ANNEX–C

GEOLOGY AND CONSTRUCTION MATERIALS

ANNEX - C

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ANNEX-C GEOLOGY AND CONSTRUCTION MATERIALS

C.1 INTRODUCTION

In the previous study made by WAPDA for the water resources development in the Malir basin, construction of two dams was proposed on the Mol and Khadeji rivers, tributaries of the Malir river.

In connection with this study, some geological and soil mechanical investigations of these damsites were also carried out by WAPDA in 1979. In addition, the following investigations were made for confirmation of and supplement to the WAPDA investigation and study.

- Site Reconnaissance
- Test Pitting 1 Pit
- Laboratory Test
  - Soil Test 7 Samples
  - Rock Test 5 Samples
- Electric Resistivity Survey 6 Points

All the investigation results are fully used for the present study of geology and materials for construction of the dams as presented in this ANNEX.

C.2 REGIONAL GEOLOGY

C.2.1 General

Pakistan extends from 23° to 27° north latitude and from 61° to 76° east longitude, and is part of Indo-Pakistan subcontinent, composed of two physiographic and geological parts known as Peninsular and Extra-peninsular.

(a) The peninsular region is a great triangular low relief region including western and eastern Ghats, the vast Decant Plateau, the Malwa Plateau and numerous low hills. The rocks are mainly of Precambrian to Cretaceous and are not folded, but faulted (refer to Colombo Plan-Reconnaissance Geology by Hunting Survey Corp. Ltd.).

(b) Extra-Peninsular region is of the great arc of folded mountains ranging from Iran and Baluchistan through the Himalayan Range to Burma; and the great crescent shaped Indogangetic plain which separates mountains. The rocks are Mesozoic and Cenozoic Eras.

C.2.2 Topography and Physiographical Features

The mountainous relief follows the general axial trend of structures, and they are:

- the foot hills of western Sindh which have gentle structure and are of low relief;
- the Nagan range of mountain front, steeply folded, intensively faulted and of high relief;
- Zarghun and Khuzdar knots folded complex; and
- Central Mekran, a region of parallel valleys and ridges.

Except for the hills of Khairpur, Indus plain is devoid of major relief and is essentially a broad and shallow basin bordered on the east by the low hills of Peninsular, India and on the west by the ranges of Baluchistan and western Sindh.

The central part is buildup with floodplain material of the Indus river, which is post Tertiary alluvium, cut by river channels. The land slope is less than 1/5,300 or 1 ft. per mile. The western part of basin is a piedmont plain that slopes gently up to the mountains. The eastern part of the basin is largely covered with sand of the great "Thar" desert.

The erosional physiography is typical of arid and semi-arid terrains, as seen by abrupt boundary between steep rocky mountains and the wide alluvial valley. The Indus river flows on a very flat plain (own-made plain,more than 1,100 km long with one-foot per-mile slope, broken by a group of pre-cambrian hills and low isolated limestone hills at Sukkar, Hyderabad and Karachi).

C.2.3 General Stratigraphy

(1) Stratigraphic Succession

A generalized stratigraphic succession of the area is summarized as follows:

Period	Epoch/Age	Formations
Holocene	Recent	Loose alluvial, wind born deposits.
	Subrecent	Cemented coarse gravels conglomerates and sandy gravels.
Tertiary	Pliocene	Manchar formations in Sindh and Karachi area. Sand stone, shale and conglomerate.
	Miocene	Gaj formations in Western Sindh and Karachi area. Lime stone, sandstone and shale.
	Oligocene	Nari formations in Western Sindh. Sand stone and limestone.

(refer to Fig. C.2-2, C.2-3 for Regional Geology)

The details of Gaj formations, Manchar formations and recent deposits found in the study area are described in the next paragraph (B).

(2) Gaj Formation - Miocene (in Colombo Plan Report)

The lowest beds exposed in the area are Gaj limestone and calcareous sandstones, and conglomerate is a minor component associated.

Near Karachi calcareous sandstones are mutually gradational with limestones. The limestone is cream coloured or pinkish white when fresh, but is brown, yellow, grey orange-brown or chalky when weathered. The beds of both limestone and sandstone are generally slabs in 0.3 - 1.5 m thick. Shale and Marl (Argillaceous limestone) are proportionally minor and are mainly drab grey (khaki). The sandstone is soft and crumbly to hard, fine grained and mostly white, yellow-brown, red-brown, grey or pinkish.

(a) Morphological Expressions

The Gaj formation, in most places, dips at moderate-to-steep angles, and the more resistant limestone and sandstone members stand out as small ridges. In the north region of Karachi, the low dipping and horizontal beds of hard limestone form plateaus with an elevation of 120 - 150 m, bordered by steep scarp.

In the type locality of Gaj River and other regions the Gaj formation conformably and transitionally overlies the Nari formations.

(b) Paleo-geological Conditions

The Gaj formation is mainly a marine assemblage, but it has fluviatile or estuarine components that demonstrate encroachment of fresh water environment from the north, near the end of Miocene. Near the Arabian sea, the Gaj formation is entirely marine. In the foreland basin, the sand and shale of the Gaj were brought in from the north, and as the basin was filled, the sea gradually retreated southward. Due to pre-orogenic deformations the anticlinal structures were developed, and due to uplift that exposed Nari,the beds of conglomerates of wide occurrence are found.

(3) Manchar Formation

The Gaj formation is overlain by the Manchar formation, in the belt from Karachi in the north, to Karachi in the south along the mountain fringe.

The sandstone and shale with subordinated amounts of conglomerate are the chief formations. The sandstone is gritty, soft, crumbly and cross-beded on fresh surfaces, which is grey or greenish grey, and brown. The shale is soft, earthy and clayey. The colours are ferruginous hues of orange, yellow brown, brick red and yellow-buff displayed in alternating beds. Conglomerate is in small amount, and the pebbles are mostly of soft sandstone, yellowish clay and sandy limestone, similar to the rocks of Nari and Gaj.

(a) Morphological

Manchar formations weather softly and underlie a terrain of low topography. Near the Karachi, the Manchar is transitional with the Gaj and the contact is not easy to define.

(b) Paleo-geological Conditions

Generally,the Manchar formations are river or fluviatile deposits, but near the Karachi these are estuarine, or even marine near the Arabian sea. They were deposited in a relatively narrow trough, which opened southward to the sea, and the shore migrated south as the trough was filled.

C.2.4 Structure and Tectogenesis

Successive cyclic periods of emergence, erosion and deposition attended the development of Hyderabad Arch and indicate pre-orogenic (Before Himalayan) deformation of a broad nature. The structure of Indus plain strata is essentially unfolded, and the structure of western Sindh is foothill belt, marginal to more intensely deformed mountains. The belt is at least 130 km wide near Hyderabad and practically disappears at Lat: 28°N, where the Indus plain laps more or less directly against the mountains.

The western hills of Sindh have broad gentle folds of tectonic style, having relatively few faults. The dips of strata are generally less than 20°, but are steeper at some localities. The axial-plane traces of many of these folds are crooked (unclear), branched and difficult to determine.

In the south west direction of Hyderabad, anticlinorium is the "Karachi-Synclinorium" which is corrugated by a multitude of small flexures; but is relatively well-defined as a unit, clearly plunging and broadening to the south.The axis of this synclinorium passes in a gentle arc from north to south. The Karachi synclinorium is also less complicated pre-orogenic (before Himalayan) structure, ordinary deformation that produced gentle doubly plunging folds; due to relatively low degree of horizontal compression. These folds are of considerably large breadth as compared with their axial lengths.

C.3 GEOLOGY OF MALIR BASIN

The geology of the Malir basin consists of Quarternary deposits, a Pleistocene tertiary Manchar formation, and a Miocene Gaj formation.

Some Quaternary deposits cover a wide area in the lower reach of the Malir river and the study area as Fluviatile deposits, and form the river bed of Fluviation and the lower and medium terrace floors in the mountains. The geology is made up primarily by the arenaceous composition followed by gravel in the upstream and by silt in the downstream area. These unconsolidated deposits are characterized by partial cementation (hard rock formation) affected by calcification generated in the upstream area or bedrock.

Although Manchar formation is primarily spread over the pediment lowland of the upper reach in the study area, it is also observed as the restberg even in other parts of the study area. Its main components are sandstone and conglomerate, with soft shale and mudstone being positioned between them.

Made up of limestone and sandstone, Gaj formations are widely distributed in the upper reach mountains including the proposed reservoir.

The following shows the strikes and dips of beds for Manchar and Gaj formations in the downstream area and the left bank of the upstream area of the Malir river, respectively:

	Manchar Formation	Gaj Formation
Strike	N 60° - 80° W	N 50° - 60° E
Dip	5° - 15° E	5° - 15° NW

C.4 KHADEJI DAMSITE

C.4.1 Geology

The proposed damsite is located at the gorge which is about 7 km upstream from the confluence of the Malir river and the Khadeji river. The river bed forms an alluvial floor with an EL. of approximate 130 m and a width of 170 m to 200 m, which is made up primarily by Quaternary unconsolidated deposits and consolidated rocks.

In the river bed, the river course moves toward the right bank which has abutment with a terrace cliff of 50°, leading to a terrace floor with an EL. of around 200 m. On the other hand, the geographical features of the left bank are marked by a relatively moderate terrace step, leading to a plane with an EL. of about 170 m.

The geology is configured by Quaternary deposits that form the river bed, and a Miocene Tertiary Gaj formation creates abutments in both banks and will become a damsite foundation rock. The Quaternary deposits are made up of a shale bed with unconsolidated medium sand, and consolidated sandstone and conglomerate, gently dipping in the direction to the right bank. The formation thickness at the center of river bed is about 8 m. With unconsolidated argillaceous soil and gravel, lower and medium terrace floors exist in the area of the upstream and downstream from the damsite.

The foundation rock of damsite consists mainly of limestone, while the Gaj formation is made up of limestone and sandstone. The major compounds of the limestone are: (1) marl and dolomite (pelitic); (2) chalk and coral sand (sandy); and (3) calcite (crystalline). Among these compounds, sandy limestone is predominant. The rock quality of pelitic and sandy limestone moderately changes each other. Both of them are crackless massive rocks with coral pieces and shelly faeces. The crystalline limestone has a hard lamellar wall with few cracks or joints.

The following figure shows compressive strength inferred from a Schmidt hammer test:

Rock	Compressive Strength (kgf/cm^2)	Hardness
Pelitic limestone (marl, dolomite, mudstone)	180 - 200	medium hard to soft
Sandy limestone (coral sandstone, chalk)	120 - 180	soft to medium hard
Crystalline limestone (calcite)	400 - 1,100+	hard rocks

The faeces, with thicknesses of 4 m to 8 m, alternate each other, with dip values of 3° to 5° in the right bank downstream. There are at least 5 hard rock beds at abutments on both banks.

Since the terrace floor of the right abutment is made up of hard limestone, very few overburdens exist and the weathered zone extent of rock mass is some 3 m. According to the drillhole log, a favorable core recovery was recorded on the right bank with Lugeon values for permeability from 1 to 4 as opposed to 1 to 6 in the river bed. On the other hand, the left abutment has a relatively thick overburden (1 m to 5 m). The permeability of rock mass is 38 to 115 Lugeon at the section about 15 m depth and 2 to 16 Lugeon below this depth (15 m to 45.7 m). In some sections, excessive leakage may be observed. Weathering and cracking of rock mass have progressed judging from a poor core recovery. Solution cavities might be present.

The strength of bedrock is presumed to be as follows:

Compressive strength	$\delta c = 120$ (kgf/cm^2)
Tensile strength	$\delta t = \frac{1}{15}\delta c = 8$ (kgf/cm^2)
Shearing strength	$\tau 0 = \frac{1}{2}\sqrt{\delta c \cdot \delta t} \fallingdotseq 15$ (kgf/cm^2)
Internal friction	$f = \tan 40^\circ = 0.8$

Generated in the soft limestone below hard limestone, solution cavities are noted mainly on the upstream left bank around damsite. Most of these solution cavities have been developing along with bedding plane and few joint wall (with some 50 m spacing). They are assumed to be caused mainly by lateral erosion of Fluviation, because the traces of cavities are new and few are seen at the higher elevation. In general, it is considered that there is no large and continuous solution cavities in the damsite and reservoir areas, judging from the following reasons; (1) Geological age of the Gaj formation is Neogene-Miocene, which is the later age than Mesozoic-Jurassic, (2) Less rainfall area, (3) Non-observation of Karst topography such as Doline and Lapies, (4) Less existence of fissure, crack, fault and fold axis in the Gaj formation, and (5) Non observation of old solution cavities along those fissure, crack, fault, and fold axis. However, the waterpass course should not be ignored since the bedrock has some pelitic portion in itself, the Gaj formation has confined water (at Gadap and Kathore) and the Khadeji river is bending at the damsite.

The reservoir is characterized by the fact that the Gaj formation folds greatly (with dip values of 5° to 15° toward the left bank) where a mountain region of the upstream left bank is in edge out, weathering is notably seen at the upper reach and there are more cracks (particularly in the right bank).

C.4.2 Construction Materials

C.4.2.1 General

Both concrete and fill-type dams will be geologically as well as topographically suitable for the Khadeji damsite. Construction materials required for these two dam types, which are obtained in and around damsite, are classified as follows:

- Gravity Dam : Concrete aggregates
  (Coarse aggregates, fine aggregates)
- Fill Dam : Soil materials (impermeable materials)
  Sand and gravels (moderately permeable to permeable materials)
  Rock materials (= do =)

Availability and characteristics of these materials in the study area are discussed in the following Subsections:

C.4.2.2 Concrete Aggregates

(1) Coarse Aggregates

Geology of damsite and its subordinate area is mainly composed of Gaj formation limestone of tertiary period. Available rock materials in and around damsite are also mainly limestone.

Rock tests of limestone samples which were obtained at damsite by drilling (see Table C.4.1) on the left bank at 3 km upstream from the damsite (see Table C.4.2), were carried out by WAPDA in 1979.

Additional rock tests of the samples, obtained from right bank of 1 km upstream from the damsite (see Table C.4.2) were carried out for this study. Results of the rock tests and evaluation of the materials are as follows:

(a) Limestone at damsite

Exposed rock obtained in the upstream of right bank

- Specific gravity on dry basis = 2.0 - 2.3
- Absorption = 5 - 9%
- Abrasion = 10 - 16%
- Loss of soundness test (by Sodium Sulfate) = 10 - 30%
- Unconfined strength = 50 - 80 kgf/cm^2

Exposed rock obtained in the upstream of left bank

- Specific gravity on dry basis = 2.5 - 2.6
- Absorption = 3.3%
- Abrasion = 9%
- Loss of soundness test = 16 - 19%

Meanwhile, unconfined strength of drilling core obtained at damsite shows qu = 50 - 300 kgf/cm^2. This implies that physical properties of the above drilling core on the left abutment appear to be slightly better than those of exposed rock at right bank. Therefore, the best rock material among five samples is the

rock obtained at left bank. Rocks in the upstream of left bank are judged to be used as corse aggregate.

(b) Quarry near the damsite

The nearest possible existing quarry is located along the Super Highway at Bholari, 100 km north-east from the damsite. Test results of materials obtained in this quarry are as follows:

- Specific Gravity on dry basis = 2.48
- Specific Gravity on surface dry basis = 2.66
- Absorption = 6.8%
- Abrasion = 4.5%
- Loss of soundness test = 17%

(2) Fine Aggregates

Fine aggregates could be produced through crushing process of coarse aggregates in general. Satisfactory quality of fine aggregates could not be expected due to poor quality of coarse aggregates around the damsite. However, a great volume of sand and gravels (sand rich in general), distributed in the river-bed of the Khadeji river, could be utilized as fine aggregates.

C.4.2.3 Soil Materials

Rocks are exposed at and around the damsite except river bed. The soil materials could be obtained at the site 4 km upstream from the damsite on the left bank.

Geological investigation of soil materials by test pits and laboratory tests was carried out by WAPDA in 1979, and the results are shown in Table C.4.3. According to the investigation, average thickness and distribution area of the materials are 1.25 m and around 2.5 km^2, respectively. Available volume of the soil materials would be as follows:

Volume = 1. 25 m x 2.5 km^2 =3,000,000 m^3 approximately.

These soil materials appear to be impermeable judging from the content of fine particles (20 - 50 % of 0.07 mm passing), though consistency is non-plastic. However, natural moisture content is assumed to be in much dryer side than optimum moisture content in laboratory compaction tests of the soil samples at borrow area of Mol damsite. To keep a proper impermeability of the materials, spraying water will be necessary to reach or exceed its moisture content more than optimum moisture content.

Soil tests of materials obtained along the Super High Way at 10 km south from the damsite were also carried out in previous study. The materials are highly fine grained. They

have 80% of 0.074 mm passing. Therefore, high impermeability could be expected. These materials could be used as contact clays.

C.4.2.4 Sand and Gravels

A huge quantity of sand and gravels are distributed along the river bed of the Khadeji river. Sand is predominant and they could be good filter materials for fill-type dams.

C.4.2.5 Rock Materials

Rock materials available around the damsite area are mainly limestone, and they could be useful, but would not be so good in quality as concrete aggregate. Meanwhile, they are good rock materials for fill-type dams.

C.4.3 Suggestions for Design

C.4.3.1 Foundation

(1) Design Value

(A) For Gravity Type of Dam

(a) Foundation Treatment

As a result of the investigation, methods of treatment will be as follows:

Location	Foundation Excavation	Grouting
Right abutment and valley section	4 - 15 m or over	Standard curtain and consolidation
Left abutment	9 - 10 m or over	Special curtain and consolidation

The form of foundation excavation should be smoothed, so that excessive concentrated stresses should not appear at irregular foundation. The certain grouting is necessary to avoid seepage through the foundation base.

(b) Shear Strength

Shear strength of foundation is as follows:

Internal friction angle = 40° - 00'
Cohesion = 150 tf/m^2

(B) For Fill-Type of Dam

(a) Foundation Treatment

Location	Foundation Excavation	Grouting
Right abutment and valley section	1 - 3 m or over	Standard curtain and blanket grouting
Left abutment	1 - 3 m or over	Special curtain and blanket grouting

The form of foundation excavation should be smoothed so as to avoid the arch action due to irregular foundation.

(b) Shear Strength

Stability analysis of foundation against sliding is not required as the foundation has a sufficiently strong rock.

(2) Basis of Design Value

(a) No joints and fractures can be seen at right abutment and valley section.

The development of solution cavities will be 1 - 15 m from ground surface, but Lugeon unit of deeper part of foundation is very small at right abutment and valley section.

(b) The valley section is covered with subrecent cemented sand and gravel deposits, and their thickness is about 4 - 9 m. These deposits should be removed for the gravity type dam.

(c) The left abutment is highly weathered, and the solution cavities are developed to deeper parts.

The core recovery is not good up to 9 m depth from the ground surface.

C.4.3.2 Construction Materials

(1) Concrete Aggregates

(a) Limestone is the main formation rock exposed along the left bank. Rocks at 3 km upstream from the damsite could be utilized as the material for the concrete aggregates.

Due to the solubility of limestone, however, sufficiently good quality of their materials may not be expected. More laboratory tests should be performed.

(b) The sand and gravels are of good quality.

(2) Rock Materials

(a) Rock materials available in and around the damsite mainly consist of limestone. The limestone is abundant and could be used as rock material.

(b) Design values are suggested as follows:

Fresh rock	internal friction angle	=	40°-00'
Weathered rock	internal friction angle	=	38°-00'

More laboratory tests (triaxial compression test) are recommended for confirmation.

(3) Soil Materials

(a) The soil materials at borrow area are SM in standard classification for soils. But these soils contain a relatively high ratio of fine particles and could be utilized as impermeable materials. However, spraying of water during compaction works will be required to obtain adequate impermeability.

(b) Design value suggested are as follows:

Internal friction angle	=	30°-00' (effective stress)
Cohesion	=	1.0 tf/m^2 (effective stress)
Coefficient of permeability	=	1 x 10^{-5} cm/sec

More laboratory tests (triaxial compression test and permeability test) should be performed for confirmation before detailed design.

C.5 MOL DAMSITE

C.5.1 Geology

The Mol damsite is located approximately 8 km from the junction with the Khadeji river. The Mol river meanders substantially in the upstream from the damsite.

The river bed forms an alluvial floor with an EL. of around 133 m and with a width of 70 m to 100 m. Since three terrace floors on the dam axis of the right abutment expand from the river bed, they reach a floor with an EL. of 180 m, dipping very moderately. On the left bank side, however, a gentle slope exists in the upper stream of the dam axis. On the dam axis, the steep cliff is followed by a floors with an EL. of 160 m and 173 m.

The river bed of Fluviation with a thickness of 5 m to 7 m is composed of loose sand and gravel formations. The river course changes from the right to left bank. At both abutments (on the downstream right bank side of dam axis and on the upstream left bank of dam axis), there are three terrace floors (with an EL. of 136 m, 142 m and 160 m) for the river bed. Two lower floors are made up of Quaternary deposits with semi-cemented clay and gravel, and consolidated conglomerate bed (conglomerate). The width of the river bed, including these lower terrace floors, becomes approximately 200 m. These floors dip toward the right bank with a gradient ranging between 0° and 5°.

The Quaternary deposits of bed rock, namely the foundation rock of damsite, are a Miocene tertiary Gaj formation. The strike of Gaj formation changes around damsite with dip values of 5° to 10°. There is a gentle antiform in the upstream right bank, and a synform in the downstream left bank from the dam axis. It is assumed from geological survey that there is an anticlinal axis along with the river bed on the dam axis.

The following figure gives the composites of the Gaj formation, formed by limestone, and their technical characteristics are as follows:

Rock faces of Limestone

Rocks	Stone	Compressive Strength* (kgf/cm^2)	Hardness
Pelitic limestone	marl stone	70 - 80	soft rocks
Sandy limestone	coral limestone	80 - 120	soft rocks
Crystalline limestone	calcite	400 - 1,000	hard rocks

Remark: * assumed by Schmidt hammer tests

The pelitic limestone moderately changes into sandy limestone. Both limestones are soft bedded rocks. There are at least three beds of crystalline limestone that is heavily cracked hard rock. These limestones exist in the form of the alternated beds. Soft and hard rocks are distributed at the river bed wall and the terrace floor, respectively.

In general, the cementation of soft rocks is poor, because they are friable due to the facts that bedding plane has developed and many pieces of coral and shell are concentratedly located. The drillhole log shows that core recovery on both banks and the river bed is good and all the permeability is less than 1 to 2 Lugeon.

Beds with solution cavities are thin beds within pelitic limestone and sandy limestone. There is one (with an EL. of 155 m) in the upstream right bank and another (with an EL. of 140 m) in the left abutment. In addition, it is reported that there are other two beds by the drillhole log for the river bed. All these solution cavities are assumed not to be caused by cracks or joints, but by the Fluvial erosion. Based on the permeability records, the solution cavities in the river bed are also assumed to be caused by the soft area in pelitic limestones.

The thickness of terrace deposits is estimated at some 10 m. The weathered zone of bed rock (mainly cracky portion) is estimated to be 7 m to 8 m based on the electric resistivity surveys.

The proposed spillway is located on the left bank at about 850 m away from the river bed, using the tributary Nadi extending from the damsite downstream. The thickness of the overburden is within 1 m and the foundation rock is made up of soft and hard shale of limestones. The drillhole log shows a favorable core recovery and permeability.

The geology of the reservoir is formed by alternation of beds with soft and hard limestone. Solution cavities mentioned above are observed only small and limited part. As described in Section C.4.1, it is generally considered that there is no large and continuous solution cavities in and around the damsite and reservoir areas, judging from the regional topography and geology. Its geological structure is characterized by a series of gentle folds, almost horizontally dipping. There is no particular difference between the reservoir and the damsite in terms of geological structure.

C.5.2 *Construction Materials*

C.5.2.1 General

Availability and characteristics of the following construction materials for the Mol dam which will be of fill-type, are discussed in later Subsections:

(a) Concrete aggregates
(b) Soil materials (impermeable materials)
(c) Sand and gravels (moderately permeable to permeable materials)
(d) Rock materials

C.5.2.2 Concrete Aggregates

Geology of the damsite area consists of Gaj formation of Tertiary, and rocks in and around the damsite are composed mainly of limestones. As a result of site reconnaissance

during this study period and laboratory rock tests of drilling cores at damsite done by WAPDA in 1979, limestones at the Mol damsite are similar to those at the Khadeji damsite (see Tables C.4.1 and C.5.1). Therefore, concrete aggregates for the Mol damsite are the same as those for the Khadeji damsite. Limestones available in and around the Mol damsite have not enough quality for the standard level of concrete aggregates. Therefore, detailed test will be required when they are used as concrete aggregates. A large volume of sands and gravels distributed in the river bed could be used for fine aggregates. Meanwhile, the nearest possible quarry site is located at Bholari. Bholari is located at about 120 km from the damsite.

C.5.2.3 Soil Materials

Since rocks at the damsite are exposed in hilly terrains in the upstream and around the damsite area, soil materials could be obtained from flat area along the river stream located at about 3 km downstream from the damsite (see Fig. C.5-4).

Test pitting and laboratory test were carried out by WAPDA in 1979. One test pitting (TP-1) was carried out in the upstream side of borrow area for soil materials, and laboratory test was performed using samples obtained from the pit (see Fig. C.5-5). Results are shown in Table C.5.2 and Figs. C.5-5 and C.5-6.

As a result of the investigation, judgement on soil materials for embankment is as follows:

(a) Soil samples for laboratory test by WAPDA were collected from the layer 1.0 - 2.0 m of depth from the ground surface. They are SM in standard classification for soils.

A large portion of fine grained particles can be observed in the layer 1.0 - 2.0 m in depth from the ground surface through the observation of the wells located there and a new test pit. Judging from the above data, soils which contain a large amount of fine particles passing 0.074 mm sieve are distributed in the layer down 1.0 - 2.0 m in depth from the ground, and their contents of fine particles appear to be 20% - 50%. Tested samples are sufficiently impermeable, however, attention shall be paid for the proper moisture control during the compaction works.

(b) Natural moisture content is at the dry side from optimum moisture content (see Fig. C.5-6).

In general, the highest impermeability of soils can be obtained slightly in the wet side than optimum moisture content. Therefore, measures of adding water during compaction works will be required to keep the higher impermeability.

(c) Soils contain a relatively high ratio of fine grained particles.

Consistency is non-plastic due to a large amount of fine grained particles are classified as silt. Therefore, the soil is judged to be vulnerable against piping without careful handling. Grain size of filter materials should be studied carefully. As a result of the field survey, average thickness of soil material is 1.0 m, and distribution area is 0.8 km^2. Therefore,

available volume = 1.0 m x 0.8 km^2 = 800,000 m^3.

C.5.2.4 Sand and Gravels

A large quantity of sand and gravels are distributed on the river bed of the damsite. Physical property of these sand and gravels in the river bed is the same as those on the Malir river.

Samples were collected at 1.0 km downstream from the damsite, and grain size analysis was carried out. Results of the analysis and range of grain size for filter are shown in Fig. C.5-7. Sand and gravels in the river bed have good gradings and quality for soil materials, and could be used as filter materials.

C.5.2.5 Rock Materials

Rock materials available in and around the damsite consist mainly of limestone. Average unconfined compression strength of limestone using drilling core is = 116 kgf/cm^2. Physical property of exposed rocks at the Khadeji damsite is similar to that of this damsite and the loss of soundness test at the Khadeji damsite is 10 - 30% (see Table C.4.2). Therefore, limestone is judged to be suitable to use as rock materials for fill-type dams.

C.5.3 Suggestions for Design

C.5.3.1 Dam Foundation Treatment and Design Value

(1) For Gravity Type of Dam

(a) Foundation Treatment

The methods of foundation treatment are recommended as follows:

Foundation excavation	5 - 15 m or over. The form of foundation excavation should be smoothed, so that excessive concentrated stresses should not act at irregular foundation.
Grouting	Standard curtain and consolidation grouting.

(b) Shear Strength

Shear strength of foundation is estimated as follows:

Compressive strength	$\delta c = 70$ (kgf/cm^2)
Tensile strength	$\delta t = \frac{1}{20}\delta c = 3.5$ (kgf/cm^2)
Shearing strength (Cohesion)	$\tau_0 = \frac{1}{2}\sqrt{\delta c \cdot \delta t} \fallingdotseq 7.8$ (kgf/cm^2)
Internal friction	$f = \tan 35° = 0.7$
Cohesion	= 78 ton f/m^2

(2) For Fill-Type of Dam

(a) Foundation Treatment

Foundation excavation	1-5 m or more The form of foundation excavation should be smoothed, so as to avoid the arch action due to irregular foundation.
Grouting	Standard curtain and blanket grouting.

(b) Shear Strength

Stability analysis for foundation against sliding is not required as the foundation has a sufficiently strong rock.

C.5.3.2 Construction Materials

(1) Concrete Aggregates

(a) Rock materials available in and around the damsite consist mainly of limestone. These limestone are poor quality due to weathered rock:

(b) The sand and gravels in the river bed are of good quality.

(2) Rock Materials

(a) The limestone is present in abundance and could be used as rock materials.

(b) Design values suggested are as follows:

Fresh rock - Internal Friction angle	=	40° 00'
Weathered rock - internal friction angle	=	38° 00'

(triaxial compression test should be performed for confirmation.)

(3) Soil Materials

(a) The soil materials at borrow area are SM in standard classification for soil. But these soils contain a relatively high ratio of fine particles so that they can be used as impermeable materials. However, proper moisture control during compaction works will be required to acquire enough impermeability and resistance against piping.

(b) Design values are suggested as follows:

Internal friction angle	=	30° 00' (effective stress)
Cohesion	=	1.0 ton f/m^2 (effective stress)
Coefficient of permeability	=	1 x 10^{-5} cm/sec

Further laboratory tests (triaxial compression test and permeability test) should be performed for confirmation before detailed design.

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TABLES

Table C.4.1 RESULT OF UNCONFINED COMPRESSION TEST AT KHADEJI DAMSITE

B.H. No.	Depth (m)	Kind of Rock	Unconfined Strength (kg f/cm2)	Geology
KD-1	2.7 - 3.0	Cemented Sand Gravels	252	Subrecent Deposits
	19.5 - 20.1	Lime Stone	17	Gaj Formation
	26.2 - 26.5	Clay Stone	268	Gaj Formation
	36.3 - 36.9	Sand Stone	288	Gaj Formation
KD-2	1.8 - 2.1	Lime Stone	163	Gaj Formation
	16.5 - 16.8	Lime Stone	122	Gaj Formation
	23.3 - 23.6	Lime Stone	71	Gaj Formation
	39.9 - 40.1	Lime Stone	168	Gaj Formation
KD-3	3.1 - 3.4	Lime Stone	52	Gaj Formation
	7.3 - 7.7	Lime Stone	87	Gaj Formation
	14.8 - 15.1	Lime Stone	161	Gaj Formation
	20.2 - 20.4	Lime Stone	67	Gaj Formation
	41.0 - 41.3	Lime Stone	57	Gaj Formation
	54.1 - 54.4	Lime Stone	85	Gaj Formation
	64.2 - 64.5	Lime Stone	87	Gaj Formation
	75.7 - 75.9	Lime Stone	178	Gaj Formation
KD-4	20.3 - 20.6	Lime Stone	115	Gaj Formation
	21.6 - 22.0	Lime Stone	96	Gaj Formation
	27.7 - 28.2	Lime Stone	187	Gaj Formation

Source: Ref. 01

Table C.4.2 SUMMARY OF ROCK TEST AT KHADEJI DAMSITE

Sample No.	Specific Gravity of Surface Dry Basis Ga	Specific Gravity of Dry Basis Gb	Specific Gravity Gg	Absorp-tion (%)	Abrasion 100 Revol Loss After (%)	Sound-ness Loss After (%)	Unconfined Strength kg f/cm2 (Average)
A	2.18	2.00	2.43	8.9	16.0	29.0	102 58 12 (57)
B	2.26	2.10	2.51	7.8	14.0	19.2	58 53 (56)
C	2.35	2.25	2.51	4.7	10.0	11.7	81 49 89 (73)
D	2.14	2.00	2.33	7.0	-	-	52 41 (48)
E	2.19	2.04	2.39	7.0	-	-	59 53 47 (53)
Average	2.11	2.08	2.43	7.1	13.3	20.0	57
S-1	2.60	2.52	2.85	3.3	9.5	16.3	-
S-2	2.50	2.42	2.72	3.3	8.9	18.7	-

Remarks: Sample No. A, B, C, D, E : Weathered rock, Present Study (1989)
Sample No. S : Fresh rock, Ref. 01, WAPDA Feasibility Study (1979)

Table C.4.3 SUMMARY OF SOIL TEST AT BORROW AREA FOR KHADEJI DAM

Pit No.	Specific Gravity of Soil Gs	Plasticity Index	Grain Size Analysis (%)				Compaction Test EC = 100%		Unified Soil Classification System
			Gravel	Sand	Silt	Clay	Maximum Dry Density g/m3	Optimum Moisture Content (%)	
No. 2	2.66	non-plastic	-	62	38		1.98	9.7	SM
No. 8	2.66	non-plastic	12	60	28		2.05	7.9	SM
No. 10	2.67	non-plastic	-	64	36		1.96	10.2	SM
No. 14	2.67	non-plastic	-	63	37		2.03	9.0	SM
No. 20	2.67	non-plastic	-	80	20		1.94	9.3	SM
No. 22	2.70	3.6	3	55	28	14	2.03	9.0	SM
No. 27	2.68	non-plastic	-	62	38		1.97	9.7	SM
No. 29	2.68	non-plastic	2	52	46		1.99	9.2	SM
A-1	2.69	8.3	-	0.8	99.2		1.78	12.9	CL
B-2	2.72	15.5	-	12.7	87.3		1.81	15.8	CL
C-23	2.67	6.7	-	22.4	77.6		1.90	11.9	CL

Remarks: No. 2 - No. 29 : Dam Site upstream 4 km
A-1 - C-23 : Along Super Highway, west-ward 5km from confluence point of Mol and Khadeji.

Source: Ref. 01, WAPDA REPORT (1979)

Table C.5.1 RESULT OF UNCONFINED COMPRESSION TEST AT MOL DAMSITE

B.H. No.	Depth (m)	Kind of Rock	Unconfined Strength (kg f/cm2)	Geology
ML-1	5.6 - 5.9	Lime Stone	126	Gaj Formation
	14.9 - 15.2	Lime Stone	67	Gaj Formation
	26.7 - 27.0	Lime Stone	150	Gaj Formation
	30.6 - 30.8	Lime Stone	102	Gaj Formation
	36.0 - 36.3	Lime Stone	189	Gaj Formation
ML-2	1.2 - 1.4	Lime Stone	76	Gaj Formation
	8.1 - 8.3	Lime Stone	114	Gaj Formation
	12.6 - 12.9	Lime Stone	158	Gaj Formation
	16.4 - 16.6	Lime Stone	28	Gaj Formation
	24.5 - 24.8	Lime Stone	171	Gaj Formation
ML-3	12.5 - 12.9	Lime Stone	197	Gaj Formation
	17.8 - 18.3	Silt Stone/ Sand Stone	258	Gaj Formation
	21.6 - 21.9	Lime Stone	138	Gaj Formation
	25.6 - 25.9	Lime Stone	101	Gaj Formation
ML-4	3.5 - 3.8	Lime Stone	28	Gaj Formation
	9.2 - 9.8	Lime Stone	93	Gaj Formation
	17.0 - 17.3	Lime Stone	108	Gaj Formation
	22.7 - 23.0	Lime Stone	26	Gaj Formation
	29.8 - 30.0	Lime Stone	73	Gaj Formation

Source: Ref. 01

Table C.5.2 SUMMARY OF SOIL TEST AT BORROW AREA FOR MOL DAM

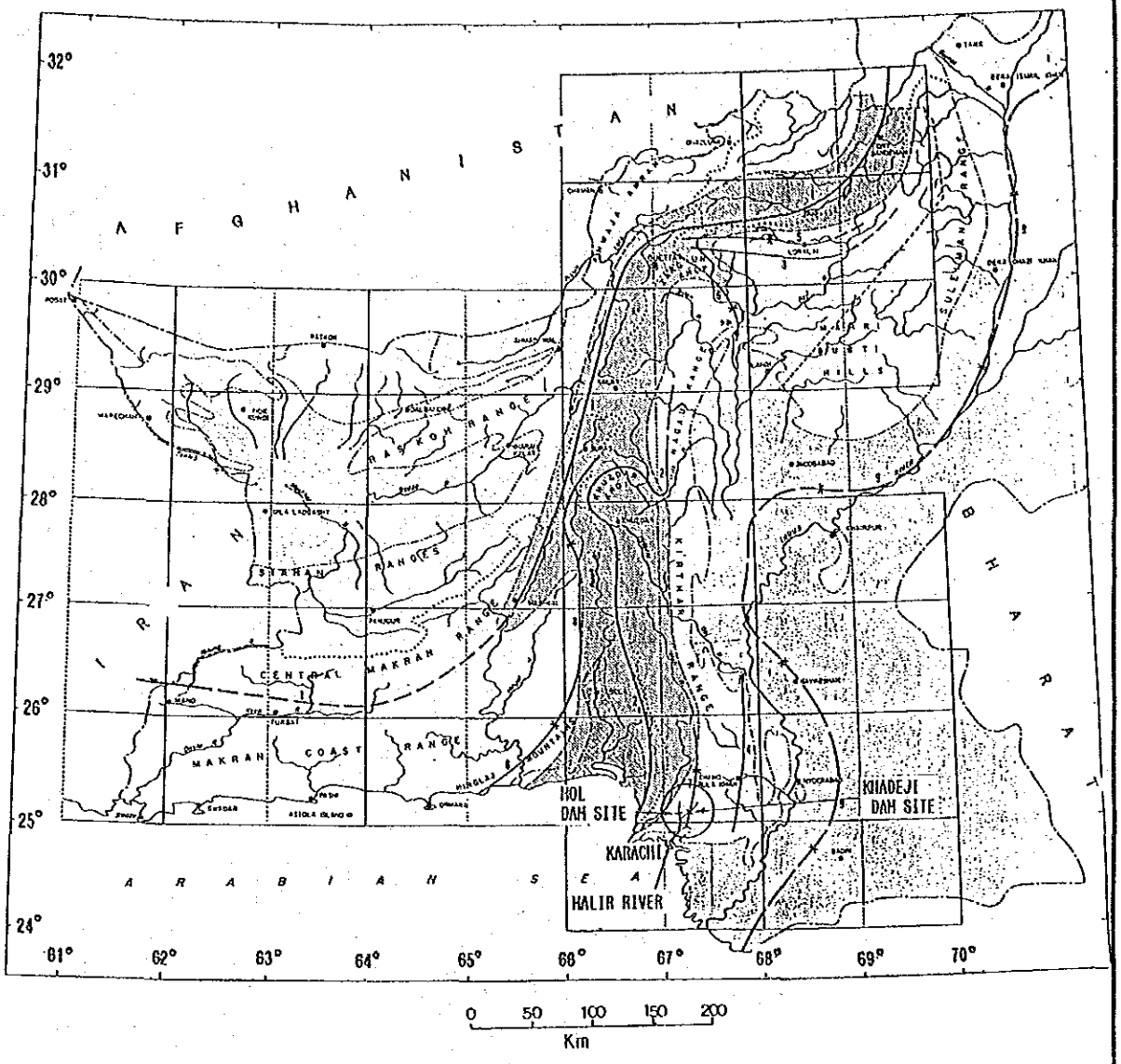
Pit No.	Depth (m)	Natural Moisture Content Wn (%)	Specific Gravity of Soil Gs	Grain Size Analysis					Unified Soil Classification System
				Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Maximum Diameter (mm)	
TP-1	0.5	2.3	2.63	8.1	69.7	14.8	7.5	9.52	SM
	1.0	3.1	2.68	0.8	51.3	39.0	9.0	6.35	SM
	2.0	2.8	2.66	2.0	89.5	8.5	-	9.52	SP
	3.0	1.5	2.69	3.0	86.0	11.0	-	12.70	SP
	4.0	3.0	2.66	28.6	54.2	17.3	-	63.50	SW
	1 - 2	2.3	2.71	0.0	53.3	38.8	8.0	4.76	SM
No. 3	0 - 1	4.2	2.66	6.0	60.0	34		-	SM
No. 6	0 - 1	3.9	2.66	3.0	64.0	33		-	SM
No. 8	0 - 1.5	6.4	2.67	0.0	71.0	29		-	SM
AG-6 Well	12.0	-	-	24.0	66.0	10		15.00	SW

Compaction Test

Pit No.	Depth (m)	Ec = 100%		Ec = 200%	
		Maximum Dry Density (g/cm3)	Optimum Moisture Content (%)	Maximum Dry Density (g/cm3)	Optimum Moisture Content (%)
TP-1	1 - 2	1.96	10.5	2.10	7.9
No. 1	0 - 1	1.95	8.7	-	-
No. 2	0 - 1	1.95	8.2	-	-
No. 3	0 - 1.5	1.93	10.2	-	-

Remarks: TP-1 : Present Study (1989)
No. 1, No. 2, No. 3, and No. 4 : Ref. 01 WAPDA Feasibility Report Study (1979)
Ec 100% : 5.625 kg.cm/cm

FIGURES



LEGEND

CITY, TOWN OR VILLAGE

INTERNATIONAL BOUNDARY

LIMIT OF MAPPED AREA

ALLUVIUM BOUNDRY

RIVER

PRIMARY DRAINAGE DIVIDE

LOCATION OF GORGE OR DEEP VALLEY WHICH IS TRANSURRENT TO TREND OF MOUNTAINS

AXIS OF TECTONIC FEATURE
1. CENTRAL ANTICLINORIUM
2. LAS BELA ANTICLINORIUM
3. SANJANI ANTICLINORIUM
4. HYDERABAD ANTICLINORIUM
5. CHINJAN SYNCLINORIUM
6. URAK SYNCLINORIUM
7. KARACHI SYNCLINORIUM
8. HINGOL SYNCLINORIUM
9. INDUS SYNCLINORIUM (approximate)

AXIAL BELT

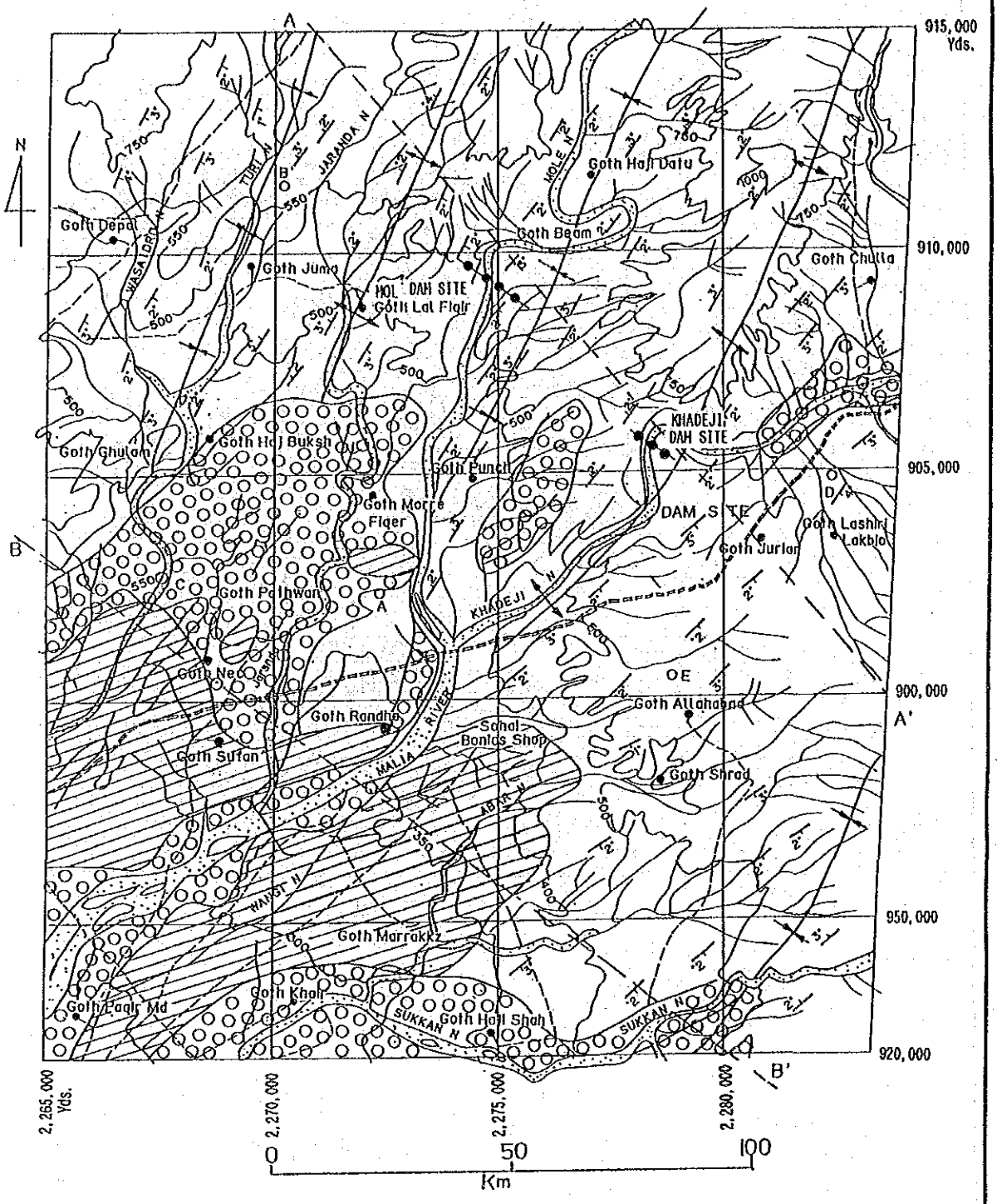
MAIN AREAS OF ALLUVIUM

Fig. C.2-1 Diagram of Drainage System

ISLAMIC REPUBLIC OF PAKISTAN
GOVERNMENT OF SIND

FEASIBILITY STUDY ON
WATER RESOURCES DEVELOPMENT PROJECT
IN THE MALIR BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY



LEGEND

TENTATIVE DAM SITE LOCATION

TENTATIVE BOREHOLE LOCATION

RECENT DEPOSITS

HANCHAR FORMATION

ASSOCIATION OF CONGLOMERATES OF GREY & RED S.ST. PEBBLES OF GAJ AND NUMMULITIC L.ST. ARE ALSO PRESSENT (UP-MIOCENE)

GAJ FORMATION

LIMESTONE YELLOW TO LIGHT BROWN IN COLOUR WITH INTERCLATION OF CLAYSTONE & SANDSTONE (L. MIOCENE)

Fig. C.2-2 Regional Geology Map

ISLAMIC REPUBLIC OF PAKISTAN
GOVERNMENT OF SIND

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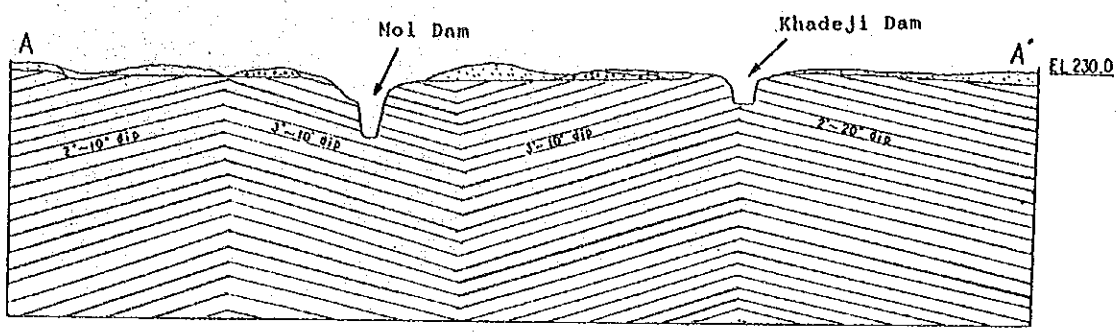
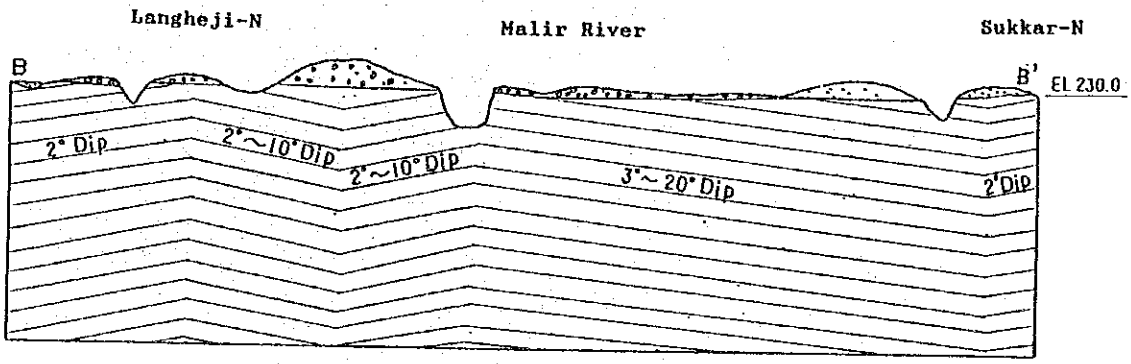


Vertical Section along AA' (Ref: Fig.C.2-2)
(Diagramatic)



Vertical Section along B B' (Ref: Fig.C.2-2)
(Diagramatic)

LEGEND

: RECENT

: HANCHAR S.ST WITH CONGLOMERATE

: GAJ L-ST

Fig. C.2-3 Regional Geology Vertical Section

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
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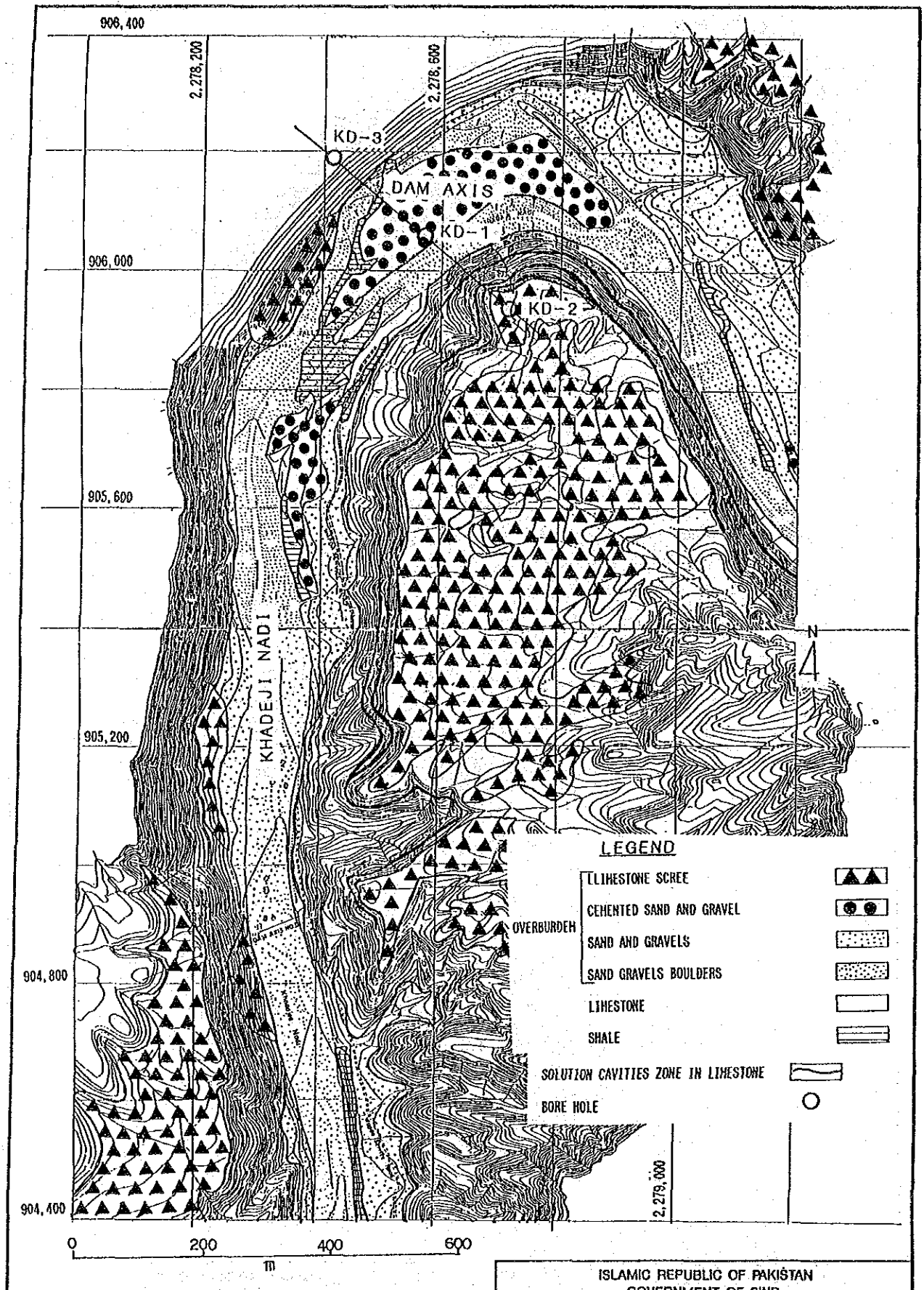

Fig. C.4-1 Geological Map of Khadeji Damsite

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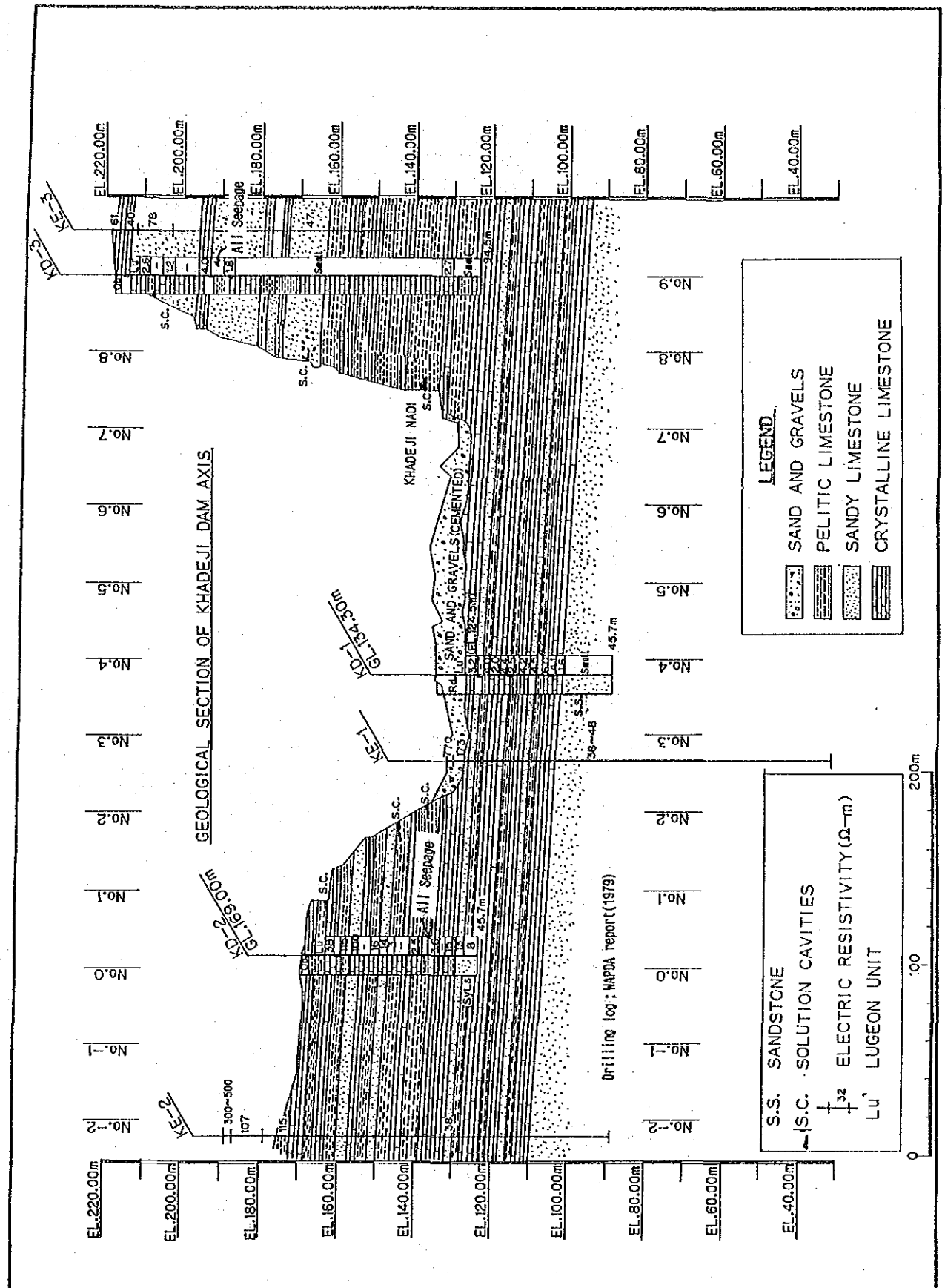

Fig. C.4-2 Geological Section of Khadeji Dam Axis (Looking D/S)

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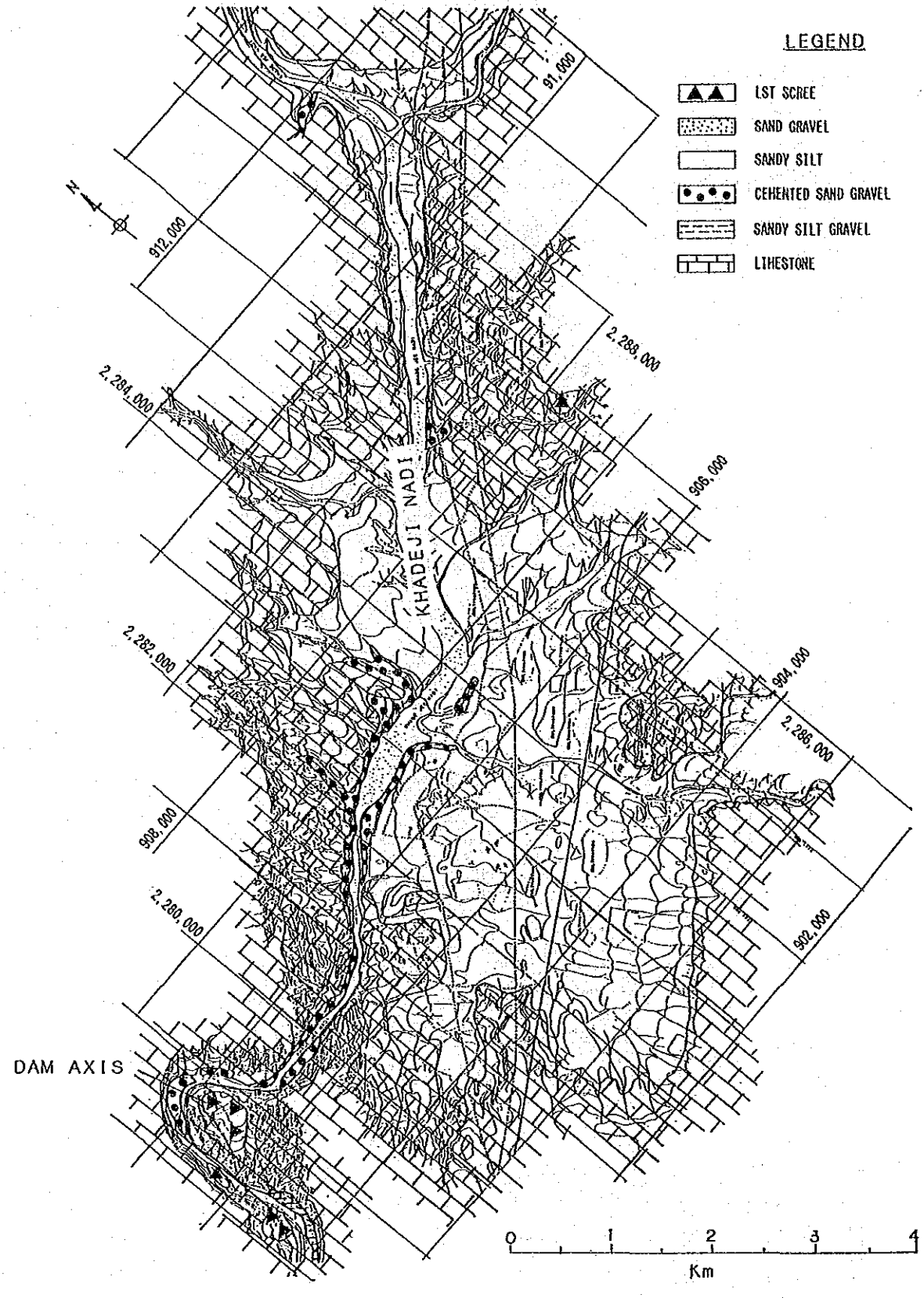

Fig. C.4-3 Geological Map of Khadeji Reservoir Area

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN
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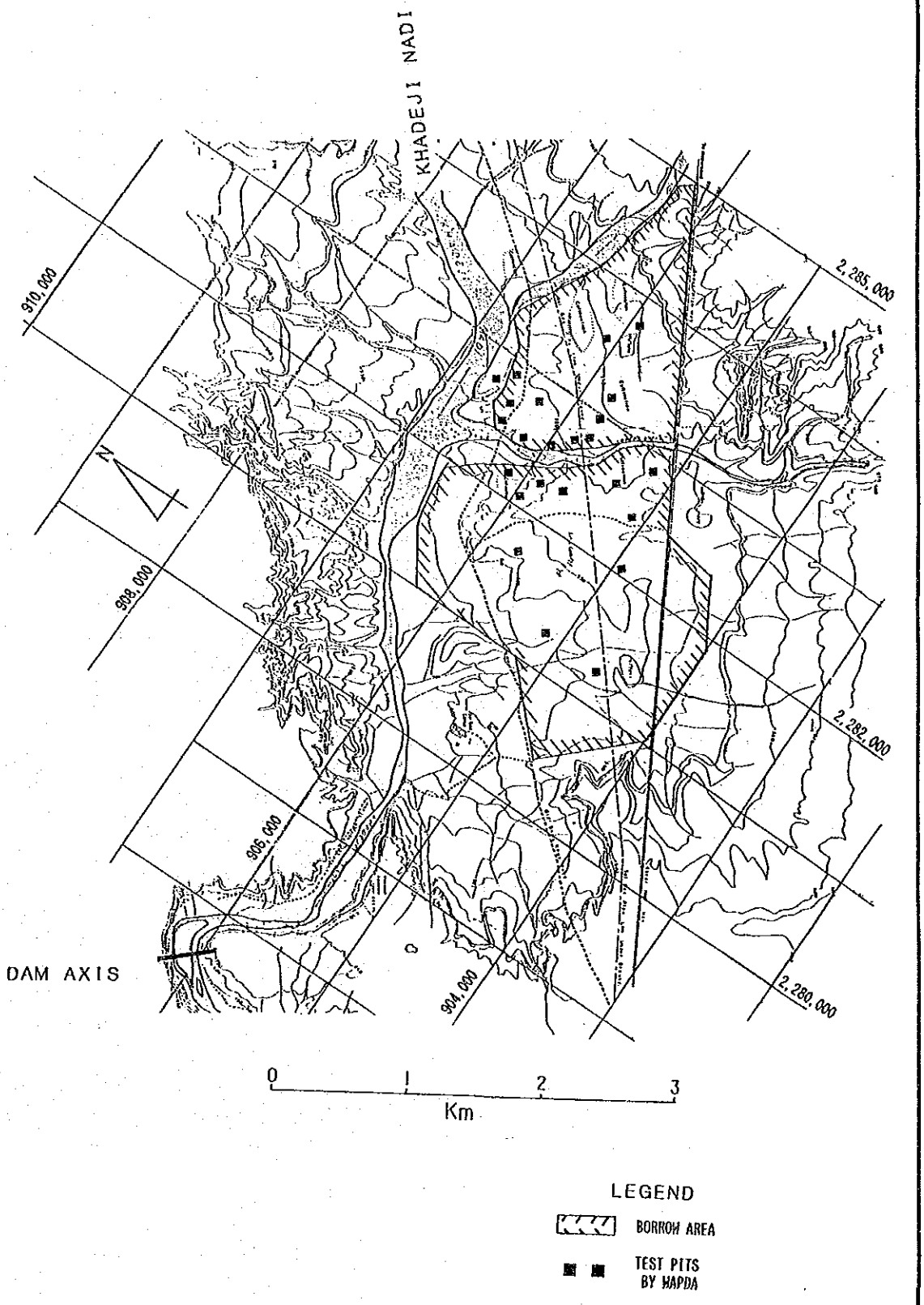

Fig. C.4-4 Location of Borrow Area at Khadeji Dam

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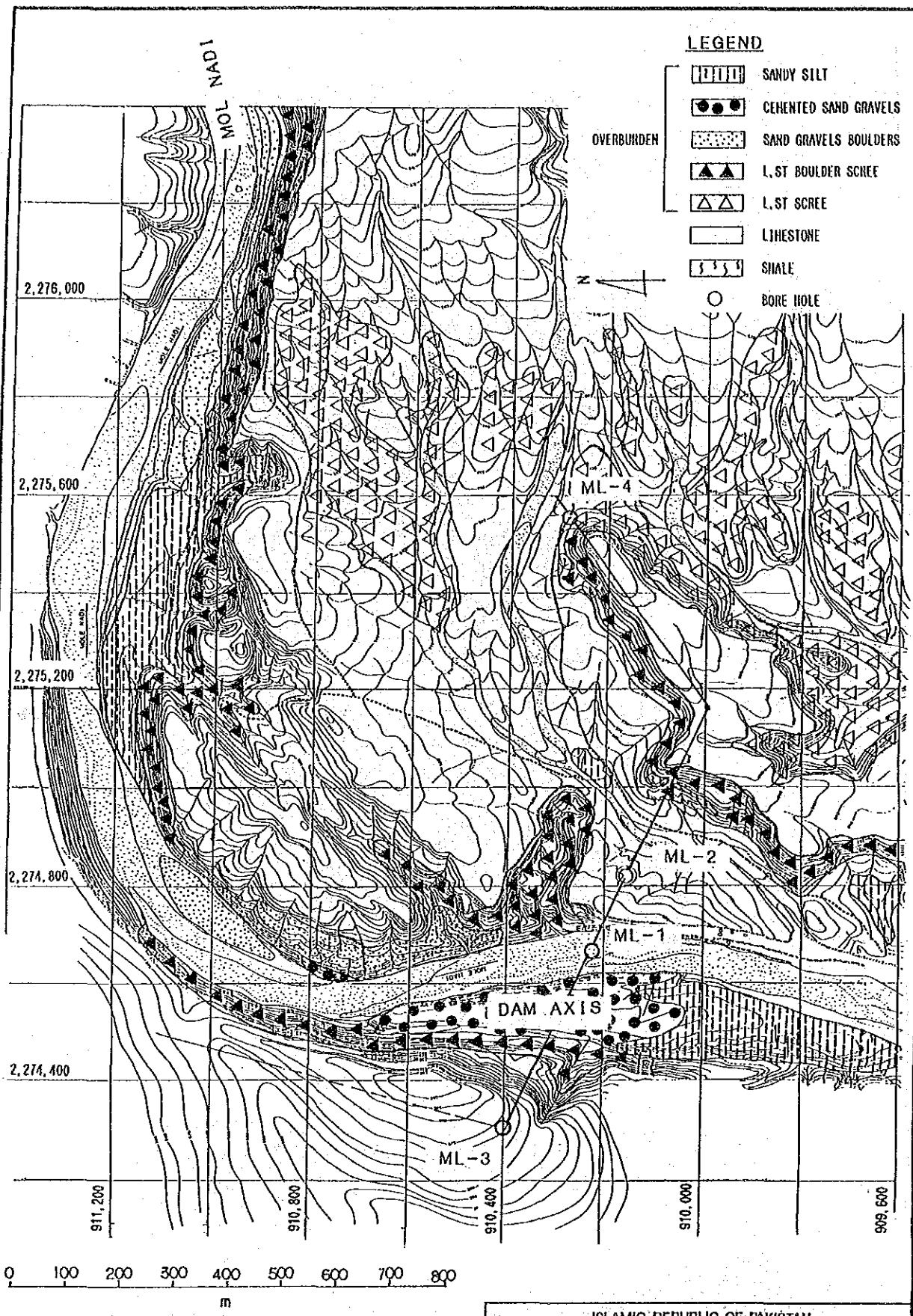

Fig. C.5-1 Geological Map of Mol Damsite

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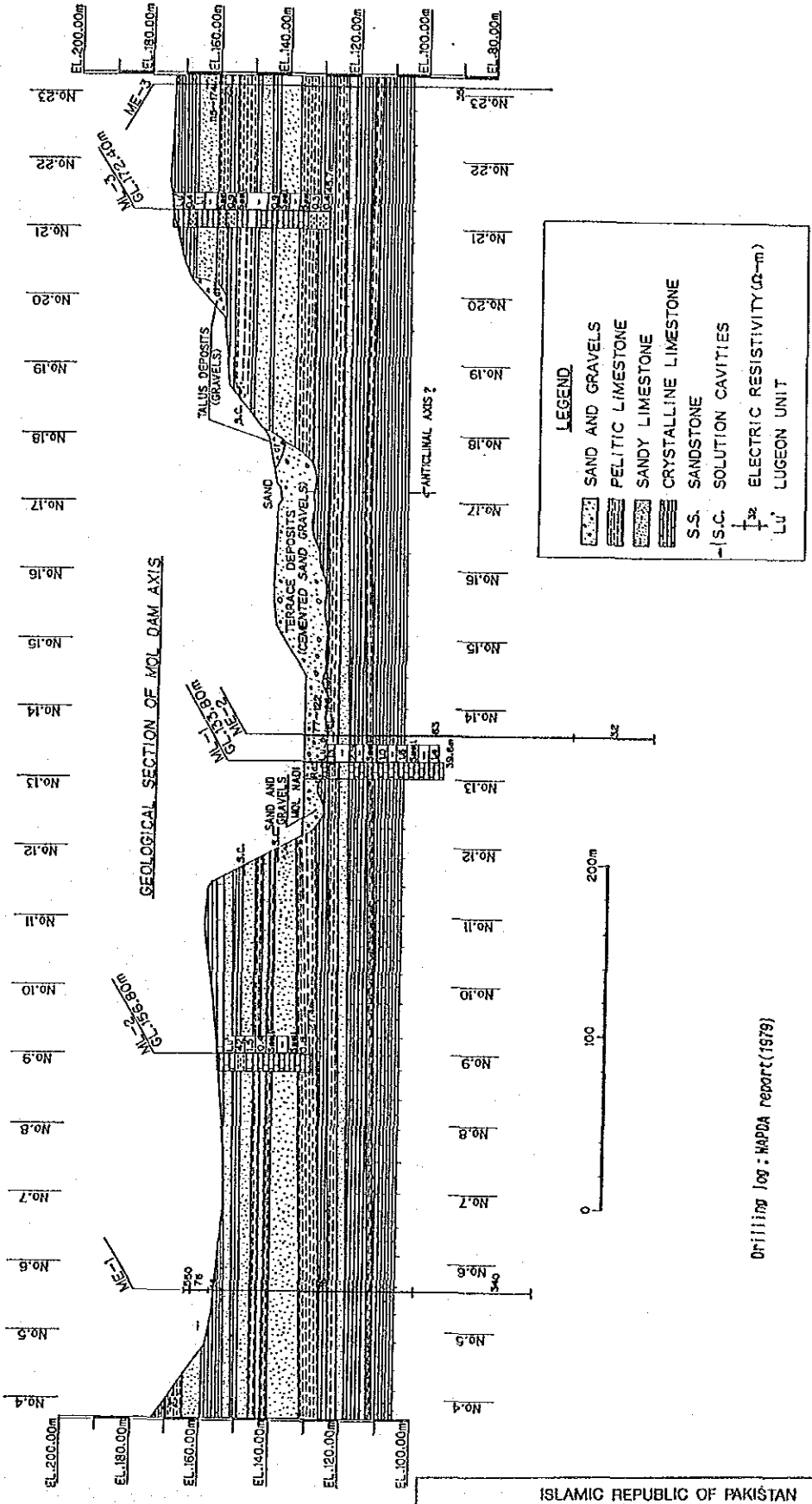

Fig. C.5-2 Geological Section of Mol Dam Axis (Looking D/S)

ISLAMIC REPUBLIC OF PAKISTAN
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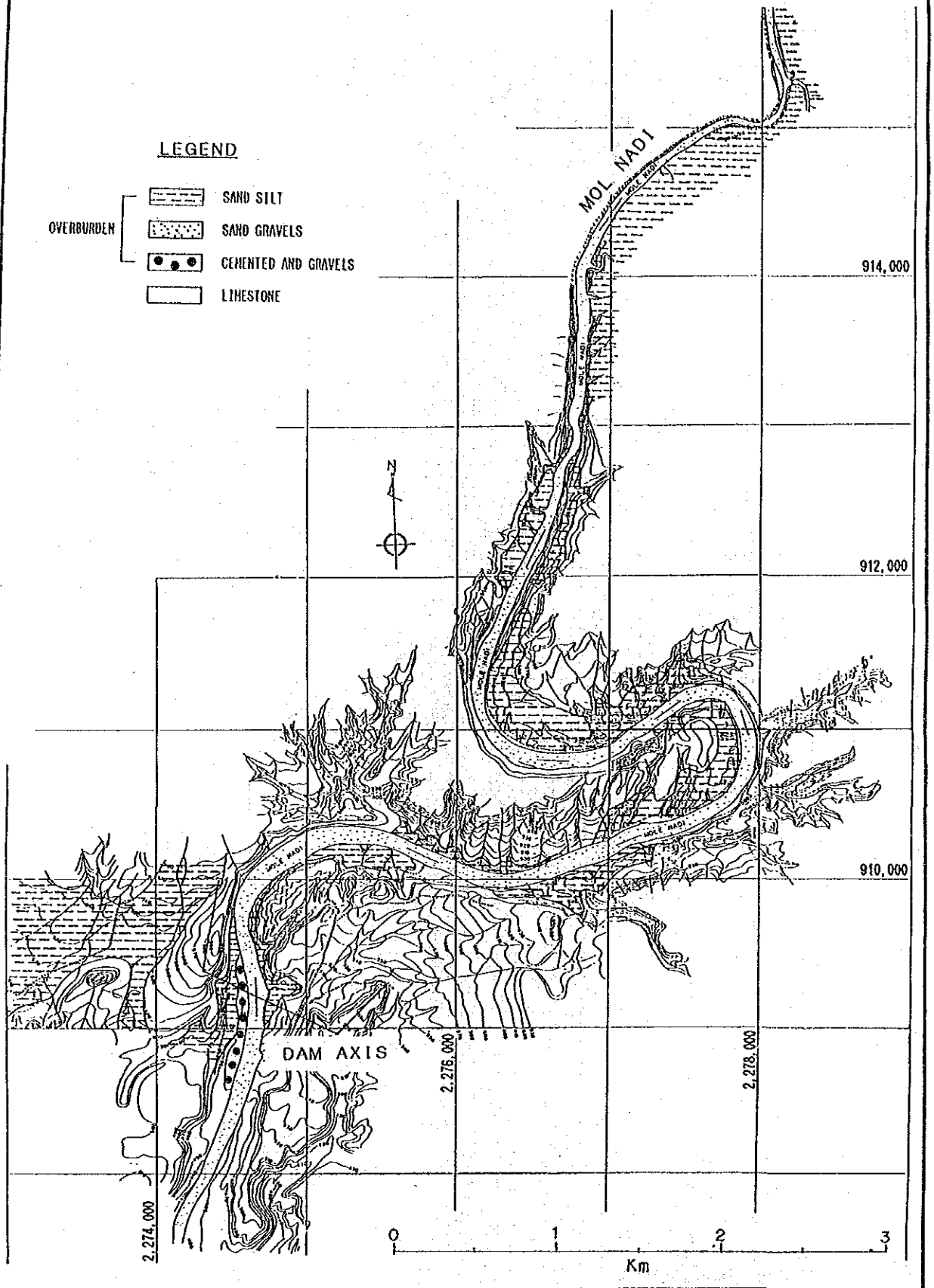

Fig. C.5-3 Geological Map of Mol Reservoir Area

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
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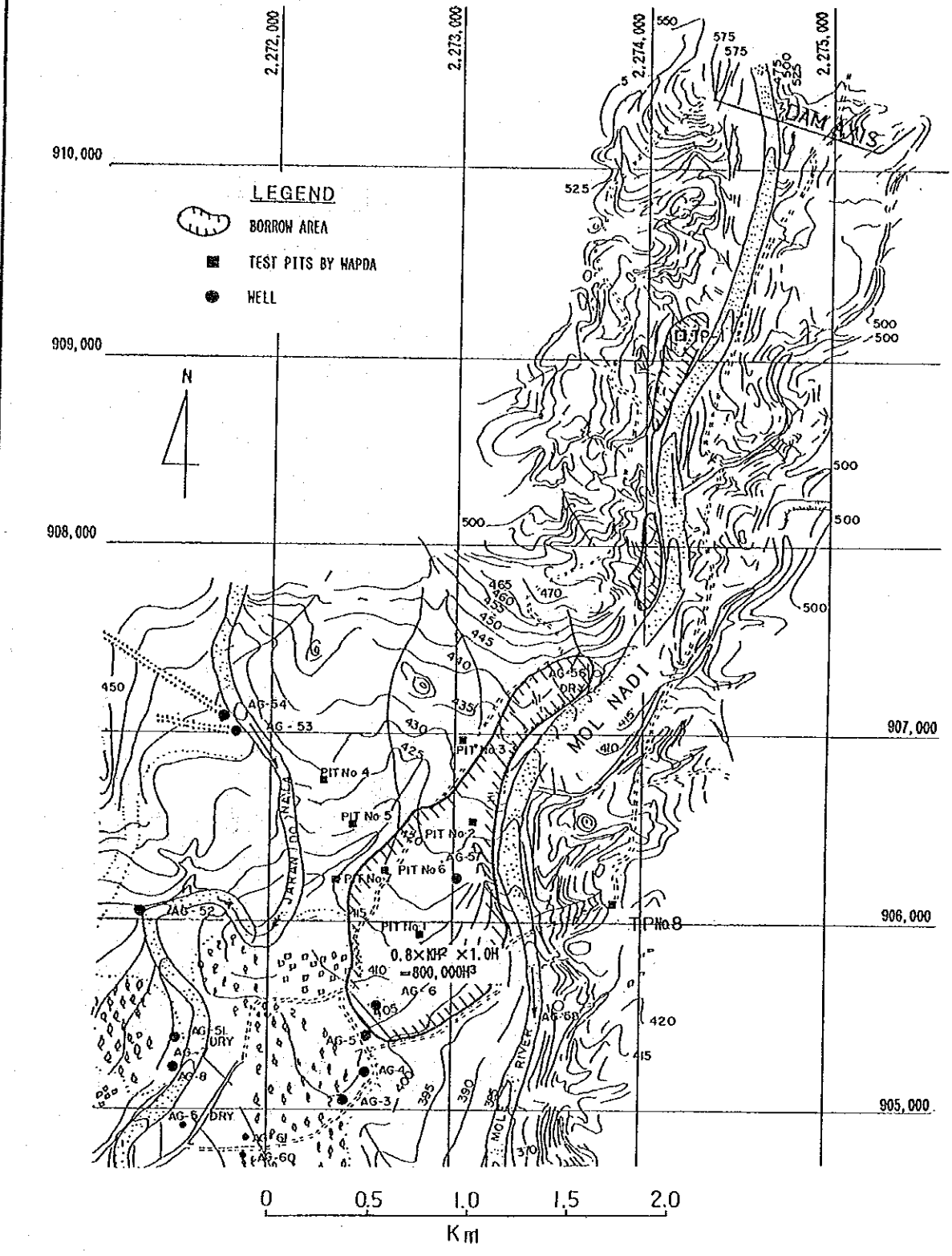

Fig. C.5-4 Location of Borrow Area at Mol Dam

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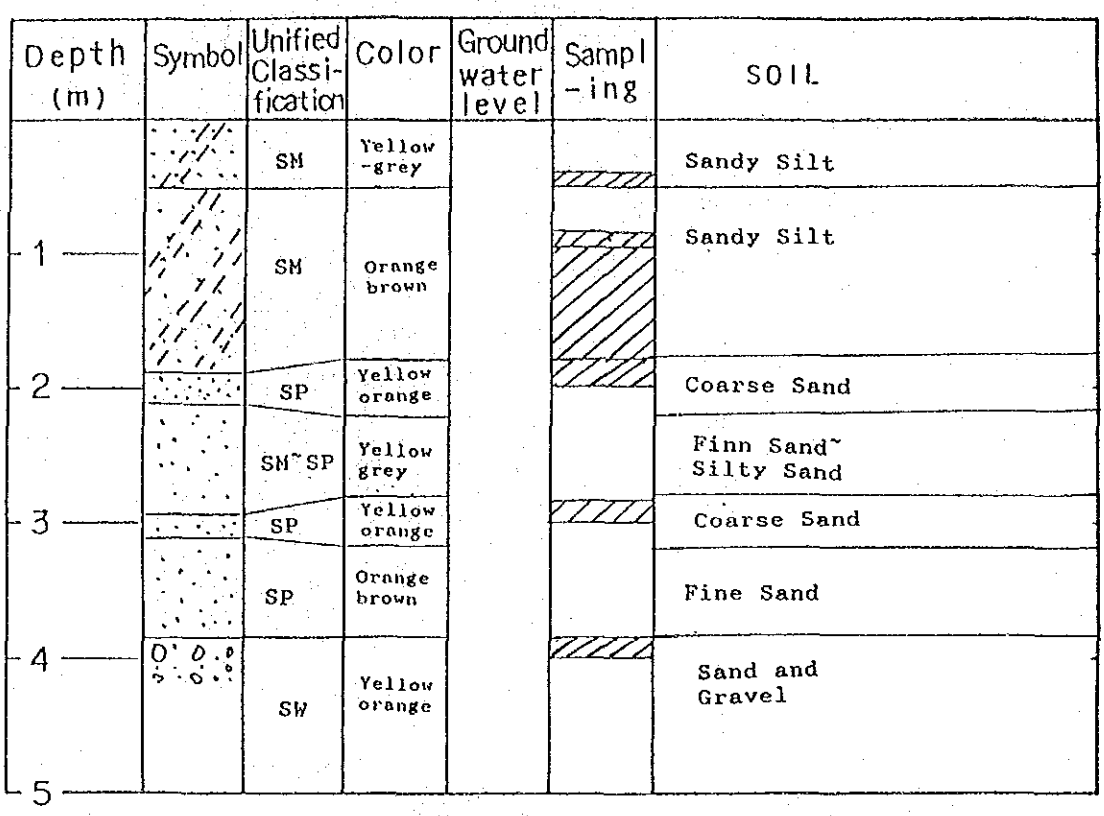

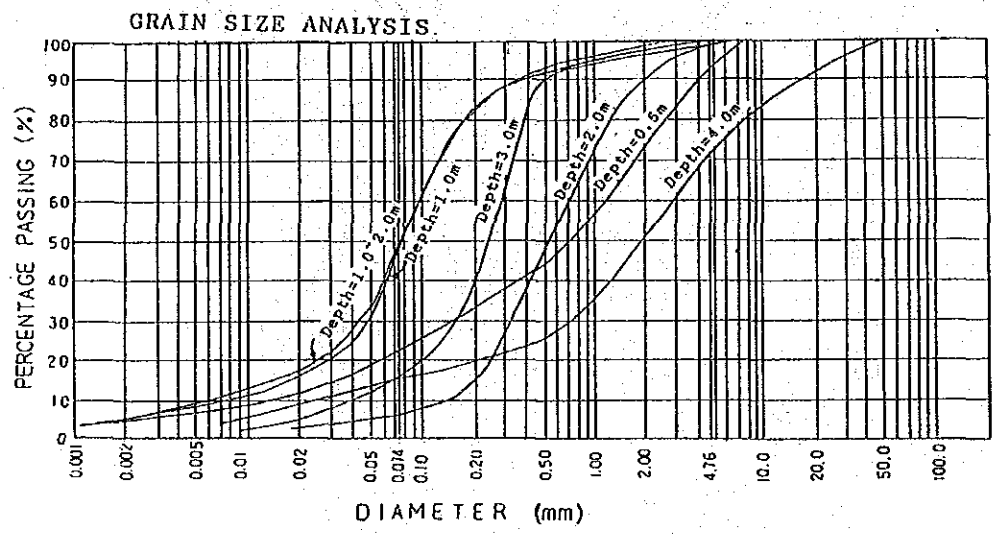

MOL DAM TP-1

Fig. C.5-5 Result of Investigation at Borrow Area (Mol Dam TP-1)

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN
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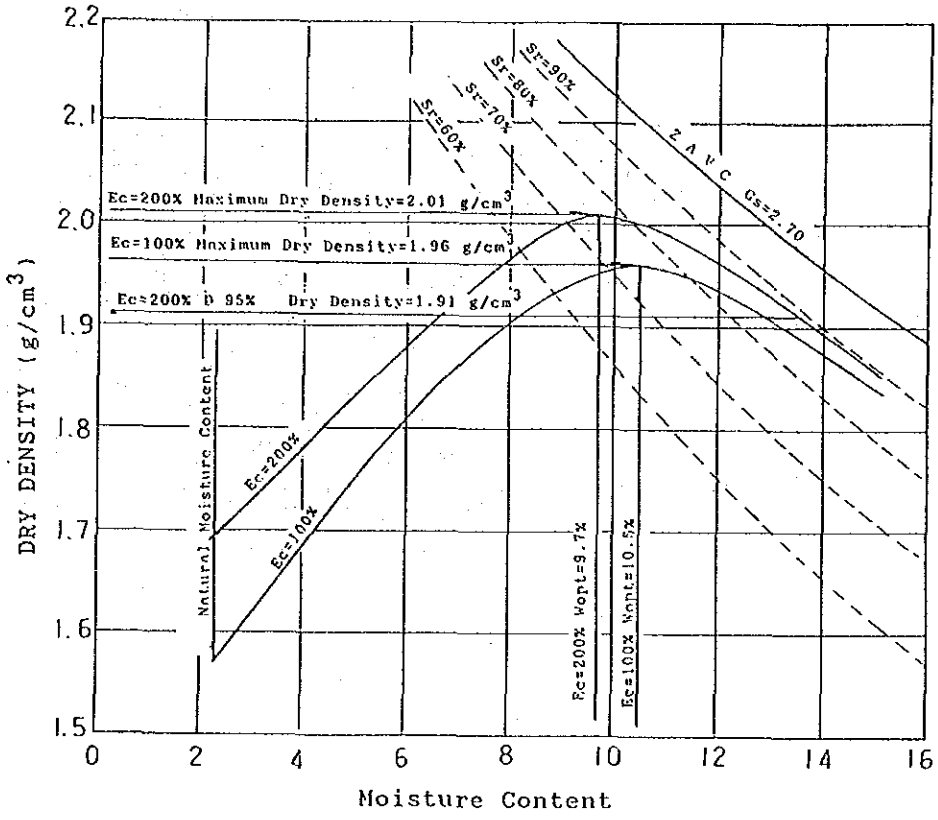

SAMPLE NAME TP-1 DEPTH=1.0~2.0m Mold Dia 15cm

(note)
Sr= degree of saturation
Z,A,V,C = Zero air void curve
Ec 100% = 5.625 Kg.cm/cm^3

Fig. C.5-6 Result of Compaction Test

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
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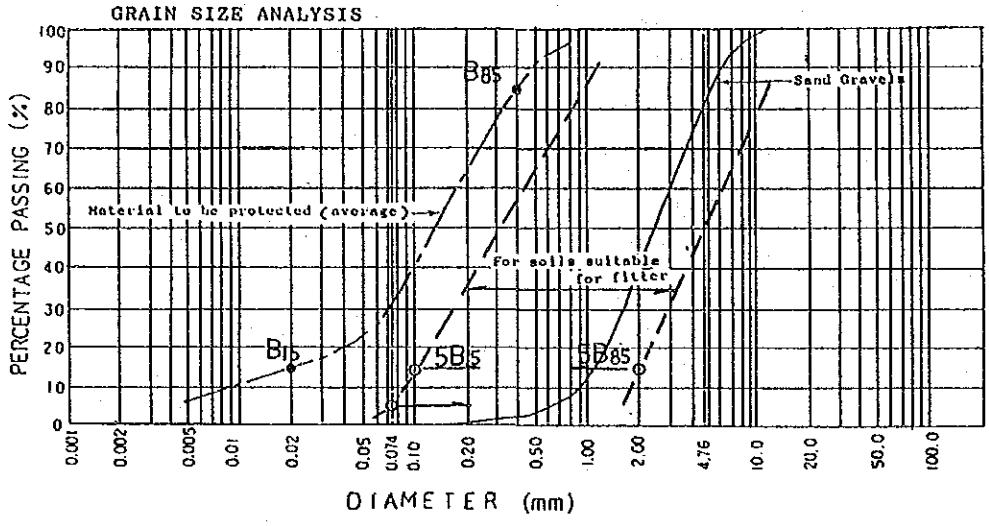

Natural moisture content Wn (%)	Specific gravity Gs	Grain size analysis					Unified soil classification system
		gravel (%)	sand (%)	silt (%)	clay (%)	maximum diameter (mm)	
0.9	2.78	20.8	78.4	0.8	-	12.0	SP

SAND & GRAVELS IN HOL RIVER

Downstream of the dam site

Fig. C.5-7 Grain Size Analysis of Filter Materials

ISLAMIC REPUBLIC OF PAKISTAN
GOVERNMENT OF SIND

FEASIBILITY STUDY ON
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IN THE MALIR BASIN

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APPENDIX

DRILL LOG

HOLE NO. ML-1 SHEET NO. 1 OF 2.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY % / cm		Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
	1	133.05 m	Recent, Subrecent Overburden		Dirty yellow in colour, consists of loose medium to coarse Sand and gravel, gravels are of Limestone rock.			0%			
	2										
	3										
	4										
	5		Miocene Gaj Limestone		Dirty brownish yellow, Cream; fine grained, mostly hard, weathered, fragmented, Solution Cavities are present at Places. Fossiliferous. Argillaceous from 6.4 to 8.6. Arenaceous from 9.3 to 10.4.	76 m-m NXL Diamond Bit Double Tube Core Barrel.		95%	6.4		
	6										
	7							95%	8.2	17.0Lu' Py≧4.0 Kgf/cm²	
	8										
	9							20%			
	10										
	11							96%	12.5		
	12										
	13		Limestone		Same as before.			94%	14.3	2.91Lu' Py≧4.0 Kgf/cm²	
	14										
	15							98%			
	16										
	17		Shale		Dark grey Coloured, Fine grained, fresh to slightly weatherd, Soft at Places.			25%		Water losses negligible	
	18										
	19		Limestone		Greyish to Yellowish Cream fine grained, moderately hard, weathered, fragmented Solution Cavities are refilled by Secondary material.			80%	20.1		
	20										
	21							80%		1.01Lu' Py≧3.9 Kgf/cm²	
	22								23.		
	23										
	24				Same as before.			80%	25.9		
	25										
	26										
	27							98%		1.61Lu' Py≧4.0 Kgf/cm²	
	28								28.9		
	29							80%			
	30										

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS. TOKYO.

DRILL LOG

HOLE NO. ML-1 SHEET NO. 2 OF 2.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	CORE RECOVERY cm	Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
	31							80%		Water takes not Lugeon.	
	32								32.2		
	33							68%			
	34		Limestone		Same as above.						
	35								35.4		
	36							95%		Lugeon Pv≧4.0 Kgf/cm²	
	37										
	38								38.1		
	39					76 m-m N×L Diamond Bit Double Tube Core Barrel.		100%			
	40				End of Bore Hole at 39.62 m.						

HOLE NO. ( )

LOG FORM-C

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS. TOKYO.

DRILL LOG

HOLE NO. ML-2 SHEET NO. 1 OF 1.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	CORE RECOVERY cm	Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
		156.79 m	Overeburden		Loose, L.st. Scree.			0%			
	1										
	2				Dirty yellowish brown to greyish, Fine grained, moderately hard, fragmeuted.			75%			
	3		Limestone								
	4							85%			
	5									5.3	
	6				Argillaceous Limestone weathered fragmeuts Jointed.					42.0Lu' Py≧2.5 Kgf/cm²	
	7							84%			
	8									7.9	
	9				Limestone is fossiliferous.					53Lu' Py≧2.5 Kgf/cm²	
	10							92%			
	11									10.9	
	12							77%		0.1Lu' Py≧4.0 Kgf/cm²	
	13										
	14				Same as above.					14.0	
	15							82%		Water losses negligible	
	16										
	17									17.0	
	18							90%			
	19										
	20									20.1	
	21							95%		Water losses negligible.	
	22										
	23									23.1	
	24							78%			
	25									0.3Lu' Py≧4.0 Kgf/cm²	
	26									26.2	
	27							10%			
	28				End of Bore hole at 27.43 m.						
	29										
	30										

76 m-m NxL Diamond Bit Double Tube Core Barrel.

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. ML-3 SHEET NO. 1 OF 2.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	CORE RECOVERY cm		Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
		172.36 m	Recent		Loose deposits.							
	1		Miocene Gaj Limestone		Green Brownish, Yellow granular texture, hard weathered, Fragmented.			77%				
	2											
	3							88%		3.0		
	4		Limestone and Claystone		Small Claystone with Limestone at places Limestone is Argillaceous.			45%			0.4Lu' Py≧3.0 Kgf/cm²	
	5											
	6									6.1		
	7		Limestone		Limestone is fossiliferous, it is Sandy at some places.			78%			1.1Lu' Py≧5.0 Kgf/cm²	
	8											
	9									9.1		
	10				Same as above.			70%				
	11											
	12									12.5		
	13		Stil-stone/ claystone		Greycolour, Fine grained weathered fragmented, Core washed during drilling, slightly plactic.			80%			Water losses negligible.	
	14											
	15									15.2		
	16		Limestone		Same as before.			79%			0.4Lu' Py≧5.0 Kgf/cm²	
	17											
	18									18.2		
	19				Brownish, grannlar in appearance, hard weathered, fragmented.			90%			Water losses negligible.	
	20											
	21									21.1		
	22				Core is generally fresh, Slightly arenacous. Jointed.			75%				
	23											
	24									24.3		
	25				Same as before.			86%				
	26											
	27									27.4		
	28											
	29							90%			0.9Lu' Py≧7.0 Kgf/cm²	
	30									30.5		

76 m-m Diamond Bit Double Tube Core Barrel.

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. ML-3 SHEET NO. 2 OF 2.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	CORE RECOVERY cm		Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
	31					76 m-m Diamond Bit Double Tube Core Barrel.				30.5		
	32							51%			Water loses 9.6 L/min/m	
	33									33.5		
	34		Limestone		Same as above.							
	35							71%				
	36									38.5		
	37											
	38							21%			Water loses 9.6 L/min/m	
	39									39.6		
	40				Light grey with rusty coloured bands, fine grained, low to medium-hard, weathered fragmented, Jipsum veins Prominent.							
	41							25%			0.3Lu' Py 3.8 Kgf/cm²	
	42		Siltstone							42.4		
	43				Same as above, Core washed by Water.							
	44							10%			0.1Lu' Py 3.8 Kgf/cm²	
	45									45.72		
	46				End of Bore Hole at 45.72 m.							

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. ML-4 SHEET NO. 1 OF 1.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	cm		Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
		167.70 m	Overburden		Loose Limestone Scree.			0%				
	1				Lightbrown, buff, Medium hard, fine grained weatherd fragmented Solution Cavities present.			55%		3.0m		
	2											
	3											
	4				Clayey Silty Sandy, Limestone, fossiliferous fractured.			71%		6.1	0.5Lu' Py≧4.0 Kgf/cm²	
	5											
	6											
	7				Same as above.	76 m-m Diamond Bit Double Tube Core Barrel.		85%		9.1	1.6Lu' Py≧4.0 Kgf/cm²	
	8		Limestone									
	9											
	10							87%		12	Water losses negligible.	
	11											
	12											
	13							90%		15.2	0.5Lu' Py≧4.0 Kgf/cm²	
	14											
	15											
	16		Siltstone/ Claystone		Greyish to Buff soft to hard indurated at Places. Weathered, fragmented, Calcareous.			83%		18.2	Water losses negligible.	
	17											
	18											
	19				Yellowish, brown, granular hard weathered, fragmented Solution Cavities present Gritty Silt and Clay present.			91%		21.3	0.1Lu' Py≧4.0 Kgf/cm²	
	20											
	21		Limestone									
	22				Limestone is fossiliferous. Clay Pockets and filling.			90%		24.3	0.6Lu' Py≧4.0 Kgf/cm²	
	23											
	24											
	25		Claystone/ Limestone		Calcareous claystone, dark grey, soft, fragmented.			82%		27.4		
	26				Limestone, light yellowish brown, fine grained weatherd, fragmented.							
	27											
	28		Limestone		Dark grey, clayey Limestone, fossilifeeous.			63%		30.48	0.1Lu' Py≧4.0 Kgf/cm²	
	29											
	30				End of Bore Hole at 30.48 m.							

HOLE NO. ( )

LOG FORM-C

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. KD-1 SHEET NO. 1 OF 2.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	cm		Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
	1	134.0 m	Sub-recent cemented SandGravel		Cemeted mass of Subangular to Sub-rounded Gravels with medium to Coarse sand. It is hard and Compact, Cementing material is Calcareous in nature, Gravels are of limestone rock,present in the Ared.	H : Size Core Barrel Diamond Bit		83%				
	2											
	3											
	4											
	5											
	6											
	7									7.9		
	8				Light cream, fine grained, Slightly to Moderately weathered,Slightly fragmented No Joints			100%			3.2Lu' Py≥3.0 Kgf/cm²	
	9											
	10											
	11									11.0		
	12				Moderately hard,massire fossiliferous at 10.0 m Limestone is arenaceous from 10.0 m - 11.8 m, few Solution Cavities are Present from 10.6 - 11.7 m around the animal shells. Limestone from 12.4 m to 13.7 m have niches and first niches is Shaley / Clayey and traces of Carboniferous material. L.st Looks gritty up to 13.6. Solution Cavities are present from 17.0 - 20.3 m which are interconnected Intercalations of clay band with L.st present 20.3 - 21.3 Moderately weathered and Highly fragmented.	76 m-m Diamond Bit Double Tube Core Barrel.		100%		12.5		4.0Lu' Py≥4.0 Kgf/cm²	
	13											
	14									14.02		
	15		Limestone					100%			3.0Lu' Py≥4.0 Kgf/cm²	
	16									16.75		
	17							100%			4.4Lu' Py≥4.0 Kgf/cm²	
	18									18.5		
	19							100%			2.5Lu' Py≥4.0 Kgf/cm²	
	20									20.1		
	21		Claystone Gaj		Light greenish, fine grained slightly to moderately hard, slightly weathered.			83.3%		21.8		
	22				Light grey fine to medium grained, Medium Hard, slightly weathered, Slightly fragmented, L.st Contains greenish Clayey inclusions upto 22.2 m slightly arenaceous from 24.3 to 26.1 m.			100%			4.2Lu' Py≥4.0 Kgf/cm²	
	23									23.1		
	24		Limestone					100%				
	25									24.5		
	26							100%			4.3Lu' Py≥4.0 Kgf/cm²	
	27		Claystone		Hard from 26.2 - 27.5 m Greenish grey fine grained slightly weathered, moderately fragmented.			88.6%		26.2		
	28		Clac.S.st.		Medium Hard Sand Stone Calcareous					27.7		
	29		Limestone		Greenish grey mediumhard Fresh, Fine grained, massive few carities 29.2 - 29.8 m			90%			6.0Lu' Py≥4.0 Kgf/cm²	
	30									29.2		
								100%				

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. KD-1 SHEET NO. 2 OF 2

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	CORE RECOVERY cm		Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
	31					76 m-m Diamond Bit Double Tube Core Barrel		100%		31.4	- 4. Lu' Py ≧ 4.8 Kgf/cm²	
	32		Limestone		Grey colour from 31.4 m Inclusion of light coloured calcareous material.			100%			1.8 Lu' Py ≧ 4.0 Kgf/cm²	
	33									33.5		
	34				Dark to lightgrey, S. st., Fine to coarse grained, more calcareous at few Places. Slightly weathered except from 35.6 - 36.3 m and 38.4 - 44.1 where it is moderately weathered. Slightly fragmented from 35.5 to 36.2 and 44.1 to 44.8 m. lightly fragmeuted from 42.6 - 44.1. Core is moderately hard.			100%			water loss negligible	
	35									35.5		
	36							95%			- do -	
	37											
	38		Sandstone					86%			- do -	
	39											
	40				Recovered as Fine - Sand Due to poorly Cemented material.			11%			- do -	
	41											
	42											
	43				From 42.6 - 44.2 it is low in hardness, recovered. Light grey, white inclusions of calcareous material are Prominent.			50%				
	44											
	45							46.5%			water loss negligible	
	46				END OF BORE HOLE.							

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. K D - 2 SHEET NO. 1 OF 2.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION	GROUNDWATER LEVEL	CORE RECOVERY %	cm	Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
		168.97m	Over burden		Loose angular Fragments of Lost.		0%			
	1				Cream, fine grained, Moderately hard, slightly weathered, moderately fragmented, solution Carities present, filled up with Argillaceous material.		93%			
	2									
	3						55.8%			
	4				L. st. gets washed in the from of small grains, it is argillaceous and soft.					
	5									
	6							6.0		
	7				Light Cream Coloured, fine grained, medium hard to hard, slightly to moderately weathered, sparsely jointed Contain Micro - fossils.		53.6%		30.0Lu' Py≧5.0 Kgf/cm²	
	8							8.3		
	9				Solution Carities present from 8.5 to 10.0 m, at few places it is Argillaceous.		95%			
	10							9.9	115.0Lu' Py≧3.0 Kgf/cm²	
	11							11.0		
	12						92%			
	13							12.9		
	14		Limestone		Same as above.		92%		100.0Lu' Py≧3.0 Kgf/cm²	
	15							14.5		
	16						67.6%			
	17									
	18							17.9		
	19						97%		16.0Lu' Py≧6.0 Kgf/cm²	
	20							20.2		
	21							20.7		
	22						70.6%		14.0Lu' Py≧5.0 Kgf/cm²	
	23							22.2		
	24						100%		3.0Lu' Py≧3.0 Kgf/cm²	
	25				Cream to Light brownish hard grannlar from 24.0 to 27.0 m.			23.7		
	26						160%			
	27							28.0		
	28						94.3%			
	29				Soft, Slightly weathered sparsely jointed, slightly to moderately fragmented.		100%		2.9Lu' Py≧5.0 Kgf/cm²	
	30							30.1		

76 m-m Diamond Bit Double Tube Core Barrel.

HOLE NO. ( )

LOG FORM-C

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. KD-2 SHEET NO. 2 OF 2.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	CORE RECOVERY cm	Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
	32		Limestone		Core is porous by the removal of fossil shells.	76 m-m Diamond Bit Double Tube Core Barrel.			30.1 31.6		
					Limestone is Agillaceous.			100%		All Set Pipe !	
	33								32.6		
	34				Same as above.			100%	34.4		
	35							106%	35.8	3.8Lu' Py≧4.0 Kgf/cm²	
	36				Dirty Yellow to cream, hard slightly weathered, highly fragmented.			95.8%	37.1		
	37				Slightly porous, Soft material of Sandy Silty and Clayey matrix.			75.8%		15.8Lu' Py≧4.0 Kgf/cm²	
	38								39.3		
	39				Same as above.			73.5%	40.2		
	40										
	41		Arenaceous Limestone		Sandy Limestone, fossil shells in the top of the layer.			77.5%		13.0Lu' Py≧4.0 Kgf/cm²	
	42								42.9		
	43		Sandy - Limestone		Same as above.			91.4%		8.0Lu' Py≧4.0 Kgf/cm²	
	44										
	45								45.4		
	46				END OF BORE HOLE.						
	47										
	48										
	49										
	50										
	51										
	52										
	53										
	54										
	55										
	56										
	57										
	58										
	59										
	60										

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. KD-3 SHEET NO. 1 OF 4.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	CORE RECOVERY cm		Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
		217.63 m	Overburden		Loose, Angular, L.st. scree.			0%				
	1				Limestone, light brownish yellow, fine grained, slightly to moderately weathered, moderately hard, fragmented, Solution Cavities are Present at places, Limestone is fossiliferous. From 1.5 - 3.0 m slightly arenaceous Limestone.			95%				
	2											
	3											
	4							100%				
	5											
	6									6.4		
	7				Clay intercalations in Limestone.			100%			7.6 Lu' Py≧5.0 Kgf/cm²	
	8											
	9									9.1		
	10				Same as above.			95%				
	11											
	12		Limestone							12.5		
	13							100%			9.2 Lu' Py≧5.0 Kgf/cm²	
	14											
	15									15.5		
	16											
	17											
	18							100%				
	19											
	20											
	21									21.6		
	22				Dirty Yellow, fine grained Slightly to Mod: Weathered, slightly fragmented. L.st. becomes arenaceous, Solution Cavities present L.st. is friable.			97%			4.0 Lu' Py≧6.0 Kgf/cm²	
	23											
	24									24.6		
	25		Calcareous Shale.		Early grey, fine grained Slightly weathered, Soft and friable. The material gets washed during drilling.			20%			All See page →	
	26											
	27									27.7		
	28		Limestone		Yellow white to brown, hard to moderately hard Slightly weathered, Slightly fragmented, Solution Cavities Present at Places.			97%			1.8 Lu' Py≧7.0 Kgf/cm²	
	29											
	30									30.7		

76 m-m NXL Diamond Bit Double Tube Core Barrel.

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. K D - 3 SHEET NO. 2 OF 4.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY % / cm		Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
	30							100%	30.7		
	31									Water losses negligible.	
	32							100%			
	33				Same as above.						
	34										
	35										
	36										
	37				Argillaceous Limestone light greenish, grey to Yellowish white. Fine grained, slightly to moderately weathered, slightly Fragmeuted. Solution Cavitied are present at Places. Limestone is fossiliferous at few Places. It is friable and gets washed during drilling.			96%		Water losses negligible	
	38										
	39										
	40										
	41										
	42		Limestone								
	43							97%			
	44										
	45										
	46							100%		Water losses negligible	
	47										
	48										
	49										
	50				Same as above.						
	51										
	52										
	53							95%			
	54										
	55										
	56							97%		Water losses negligible	
	57							100%			
	58										
	59							80%			
	60										

76 m-m NXL Diamond Bit Double Tube Core Barrel.

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. KD-3 SHEET NO. 3 OF 4.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY % cm		Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
	61					76 mm NXL Diamond Bit Double Tube Core Barrel.		80%		Water losses negligible.	
	62										
	63										
	64							90%		Water losses negligible.	
	65										
	66							96%			
	67										
	68										
	69							90%			
	70		Limestone		Same as above.						
	71										
	72							100%			
	73										
	74							97%			
	75										
	76										
	77							84%			
	78										
	79										
	80										
	81							45%			
	82										
	83										
	84								84.4		
	85							30%			
	86									1.7Lu' Py≧5.0 Kgf/cm².	
	87								87.4		
	88		Clay-stone		Clay-stone L.st.argillaceous Light greenish grey, white, Fine grained moderately hard, slightly weathered and fractured.			93.5%		Water losses negligible.	
	89										
	90										

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

DRILL LOG

HOLE NO. K D - 3 SHEET NO. 1 OF 4.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY %	CORE RECOVERY cm	Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
			Clay-stone		Same as above.	76 m-m N×L Diamond Bit Double Tube Core Barrel.					
	91		Gaj Limestone		Grey Colour, Fine grained hard slightly weathered, slightly to moderately fragmented.			93%		Water losses negligible.	
	92										
	93										
	94							100%			
	95				End of Bore hole at 94.49 m.						

HOLE NO.

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS. TOKYO.

DRILL LOG

HOLE NO. KD-4 SHEET NO. 1 OF 1.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION		GROUNDWATER LEVEL	CORE RECOVERY % / cm	Water Pressure test Lugeon value (Lu') Yield Pressure(Kgf/cm²)	DEPTH
		176.17 m	Overburden		Loose rock pieces.			0%		
	1				Broken, Angular to subangular, L.st. rock fragments of various sizes.			40%	All Water See page →	
	2				Light Yellowish to Pinkish brown, fine grained, slightly to moderately weathered moderately hard, highly fragmented, Solution Cavities present at places. Secondary material of argillaceous natur present.			50%	All Water See page →	
	3									
	4							53%		
	5									
	6									
	7				Same as above.			45%		
	8									
	9									
	10				Highly fragmeuted, moderately weathered, No Joints. L.st. is soft and friable, gets washed during drilling.					
	11							0%	All Water See page →	
	12									
	13									
	14									
	15									
	16				White Coloured L.st., highly fragmeuted. Inter calations of Clay pieces. Hard, Cream, with Cavities.			10%	All Water See page →	
	17									
	18		Limestone							
	19				Yellowish, hard, Solution Cavities present, mod: fragmented and weathered Sparsely Jointed, micro fossils are present at places.			63%	All Water See page →	
	20									
	21									
	22				Slightly fragmented, Slightly weathered, no jointing present.			85%	All Water See page →	
	23									
	24							28%		
	25				Brownish Yellow, Sandy, hard, massive, calvies prominent. Slightly fragmented, Slightly to moderately weathered Sparsely Jointed.					
	26									
	27							86%	All Water See page →	
	28									
	29									
	30									
		At 30.48,			END OF BORE-HOLE.					

76 m-m BxL Diamond Bit Double Tube Core Barrel.

HOLE NO. ( )

LOG FORM-C'

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.