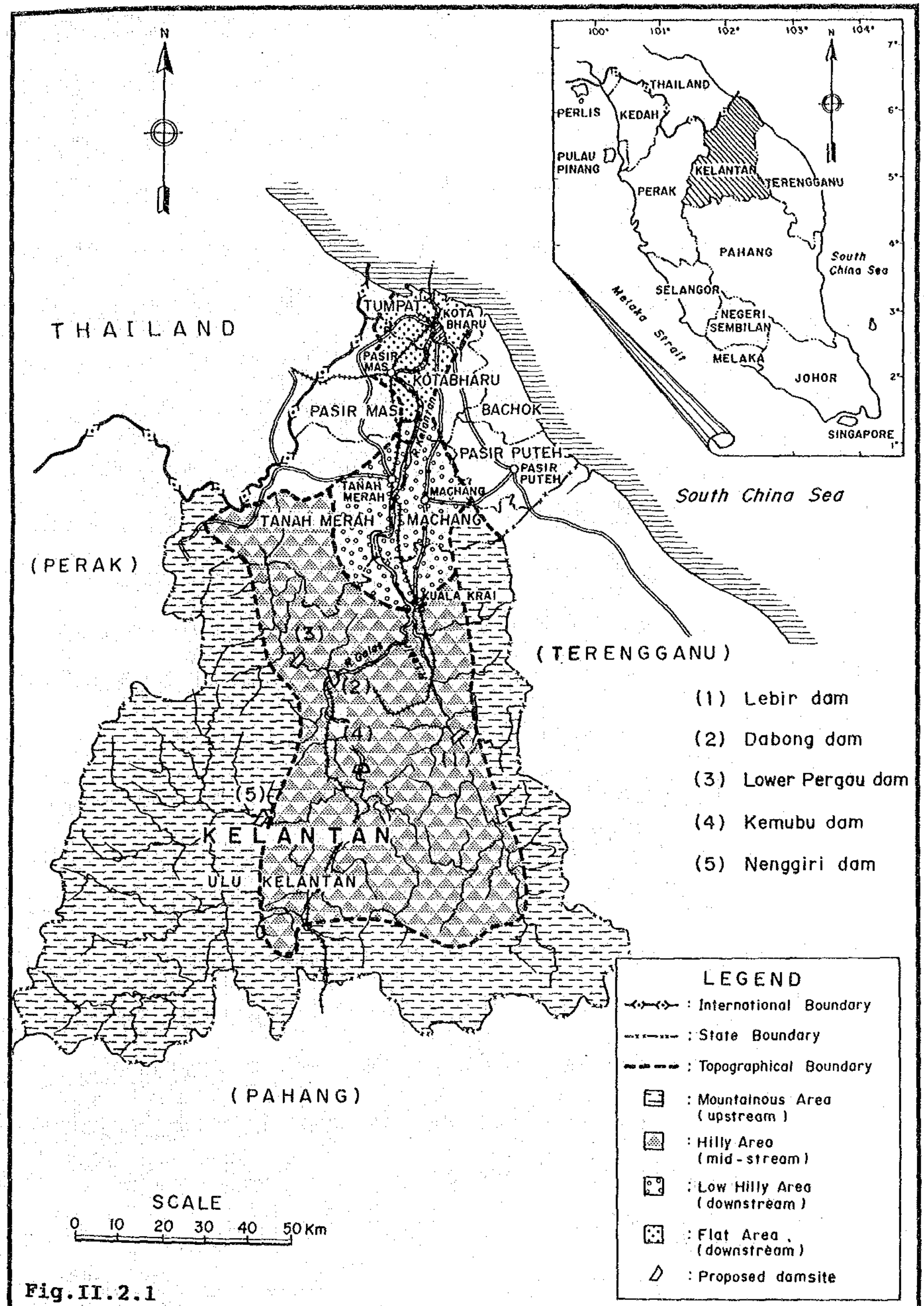

Fig.II.2.1

Location Map of the Kelantan River Basin

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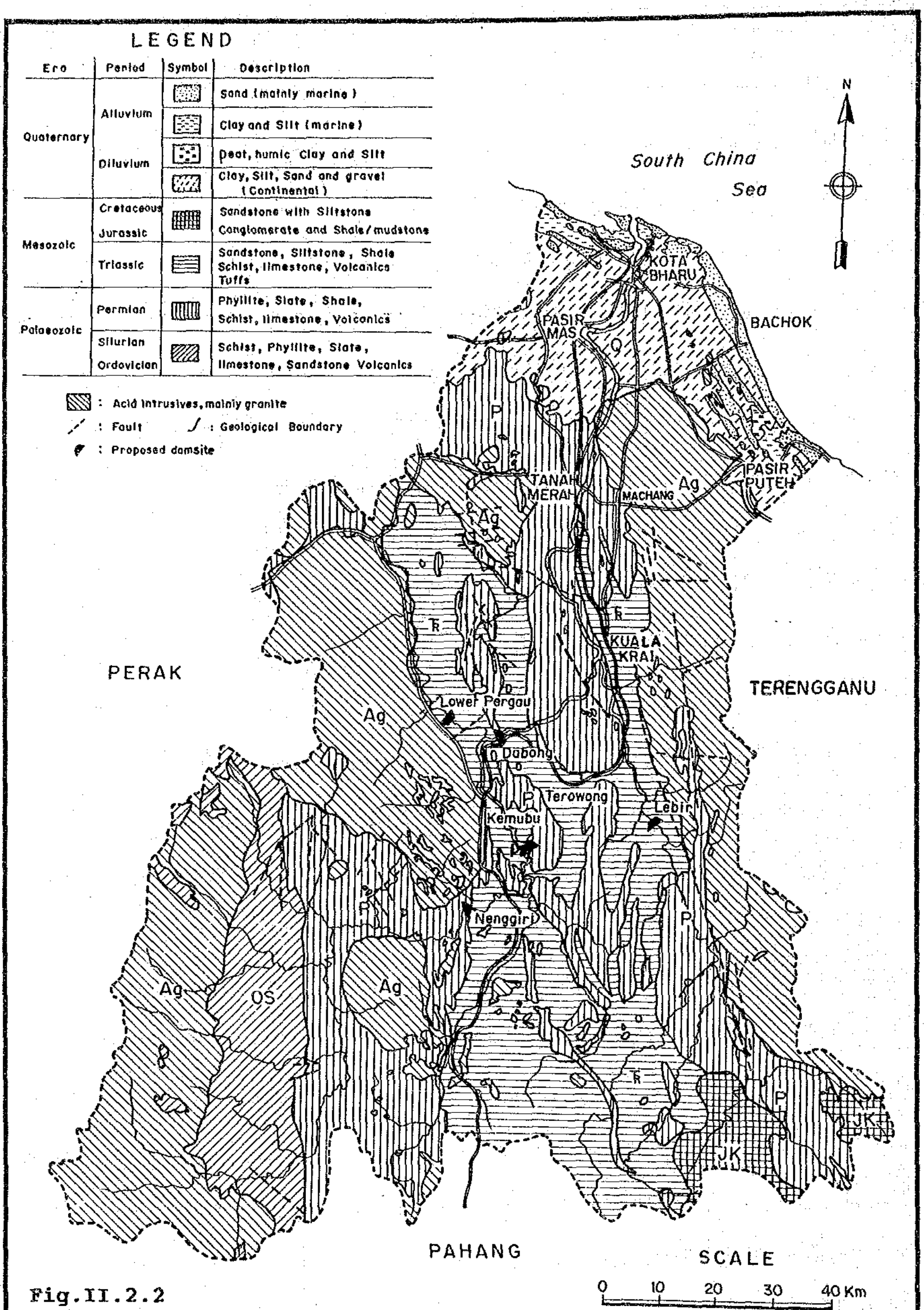

Fig.II.2.2

Geological Map of the Kelantan River Basin

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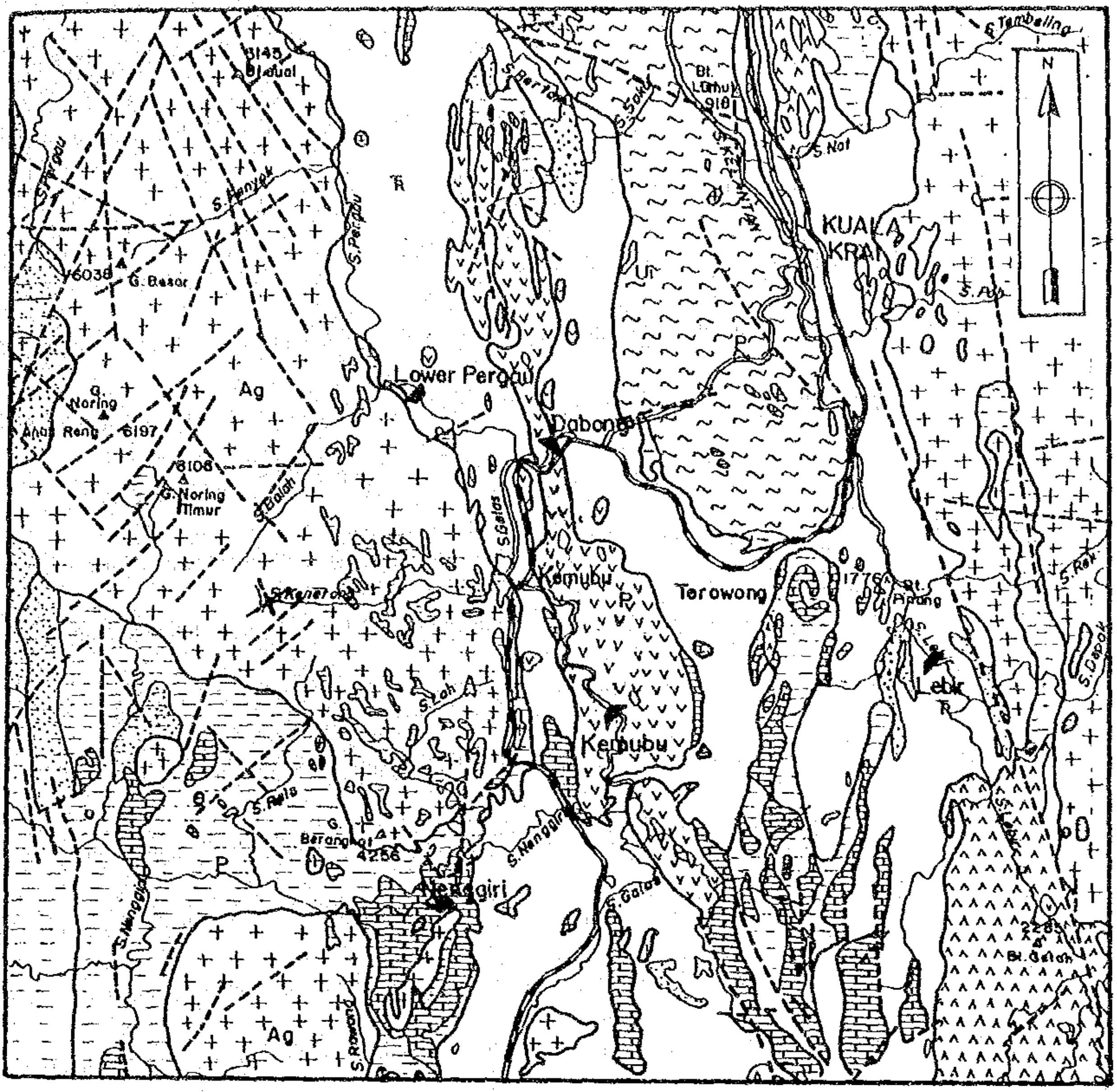

LEGEND

Era	Period	Symbol	Description
Mesozoic	Triassic		Sandstone, Siltstone, Shale, Schist, Limestone, Volcanics.
			Conglomerate.
Paleozoic	Permian		Phyllite, Slate, Shale, Schist, Limestone, Volcanics.
			Limestone.
			Conglomerate.
			Schist.
			Quartz-mica-schist (around damsites), Acid volcanics mainly pyroclastics
			Basic volcanics mainly pyroclastics.

+ + : Acid intrusive, mainly granite.

Fault . Geological Boundary .

Proposed damsite .

National railway.

Fig.II.2.3 Regional Geological Map of Damsites

SCALE

0 10 20 30 40 Km

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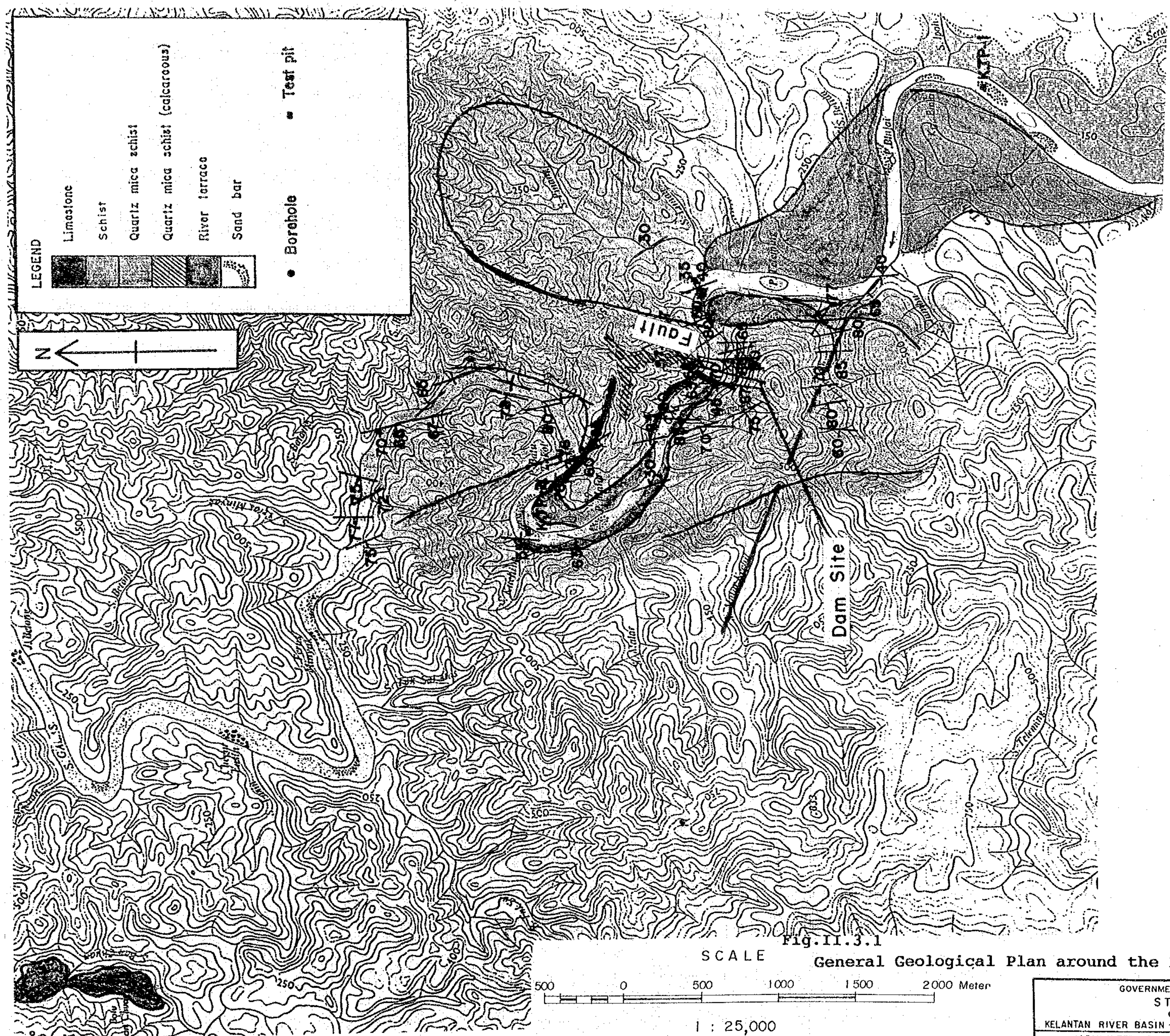

Fig.II.3.1

General Geological Plan around the Kemubu Damsite

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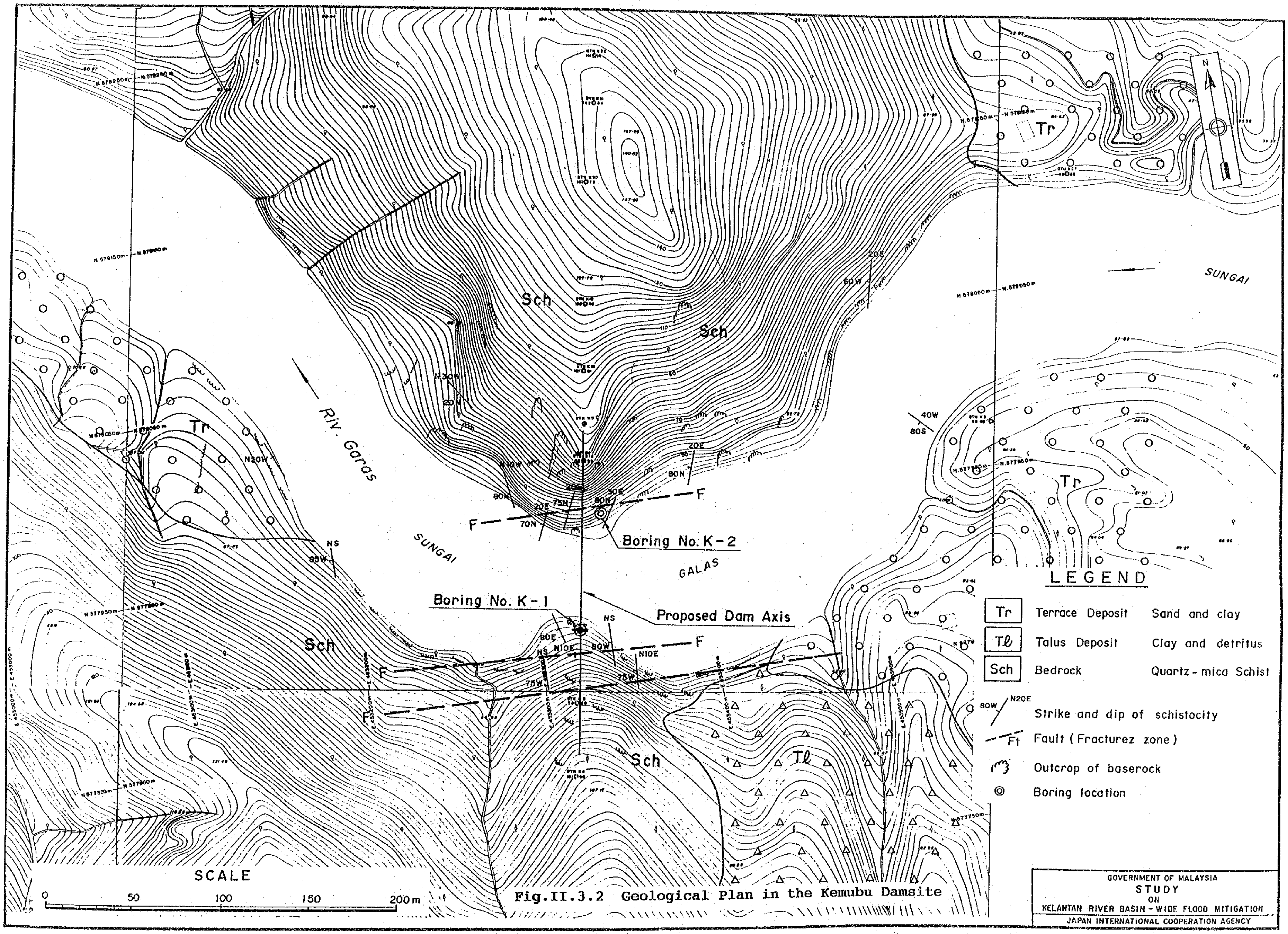

Fig.II.3.2 Geological Plan in the Kemubu Damsite

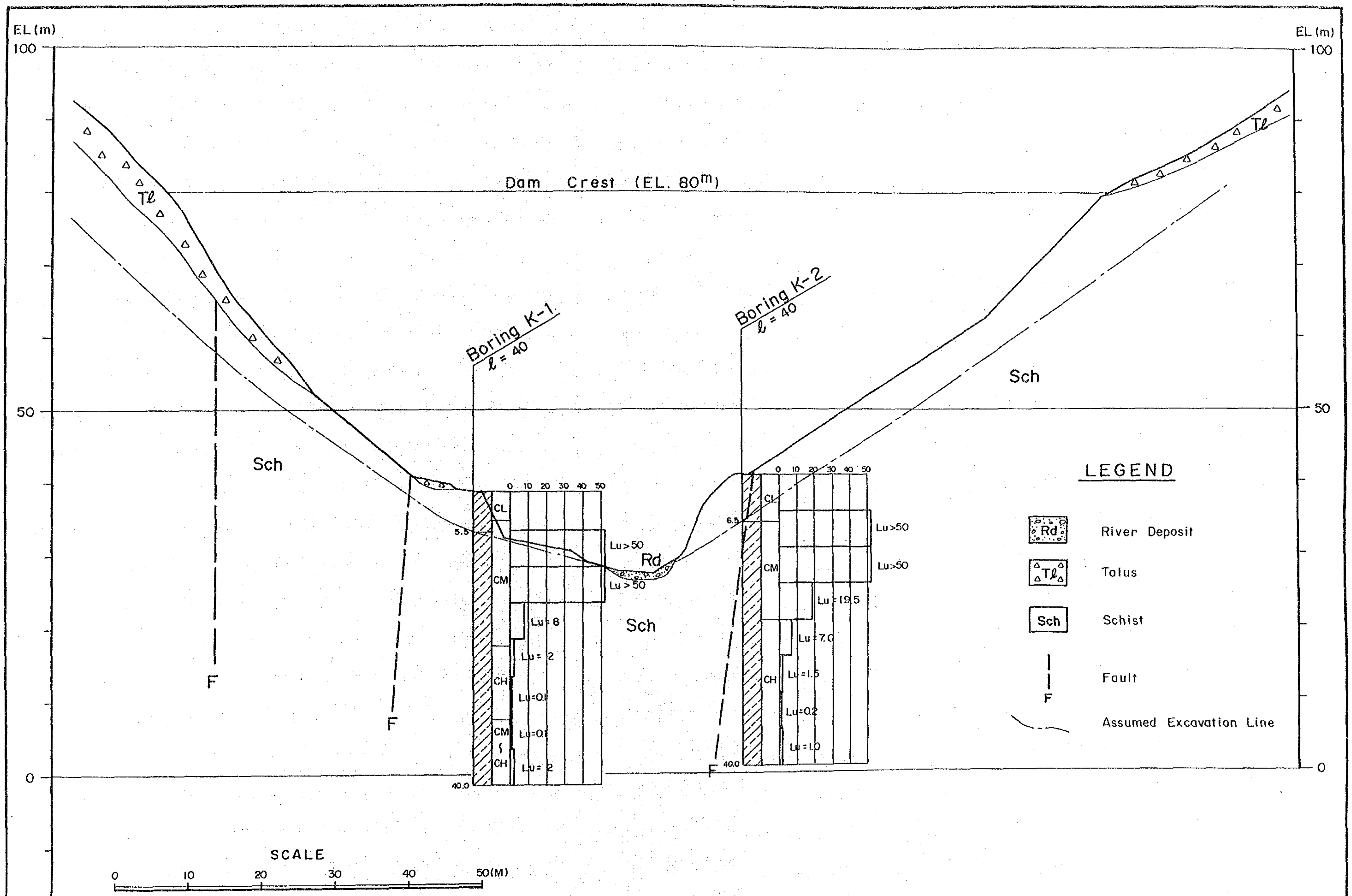

Fig.II.3.3 Geological Profile in the Kemubu Dam

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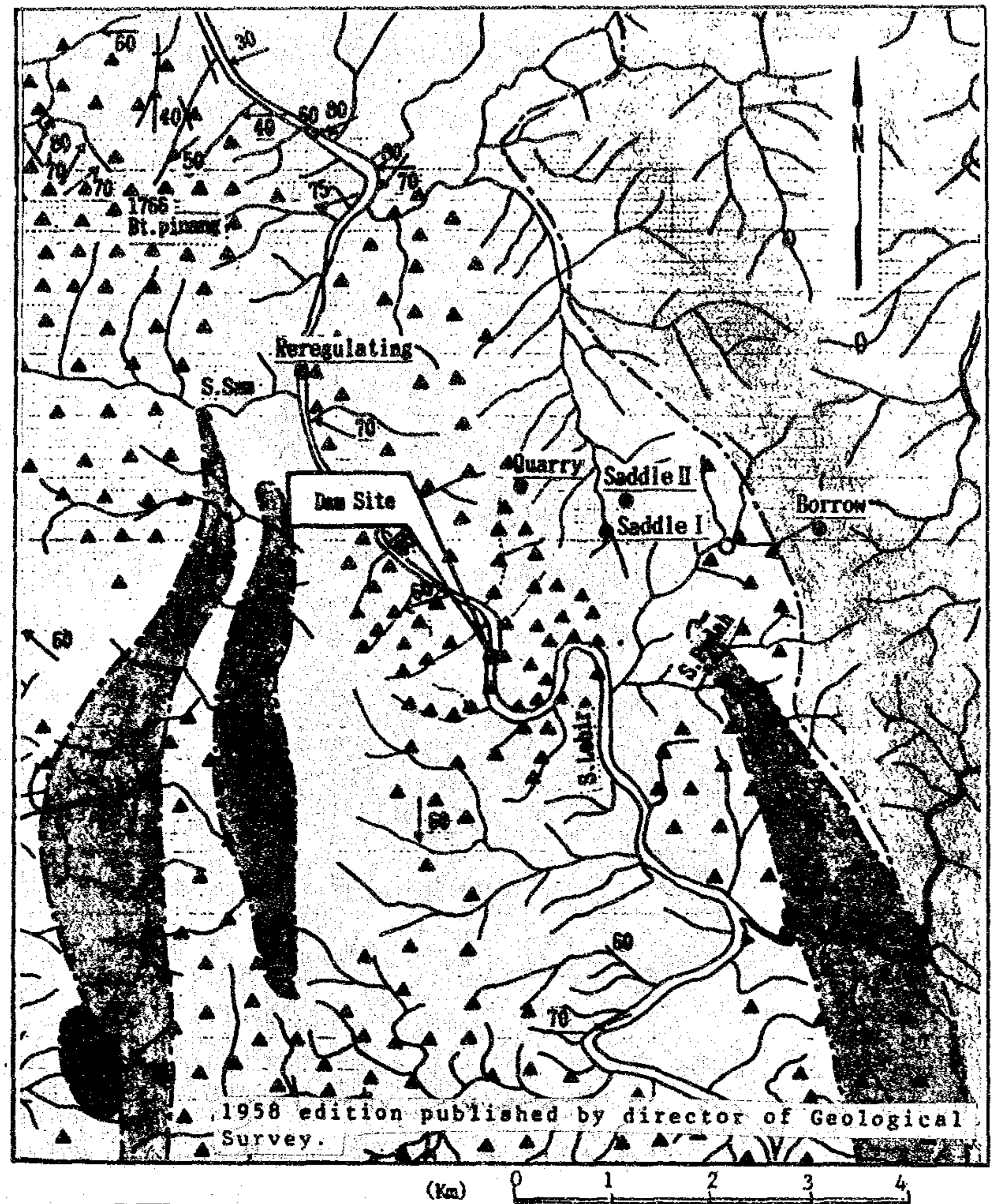

Segimentary Rocks, mainly argillaceous with interbedded Limestone, Quartzite and Volcanic rocks. Brown dots indicate distribution of Tuff and Lava.

Tuffaceous conglomerate and sandstone including quartzite.

Granite, Granodiorite and related rocks.

Massive crystlline Limestones.

(a)Geological Boundary accurate to within 100 yards.
(b)More doubtful boundary.

Arrow indicating dip of bedding on schistosity.

Fig.II.4.1

Geological Map in the Lebir Damsite

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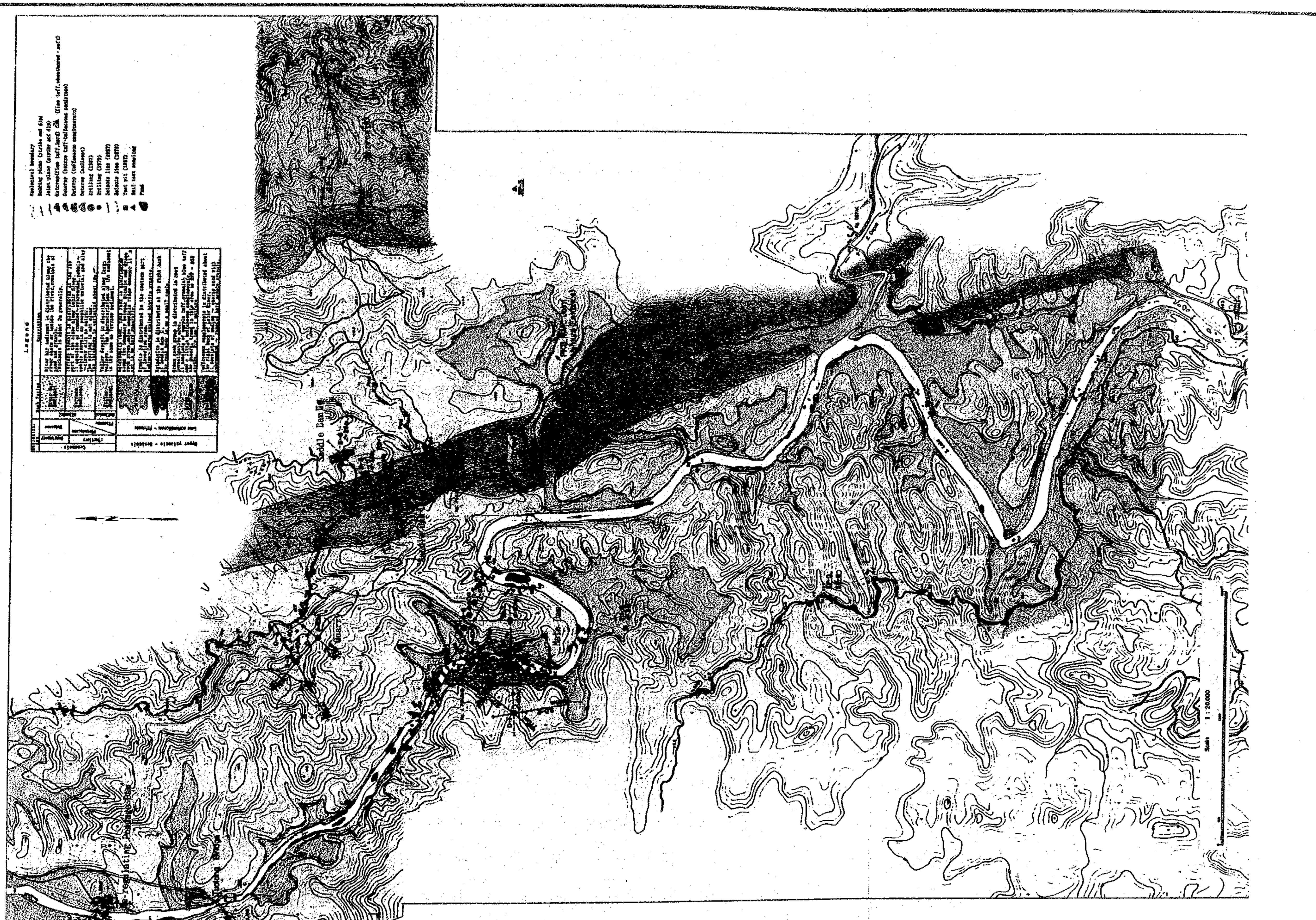

Fig.II.4.2 Geological Map in the Project Area

After "FEASIBILITY STUDY REPORT ON LEBIR DAM PROJECT" by JICA (1989)

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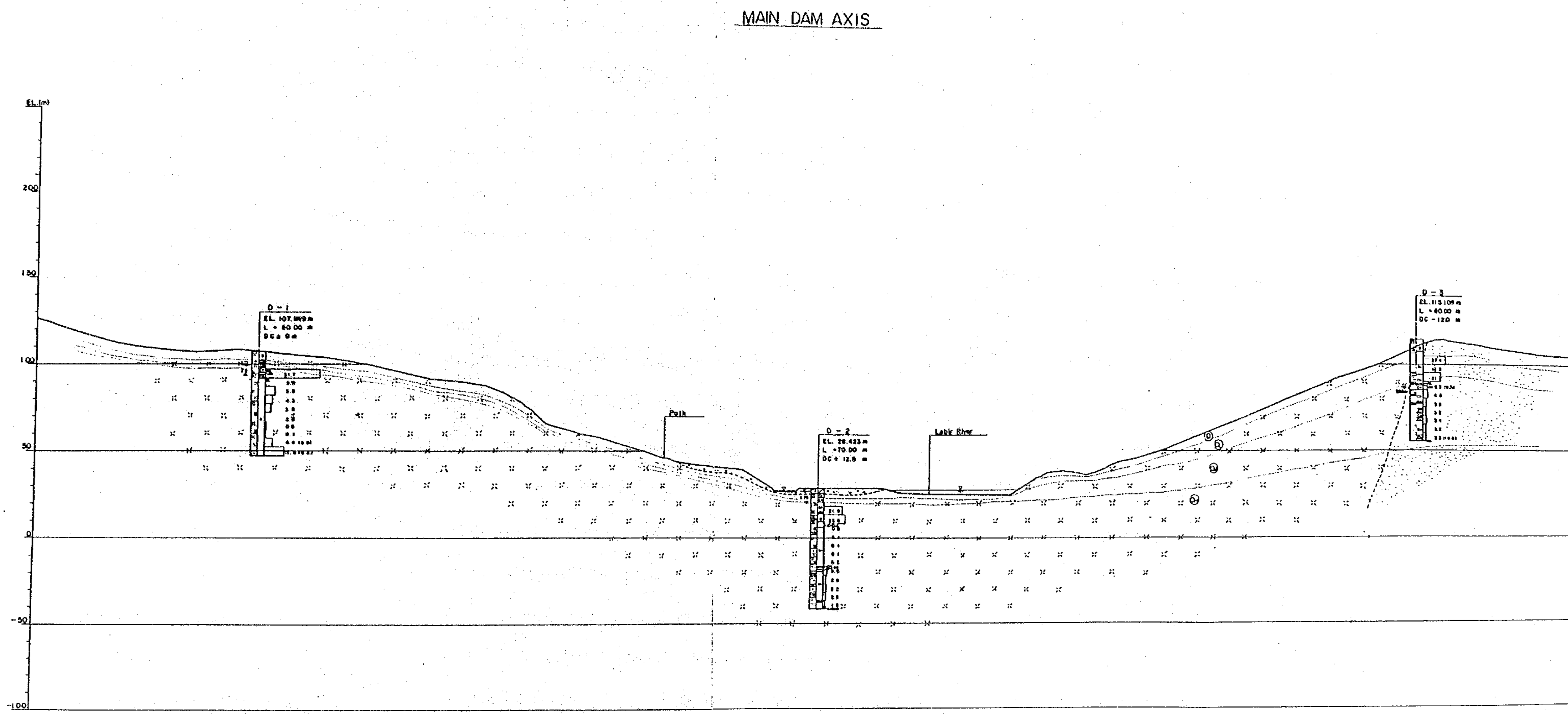

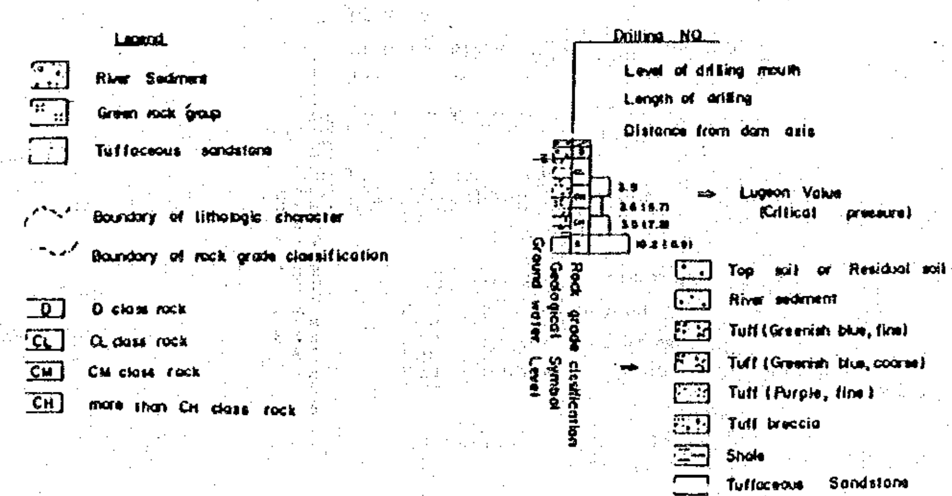

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Fig.II.4.3 Geological Profile in the Lebi

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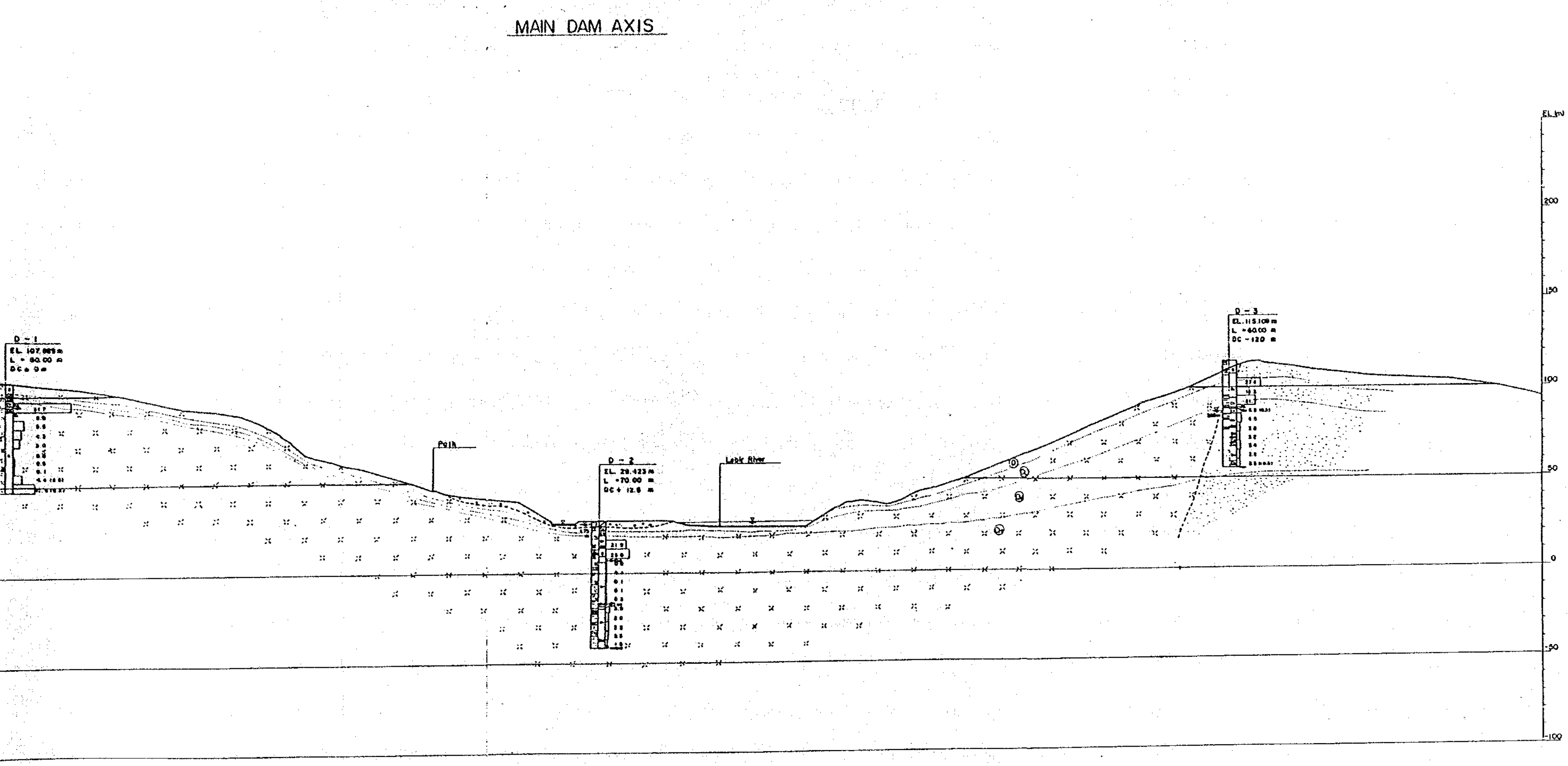

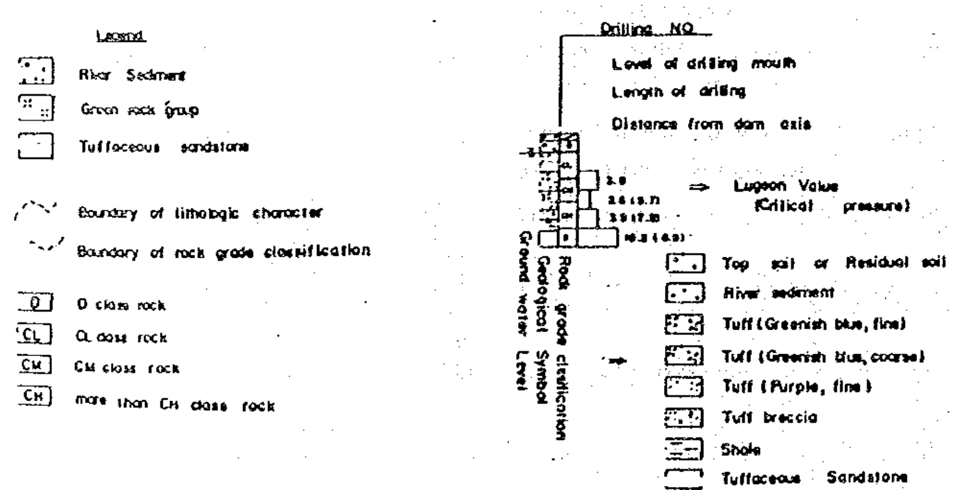

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Fig.II.4.3 Geological Profile in the Lebir Dam (Main Dam)

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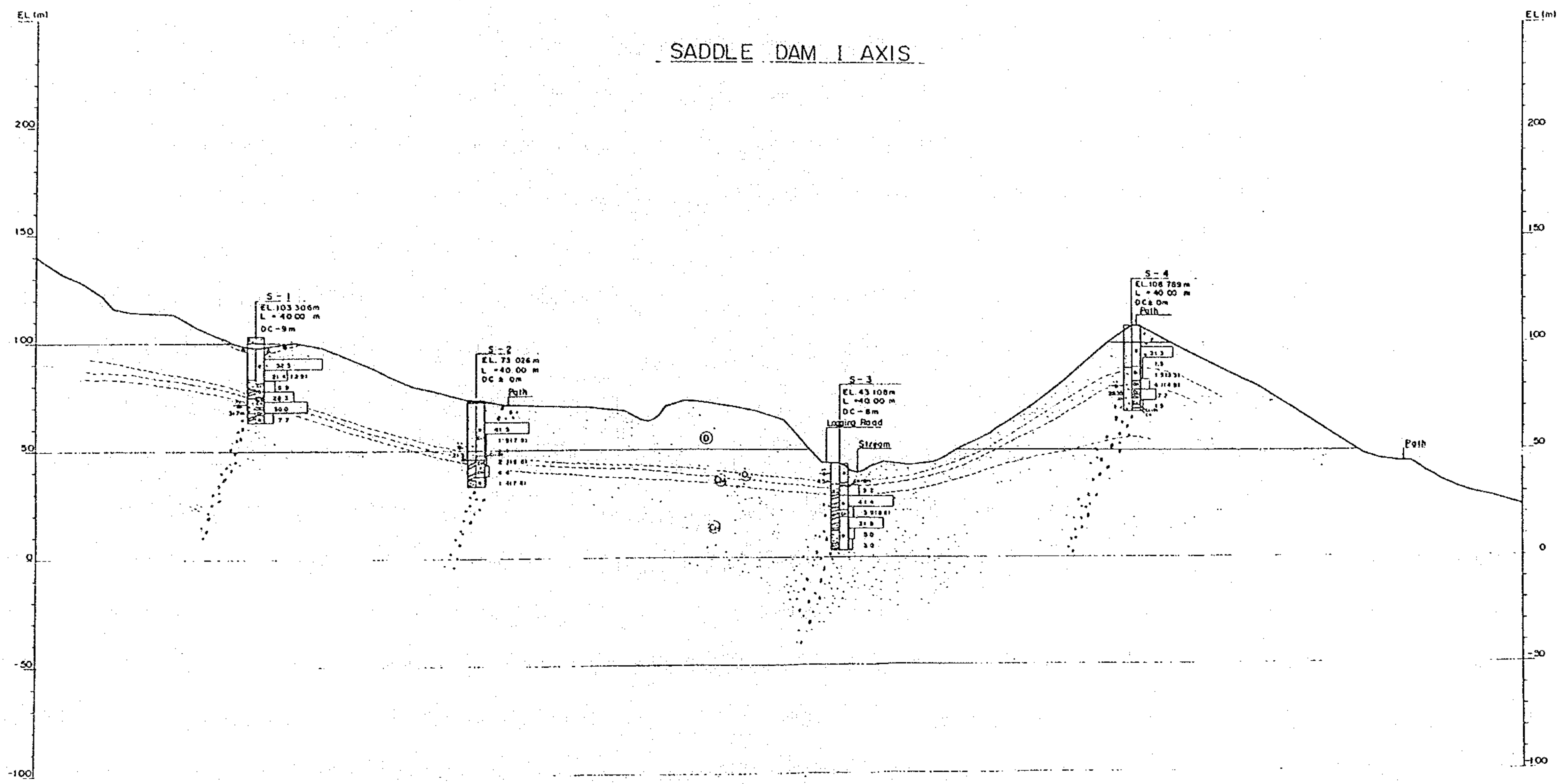

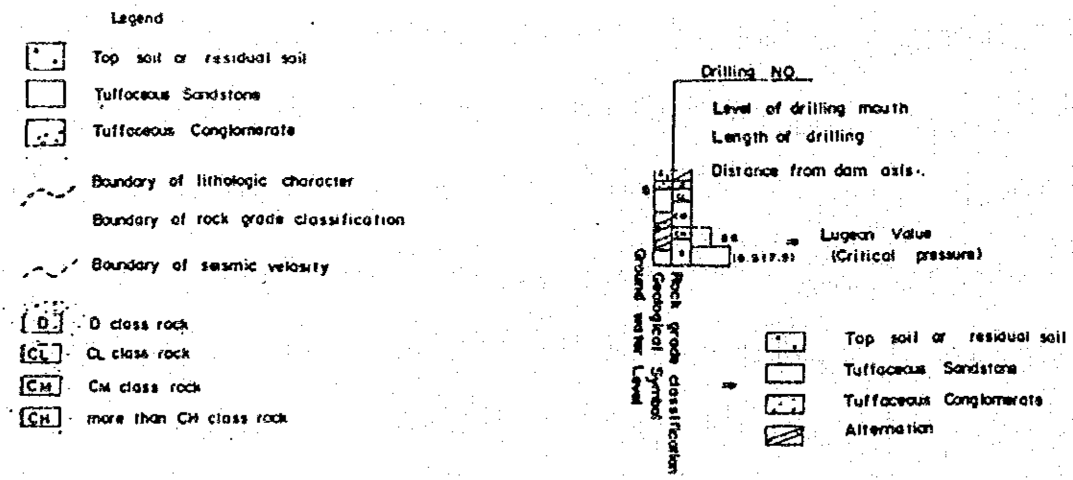

After "FEASIBILITY STUDY REPORT ON LEBIR DAM PROJECT" by JICA (1989)

Fig.II.4.4 Geological Profile in the Lebir Dam (Saddle Dam)

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ANNEX III

HYDROLOGICAL STUDY

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III. HYDROLOGICAL STUDY

1. INTRODUCTION

The Master Plan Study on the Kelantan River clarifies the physical aspect of hydrological behaviour in the basin. In ANNEX II of Supporting Report for Master Plan Study, the historically large flood was assessed, and then the appropriate scale of structures for flood mitigation and their combination were envisaged for the scale of the probability of once in 50 years.

In this ANNEX, the hydrological condition in the Kelantan River basin and the results of hydrological analysis in the Master Plan Study are summarized for the pre-feasibility study on the combination plan of Lebir dam, Kemubu dam and river improvement. Although the probable flood corresponding to the probability at Guillemard Bridge was utilized for evaluating flood mitigation effect of structures in the Master Plan Study, those corresponding to the probability at damsites are also mentioned in this report.

2. HYDROLOGICAL CONDITION

The State of Kelantan was exposed to the northeast monsoon for the period from November through January, the periodic extreme flooding due to heavy rainfall brings about the overbank flow in the coastal plain from the Kelantan River.

The Kelantan River basin is characterised by the vast coastal plain and the relatively small flow capacity of river channel. The flow capacity of 5,500 m^3/sec corresponds to the arithmetic average of annual maximum peak discharges at Guillemard Bridge having a catchment area of 12,080 km^2.

The annual basin mean rainfall in the State of Kelantan is estimated at 2,700 mm on an average as shown on Fig.III.2.1. The monthly mean rainfall data show that around 50% of annual rainfall on an average occurs from October to December in the coastal plain, while those in the upstream basin are evenly distributed throughout a year. (refer to Fig.III.2.2) The annual basin mean rainfall is estimated at 2,400 mm for the catchment of Kemubu dam and at 2,600 mm for that of Lebir dam.

The annual mean runoff of 540 m^3/sec is recorded at Guillemard Bridge. The ratio of annual runoff volume to the volume of annual basin mean rainfall is estimated at about 52%.

The sediment deposit volume in the reservoir of storage dams were estimated based on the other schemes in and around the Kelantan River basin. The average annual sediment deposit volume of 410 m^3/km^2/year was applied to determine MOL for the reservoir of storage dams.

Tidal data at Geting locating at the river mouth of the

Golok River is the nearest tidal level gauging station from the river mouth of the Kelantan River. The data was then adjusted referring to MSL at Kuala Terengganu in order to set at the equivalent datum level with those for the topographic survey. The adjusted datum level was set at El.0.259m and its mean HWL was estimated at El.0.691m at the river mouth of the Kelantan River.

3. PROBABLE FLOOD

3.1 River Basin Model

The model comprises the upper reaches of the Kelantan River having a catchment area of 12,080 km2. The catchment is divided into 26 sub-basin and 15 river stretches as shown in Fig.III.3.1.

The model was developed to assess the physical aspect of hydrological behaviour in the upstream basin and the appropriate scale of structures for flood mitigation. The concept of the model is described in the ANNEX II of Supporting Report for Master Plan Study.

The configuration of the model are enumerated below.

Item	nos.
Sub-basin	26
River stretch	15
Base point	69
Provisional damsite	5

The schematic diagram of arrangement of the above are shown in Fig.III.3.2. The location of representative rainfall gauging stations and Thissen's polygon are shown in Fig.III.3.3. The area of each Thiessen's polygon contributing to each sub-basin are listed in Table III.3.1.

Runoff coefficient was estimated deriving from the relationship between the volume of direct runoff at the time of flooding and the accumulated rainfall depth. The flood hydrographs in 1983 and 1984 were adopted to estimate the runoff coefficient since both hourly water level data at Guillemard Bridge and hourly rainfall records in the upstream basin are available. The data show the runoff coefficient of 0.55 is adequate until the accumulated rainfall depth reaches 200 mm, while it changes from 0.55 to 1.0 when the accumulated rainfall depth is more than 200 mm.

The duration of probable rainfall was defined on the basis of the following relationship at Guillemard Bridge.

(i) direct runoff depth vs. accumulated effective rainfall depth, and

(ii) annual maximum peak discharge vs. basin mean rainfall