ANNEX 2

GEOLOGY

THE STUDY
ON
COMPREHENSIVE RIVER WATER MANAGEMENT PLAN
IN
JABOTABEK

Annex 2
Geology

Table of Contents

List of Tables

List of Figures

1. GEOLOGY

1.1 General Geology

West Java can be divided physiographically and structurally into four belts (Bemmelen, 1949) extending in the east-west direction and from south to north as indicated below :

- Southern mountains of West Java;
- Bandung zone;
- Bogor zone;
- Lowland plain of Jakarta.

The Study Area (Jabotabek) lies in the southern mountains comprising volcanoes located in the southern part of the Study Area, the Bogor zone of rolling hills in the southern part of Cibinong and western part of Bogor, and the lowland plain with an elevation lower than 100m in the northern part of the Study Area.

All the main rivers in the Study Area originate in the southern mountainous area and discharge into the Java Sea after flowing through the hilly area of the Bogor zone and the flat lowland plain.

According to the results of field reconnaissance, review of previous studies, and the geological literature published by the Geological Research and Development Center of the Directorate General of Geology and Mineral Resources (Geological Map of the Bogor Quadrangle, 1986; Geological Map of the Jakarta and Kepulauan Seribu Quadrangles, 1992), the geology in the Study Area is composed of alluvial of the Holocene (mainly in the lowland plain), terrace deposit of the Pleistocene (mainly alluvial fan in the Bogor zone and lowland plain), tuffaceous sedimentary rocks of the Pliocene to Miocene (mainly in the Bogor zone) and southern volcanoes of the Miocene.

The Tertiary sedimentary rocks in the Bogor zone are part of an anticlinorium of the Neogene Strata intensively folded in the east-west direction by the movement of major tectonic plates, the Indian Ocean-Australian Plate and Eurasian Plate. The sedimentary rocks in the Bogor zone comprise several formations: The Rengganis Formation, Bojongmanik Formation, Klapanunggal Formation, Jatiluhur Formation, Genteng Formation, and Serpong Formation. These formations are superposed monoclonal by from south to north and from lower to upper horizons in order. They are mainly composed of fine to coarse tuffaceous sandstone and Pumiceous tuff of lapilli tuff which belongs to the Genteng Formation of the Late Miocene to Pliocene in the Study Area, except the Klapanunggal Formation which is composed of reef limestone.

The southern volcanic mountains were formed by basalt, diorite, volcanic breccia and andesite, which erupted and/or intruded along the faulting zone in the Miocene and are called undifferentiated older volcanic rocks and younger volcanic rocks in the Geological Map of the

Bogor Quadrangle. Younger volcanic rocks are classified into the volcanic rocks from G. Endut-Prabaki, G. Salak, G. Pangrango, G. Gede, G. Gegerbentang, and G. Kencana-G. Limo mainly in the Study Area.

The superficial deposits in the lowland plain consist of the following :

- Alluvial : clay, silt, sand, gravel, pebble, and boulder
- Beach ridge deposits : coarse sand, well sorted, with molluscan shells
- Alluvial fan : bedded fine tuff, sandy tuff, interbedded with conglomeratic tuff.

The geological map of the Study Area and the local stratigraphy are shown in Figure 1 and Figure 2, respectively.

The geological evolution of the Study Area started in the Early Miocene, with the deposition of the Rengganis Formation by gravity flow in the southern rim of the back-arc basin. In the Middle Miocene the area was uplifted, the eastern part turning into a shallow sea where the Klapanunggal Formation and the Jatiluhur Formation which interfinger with each other, were deposited. The Bojongmanik Formation was deposited in the western part of the area. These formations were then uplifted, folded and faulted, and intruded by the Dago Basalt unit in the Mio-Pliocence eras. In the Early Pliocene the northern part of the area subsided, resulting in the deposition of the Genteng Formation. The area was then uplifted again and formed the Serpong Formation. This was followed by the Volcanic Rocks and Sudamanik Andesites. In other places, transgression (subsidence) occurred, allowing reef limestone to grow until the present time. After the last tectonic event, the area has been relatively stable. In the southern part, the volcanic products form higher morphology, and by erosion processes, alluvial fans, beach ridges, sand dunes and alluvium were deposited.

From "Geology of Indonesia" by Van Bemmelen (1949), the Geological Map of West Java (1977), Geological Map of the Jakarta Quadrangle (1992) and Geological Map of the Bogor Quadrangle (1986), the generalized geological cross-section from south to north in the Study Area is as shown in Figure 3.

1.2 Geological Units in the Study Area

The geological units which are mainly encountered in the Study Area and should be taken into consideration in the review of the construction plan for the flood control dams, new floodway, improvement of river and drainage channel, and construction of pumping facilities, etc.

(1) Older Volcanic Rocks

This formation is the undifferentiated old Quaternary volcanic deposits composed of breccia and lava flows, andesitic to basaltic, locally including agglomerates and pumiceous tuff, and mostly weathered. This unit is widely distributed around the west portion of the southern mountains, in the southwestern area of Bogor.

(2) Younger Volcanic Rocks

The following three formations are encountered in the upper reaches of the Cisadane river and the Ciliwung river, in the southern mountains :

(a) Volcanic rocks of Salak consisting of tuffaceous breccia and lapilli, basaltic andesite and lahar, mostly strongly weathered. Volcanic breccia is composed of subangular andesitic gravel and boulders of 5 cm in diameter in tuffaceous matrix. The weathered portion, at a depth of approximately 10 m to 20 m, appears to consist of yellowish brown sandy to clayey soil with intensively weathered rock fragments. Fresh volcanic breccia is well consolidated and andesitic gravels and tuffaceous matrix are well cemented. Volcanic breccia is massive but not very hard as a whole, and has no clear joint systems or cracks. Locally some porous volcanic breccias with a rather high permeability coefficient in the order of 10^{-3} cm/s is observed.

(b) Volcanic rocks of Pangrango which exist on the northern slope of Gunung Pangrango and Gunung Lingkung, between the Cisadane river and the Ciliwung river. These rocks consist of older deposits, lahar and lava, andesitic basalt with oligoclase-andesite, labradorite, olivine, pyroxene and hornblende, mostly strongly weathered.

(c) Breccia and lava of Kencana and Limo which exist on the northwestern slope of Gunung Kencana and Gunung Limo, and consist of blocks of andesitic tuff and andesitic breccia with abundant pyroxene phenocrysts and basaltic lava, mostly strongly weathered.

(3) Bojongmanik Formation

This formation is the sedimentary rock composed of an alternation of sandstone and claystone with intercalation of limestone and tuff in the upper part. In some places lignite intercalations are found. Upwards the tuff content becomes larger, turning then into layered fine tuff and pumiceous tuff. As a whole, the rock is light gray, and brownish yellow when weathered. In general the rocks are well bedded; sedimentary structures such as graded bedding, cross-bedding, and lamination are common. The formation was deposited in a shallow neritic to brackish water environment. This formation is distributed superficially in the hilly western portion of the Study Area and widely constitutes the bedrocks in the Bogor zone and the lowland plain of Jakarta. The Bojongmanik formation is generally classified into soft rock from the geotechnical point of view. In general, the top portion of the soft rock layers, of which thickness ranges from one to more than 10 m, is weathered and disintegrated into small fragments, and N values are often less than 50. However, the fresh rock portion has enough strength for foundations of the fill-type dam and structures for the waterway, etc.

(4) Jatiluhur Formation

This formation consists of marl and clay shale, and quartz sandstone intercalations. It becomes more sandy toward the east. This formation is distributed in the eastern portion of Cibinong-

Bogor line.

(5) Klapanunggal Formation

This formation mainly consists of thick massive reef limestone, which is divided into coral limestone, sandy limestone, marl, and green glauconitic quartz sandstone intercalations. This limestone formation interfingers with the Jatiluhur Formation which develops superficially in the eastern portion of Cibinong-Bogor line and in the west portion of Bogor (G. Cibodas). The rocks of this unit are used as a source of construction materials, such as cement and road basement material.

(6) Genteng Formation

This formation is the sedimentary rock classified into soft rock as same as the Bojongmanik Formation. The unit consists of tuffaceous sedimentary facies which are composed of tuffaceous sandstone, pumiceous tuff, lapilli tuff, welded tuff, claystone, and conglomerate. The Genteng Formation is distributed superficially in the hilly western area of Serpong and widely overlies the Bojongmanik Formation as bedrocks in the west area of Jakarta. This formation is white to gray or dark gray in color and is soft and compact but partly fractured with weathered open crack joints.

(a) Tuffaceous Sandstone

The sandstone facies, fine to coarse grained, is the main facies of the Genteng Formation. It is gray to dark gray, and usually contains some pumices and lapilli occasionally together with conglomerates. The coarse grained sandstone shows a laminated structure of volcanic rock fragments and is poorly cemented and stained with iron minerals.

(b) Tuffaceouse Claystone

This facies usually consists of intercalated brown to brownish gray claystone and is occasionally found together with pumice. It is dense and compact but partly soft and fractured with slicken sides.

(c) Pumiceous Tuff

This facies is composed of whitish fine to coarse grained pumice together with volcanic sand and some lapilli. The pumice is usually weathered, soft and light in weight. Therefore the pumiceous tuff is slightly weathered, porous, uncompacted, and easily broken by hammer hitting.

(d) Lapilli Tuff

This facies is usually slightly weathered and well to moderately cemented, but clay seam joints are developed in some part. The fragments of lapilli tuff consist of hard basalt and andesite, of which color is dark gray to gray. The matrix of lapilli tuff consists of very fine grained tuff which is usually slightly weathered and soft.

(e) Welded Tuff

This facies is generally compact, massive, fairly dense, and well cemented, light to medium gray color. It is relatively light in weight, with a slightly weathered portion. The rock contains breccia, pumice, and scattered lapilli.

(7) Serpong Formation

This formation consists of alternating conglomerate, sandstone, siltstone, claystone with plant material, pumiceous conglomerate, and pumiceous tuff. The pumiceous tuff is poorly cemented, compared with that of the Genteng Formation, and is intercalated with black sandy thin layers with a cross-bedding structure. This unit is distributed superficially and sporadically along the middle reaches of the Cisadane river and Cimanceuri river around Serpong. According to previous investigations, the formation was weathered with about 10 m in depth and it has N values ranging from 5 to 18 in the weathered upper portion but more than 50 in the lower fresh layer.

(8) Banten Tuff

This formation overlies the Genteng Formation in the northwestern portion of the Study Area in and around Tangerang. The unit consists of tuff, pumiceous tuff, tuffaceouse sandstone and it is mostly strongly weathered and soft.

(9) Alluvial Fan

This deposit is the result of weathering and redepositing process of Quatenary volcanic products and consists mainly of silt, sand, gravel, and boulders. This layer covers most of the undulated area from Bogor to near the lowland plain of Jakarta, except the lower areas of rivers or valleys where the surface is covered with alluvium deposit. The color of the layer is dominantly reddish/ yellowish/ light brown to brownish / dark gray, and black of some places. This alluvial fan is composed of soft to very stiff clay, silt and clayey to sandy silt with medium plasticity, and contains subrounded gravels (5-20 mm in diameter) in some places. The thickness of the layer is mostly less than 10 m. Its N values ranges from 2 to more than 50.

(10) Alluvial

This deposit unit is actually a mixture of valley deposit, river deposit, and beach deposit and mainly consists of clay, silt, sand, gravel, pebble and boulder containing organic materials or shell fragments at the local part. The lowland plain and coastal plain are dominantly covered by this unit and can be considered as very soft to soft soil (applicable to clay/ silt) and very loose to loose soil (applicable to sand), with brownish gray or gray (dark/ light) color. The beach ridge deposit consists of very loose coarse sand to silty sand, and it's well sorted, with mollusc shells, and can be found along the old beach ridge around Cengkareng, Tuge, and Cakung.

The hydro-geological map and the schematized north-south cross-section reviewed recently in the JABOTABEK Water Resources Management Study (1994) are shown respectively in Figure 4 and Figure 5 as reference information for future studies.

2. GEOTECHNICAL INVESTIGATION IN THE MASTER PLAN STUDY

2.1 Geotechnical Investigation for Flood Control Dam

For the construction of a flood control dam in the Study Area, the following three possible damsites have been selected after reviewing the reservoirs proposed in the previous studies, topography and hydrology, and from the result of the detailed reconnaissance.

(a) Depok Dam : Ciliwung river, close to Depok city, having a watershed of 260km^2 out of the total watershed of 347 km^2.

(b) Ciawi Dam : Ciliwung river, at Cibogo, 10 km southeast of Bogor, with awatershed of 85 km^2.

(c) Limo Dam : Pesanggrahan river, close to Cinere and Limo, with a about 70 km^2 watershed of about 70 km^2 out of the total watershed of 100 km^2.

The locations of the above damsites are shown in Figure 6.

The Depok dam was originally proposed as a multiple purpose storage reservoir and designed in detail as a filltype dam with 40 m height and a full reservoir capacity of 14.1 x 10^6 m^3 by the local consultant in 1986, but it has recently been discarded due to serious drawbacks of land acquisition and resettlement. However it is recommended to evaluate this scheme as the flood control dam in case of scale down in this Study. The geological conditions necessary for reviewing this scheme have been already known in the previous detailed design stage, therefore no additional geotechnical investigation is necessary.

The Ciawi dam has been selected as the only possible damsite with flood control function in the Ciliwung river from the viewpoint of topography and hydrology in the case the Depok dam scheme is discarded. It is recommended to evaluate of this scheme even if it has a relatively small reservoir/ embankment ratio, after checking geological conditions in this Study.

The Limo dam was proposed originally to control Pesanggrahan river floods by a French consultant in 1980, but it has been confronted with land acquisition and resettlement problems due to dense land use by rapid urbanization of the DKI Jakarta outskirts and discontinued also for the reason of relatively small river catchment area. However it is recommended to consider again this scheme for flood control purpose by modifying facilities or scale as well as moving the damsite upstream.

In order to obtain the basic geological and geotechnical information on the above possible flood control damsites, i.e. Ciawi and Limo, the following geotechnical investigation works were carried out by the local contractor under a subcontract basis.

Dam Site	Drilling Site	Drilling Depth(m)	Remarks
Limo Dam A	PDA - 1	50	Right abutment
Limo Dam B	PDB -1	50	Right abutment
	PDB - 2	40	River bed
Limo Dam C	PDC - 1	60	Left abutment
	PDC - 2	40	River bed
Ciawi Dam	CD - 1	60	Right abutment
	CD - 2	40	River bed
	CD - 3	60	Left abutment
Total	8 holes	400	

Locations of the above damsites and drilling works are shown in Figure 7 (Limo Dam A, B and C) and Figure 8 (Ciawi dam).

In total, 8 drillings with standard penetration test (SPT) and permeability test (Constant Head Test) in uncemented deposits, and water pressure test in bedrocks (Lugeon Test) were carried out.

All of the results of investigation such as drilling logs with results of SPT and Lugeon test, etc. are compiled in the Attached Reference Data.

2.2 Geotechnical Consideration

(1) Geotechnical Consideration for Dam Construction

As mentioned above, the three 3 possible dam sites for flood control purpose, name by the Depok dam (Ciliwung River), Ciawi dam (Ciliwung river), and Limo dams A, B, and C from downstream, have been selected initially as shown in Figure 6.

(a) Depok dam/ Limo dams

As shown in the geological map (Figure 1) and the generalized geological cross-section (Figure 3), the Limo damsites A, B, and C, and Depok damsite are located on a quite similar formation, the Bojongmanik Formation, which is overlain by an Alluvial Fan (overburden). Also a correlation study based on the results of drilling works for the Limo damsites in this Study and the previous investigation results of the Depok damsite (Detailed Design Works of the Depok Dam, Stage II, 1985, by P.T Indra Karya) shows that the geology at the Limo damsites corresponds to the Depok dam site, i.e., the lower layer belongs to the Bojongmanik Formation, the sedimentary rock consisting of an alternation of sandstone and claystone with an intercalation of limestone and tuff, and the upper layer consists of the deposit called Alluvial Fan or overburden, consisting of soft clay to stiff clay, silt, sand, gravel, and boulders. Therefore, the geotechnical conditions and the detailed design performed for the Depok dam in 1986 are well referred to for the Limo dams in this Study.

The baserocks of the Depok dam and Limo dams are the sedimentary rocks belonging to the Bojongmanik Formation and classified as rather soft rock from geotechnical point of view.

Core drilling was carried out to a total depth of 240 m at 5 holes at the proposed damsites in the Pesanggrahan river. The drilling investigation at both abutments of the 3 damsites shows the presence of clayey silt, sandy silt and loose gravely sand with N values in the range of 7 to 25 mostly in the upper portion of less than 13 m in depth. Dense sand, very stiff to hard sandy silt or clayey silt, and weathered limestone layers with N values of more than 50 exist in the lower portion in general.

As shearing strength of baserocks is assumed to be less than 50 tons/m^2 from N values obtained in previous investigations and the present investigation, the rockfill or earthfill dam type should desirably be selected for such rather soft foundation.

The engineering properties of baserocks applied in the Depok dam design were as follows:

Density	:	γ_{wet} = 1.77 t/m^3, γ_{sat} = 1.78 t/m^3
Shearing strength	:	C' = 8.5 t/m^2, $\varnothing'$ = 24.2°

where,

γ_{wet}	:	wet density
γ_{sat}	:	saturated density
C'	:	cohesion in terms of effective stress
$\varnothing'$	:	internal friction angle in terms of effective stress

A part of sedimentary rocks for dam foundation such as sandstone, intercalation of limestone and tuff and pumiceous tuff layer, have a little higher permeability coefficient ranging from 10^{-3} to 10^{-4} cm/s.

In case the storage dam scheme for multiple purpose is adopted instead of the check dam scheme for only flood control purpose, countermeasures against water leakages from the foundation, such as grout treatment or impervious blanket treatment, will be required.

Availability of embankment materials in quality and quantity and transportation of the same are also another important conditions for dam type selection. In consideration of the available embankment materials in and around the Project areas, the earthfill dam type is recommendable for the Limo dam considering mainly the difficulty of obtaining rock embankment materials, and also the limitation of dam height to less than 40 m from riverbed because of the topographic condition.

From the geological point of view, the Limo A, B and C dam sites are almost similar as far as the dam construction is concerned.

(b) Ciawi Dam

The Ciawi damsite is composed of Younger Volcanic Rocks of G. Pangrango named in the Geological Map of the Bogor Quadrangle (1986), which consists of old deposits, lahar and lava, andesitic basalt with oligoclase-andesinte, labradorite, olivine etc., mostly strongly weathered.

Core drilling was carried out to a total depth of 160 m at 3 holes at the proposed damsite. The drilling result at both abutments reveals the existence of an intensively weathered layer of approximately 20 m thick, consisting of brownish clay to dark brown sandy silt with N values in the range of 2 to 14.

The lower layer which consists of the Breccia and Lava unit from G. Kencana, is an intercalation of andesite lava, gravely sand, fine sand, silty clay, andesite and breccia, with N values of more than 50 in general.

The river deposits, with a thickness of about 13 m, consisting of loose sand and gravel with boulders, are found along the riverbed at this damsite. In addition, a rather highly permeable layer composed of gravely sand or sand layer and breccia, with a Lugeon unit ranging from 10 to 50 exists in the lower portion.

Based on the above geological and geotechnical conditions, the rockfill dam type with a vertical clay core recommended for the Ciawi dam, considering the rather large dam height of the 60 m class. Further, it is important to keep in mind the existence of a rather thick layer of river deposits in the riverbed and the small reservoir/ embankment ratio in evaluating this scheme in the next stage.

(2) Construction Material Sources

The potential construction material sources for the proposed filltype dams are shown in Figure 9, which were proposed in the water resources and flood control studies in the past and confirmed by the field reconnaissance in this Study.

(a) Impervious Earth Material

In general it would be rather easy to obtain a large amount of suitable earth materials in the vicinity of the proposed damsites because all the potential borrow sites are composed of weathered volcanic rocks or alluvial fan (overburden), which have been confirmed to be suitable impervious materials, through actual constructions and according to the data of the previous studies.

The engineering properties of impervious materials applied in the previous studies, which correspond to the embankment works for such structures as filltype dam and dike on the river in the Study Area, are as follows:

Density : γ_{wet} = 1.61 ~ 1.68 t/ m^3, γ_{sat} = 1.65 ~ 1.72 t/m^3

Shearing strength : $C = 2.0 \sim 5.4$ t/m², $C' = 1.0 \sim 2.0$ t/m²

$\varnothing = 9.0 \sim 12.5°$, $\varnothing' = 25.0 \sim 33.0$

where, C : cohesion in term, of total stress

$\varnothing$: internal friction angle in terms of total stress

The compaction of the above materials was performed mostly by tamping roller or pneumatic roller.

(b) Sand and Gravel Material

Sand and gravel to be used for concrete and filter or transition material can be obtained mainly along the Cisadane river, Ciapus river and Cipamingkis river, where large deposits of sand, gravel and stone are available. Several private companies are exploiting these deposits and processing sand and gravel by operating crushing plants. Among these materials, the Cipamingkis river materials are rather inferior in quality for concrete aggregate due to a high/ content of pumice fragments. The engineering properties of materials for filter zone applied in the past studies are as follows:

Density : $\gamma_{wet} = 1.74$ t/m³, $\gamma_{sat} = 1.89$ t/m³

Shearing strength : $C(C') = 0$ t/m² $\varnothing(\varnothing') = 35.0°$.

(c) Rock Materials

The promising rock quarries are composed of Andesite of Sudamanic Volcano or Older Volcanic Rock named in the Bogor Quadrangle (1986), which are located in the western hilly part (Rumpin) of the Study Area. Private companies are producing sand and gravel, and rock material by operating crushing plants. Other quarries such as the proposed quarries in G. Cibodas and Cibinong Limestone, which are composed of limestone of the Klapanunggal Formation, could be recommended for the inner shell zone of rockfill dams or base materials for roads. The northern steep ridges of G. Salak, around El. 900 m (near Taman, upstream of Ciapus river), are composed of hard andesitic rocks, mainly andesitic lava. It is recommended that this ridge area be further investigated as a source of rock material for the Ciawi dam construction.

All the above rock material sources except the limestone quarries have some difficulties in transpiration because most roads are in poor condition. The design engineering properties of hard andesitic rocks in the past studies are as follows:

Density : $\gamma_{wet} = 1.90$ t/m³, $\gamma_{sat} = 2.12$ t/m³

Shearing strength : $C(C') = 0$ t/m², $\varnothing(\varnothing') = 40.0°$.

(compacted by vibrator roller).

(3) Geotechnical Consideration for Floodway Construction

The objective work is excavation of 2 tunnels for the new floodways in the Study Area including (i) Angke - Cisadane Floodway, near Pakujaya and (ii) Ciliwung - Cisadane Floodway, in Bogor

Although no drilling work nor laboratory tests have been carried out at the sites, the various studies in the past, the geological maps of Bogor and/or Jakarta Quadrangle (1992) and the results of the Ciawi dam drilling, etc., suggest the following geological conditions.

(a) Angke - Cisadane Floodway

This floodway site is underlain by Tertiary tuffaceous sedimentary stones of the Genteng Formation and the Bojongmanik Formation which are covered by the Banten Tuff unit with overburden layers and/or alluvial along all the tunnel route of about 5 km long.

Tuffaceous sedimentary rocks of the Genteng Formation and Bojongmanik Formation are generally classified into soft rock from the geotechnical point of view. Generally, the top portion of the soft rock layers, of which thickness is less than 10 m, is weathered and disintegrated into small flagments, and N values are often less than 50. However, the fresh rock portion has enough strength with N values of more than 50 for foundation of structures, cut slopes and tunnels. At least the following design strength values can be expected:

Strength parameter (drained) : $C = 10.0$ t/m^2, $\varnothing = 30°$.

Density : $\gamma_{wet} = 1.80$ t/m^3.

The Banten Tuff unit is dominant in this area as the subsurface layer with more than 15 m thickness, and it consists of an alternation of pumiceous tuff, tuff and tuffaceous sandstone, of which N values are mostly more than 50 except the top portion of this unit. Therefore strength parameter will be nearly the same as that of the Genteng and Bojongmanik Formations. However, the permeability coefficient of the pumiceous tuff and tuffaceous sandstone of the Banten Tuff unit as well as some of the Genteng Formation ranges from 10^{-3} to 10^{-4} cm/s. Therefore it will be required to study some countermeasures against groundwater leakages etc. in the next stage.

The surface soil layers, overburden resulting from the Banten Tuff and top soil, which have a thickness of less than 10 m and N values of 2 to over 50, shall be treated carefully for slope cut and construction of structures because of their low strength and high compressibility. For reference, the soil properties of the surface soil layers which were sampled near the Project area and tested in the previous studies, are shown below:

Soil type	LL (%)	w_n (%)	Sr (%)	C (t/m²)	Ø (°)	e_o	Pc (t/m²)	Cc	Cv (cm²/d)
clay	187.0	58.0	95.4	1.5	18.0	1.689	15.8	0.30	150
silty sand	50.0	37.0	99.0	1.1	2.5	0.974	9.0	0.16	500
sandy tuff	113.4	52.0	93.0	4.7	17.7	1.509	11.4	0.31	500
clay	121.0	46.0	97.0	6.5	8.5	1.256	19.5	0.31	250
silty sand	103.0	69.0	95.0	1.2	2.9	1.998	6.0	0.48	350
w.s. stone	91.0	51.0	87.0	0.5	11.9	-	-	-	-
sandy clay	184.0	147.0	97.0	0.3	3.0	-	-	-	-
silt	124.0	36.0	78.0	5.0	6.7	1.283	6.2	0.34	350
clay	141.0	62.0	87.0	1.5	15.5	1.909	18.5	0.56	500

Notes:
w.s. stone : weathered sandstone
LL : liquid limit
w_n : natural moisture content
Sr : degree of saturation
C : cohesion in terms of total stress
Ø : internal friction angle in terms of total stress
e_o : void ratio
Pc : preconsolidation pressure
Cc : compression index
Cv : consolidation coefficient

(b) Ciliwung - Cisadane Floodway

The floodway area is assumed to have nearly the same geological conditions as those at the Ciawi damsite, based on the Geological Map of the Bogor Quadrangle (1986). The site is composed of the Breccia and Lava unit from G. Kencana and G. Limo in the lower portion underneath Volcanic Rocks of G. Pangrango, namely Younger Volcanic Rocks. All these volcanic products along the approximately 2 km long tunnel route are intensively weathered to a depth of about 20 m as revealed during the Ciawi dam geotechnical investigation. The weathered portion consists of clay to silt with N values being often less than 15. However the fresh rock portion, such as fresh volcanic breccia, which will cover most of the tunnel route due to topographic conditions, is well consolidated and the andesitic breccia is massive but not very hard in general, and has no clear joint systems or cracks. N values of the fresh rocks are all in the range of more than 50, however the permeability coefficient of some volcanic breccias is in the order of 10^{-3} to 10^{-4} cm/s.

Normal mechanical excavation in soft rocks can be applied for the construction of this tunnel, except some measures for solving groundwater problems. It is necessary, however, to confirm the detailed geological conditions, such as the velocity of elastic wave propagation, by geological survey on the exact tunnel route in the next stage.

(4) Geological Consideration for Lowland Plain

For the drainage and flood control purpose, such as structural measures for improvement of river and drainage channels and construction of drainage facilities in and around the lowland plain, especially in DKI Jakarta, a detailed site investigation at the exact locations of the above structures is required in order to design the foundations of these structures properly. Based on the available data from the previous studies, the following preliminary foundation characteristics of the lowland plain can be considered in the master plan study stage.

As typical reference data on geological conditions in the lowland plain, the Report on Eastern Banjir Canal (Upstream) Soil Mechanics Investigation (East JAKARTA Flood Control Project, Design Report III, July 1990) can be referred to and reviewed because all kinds of soil types have been covered.

As shown in Figure 10 and Table 6, an interpretation of the geological conditions in the lowland plain is described below ;

(a) Alluvial (Holocene) Unit

This deposit is actually a mixture of valley deposit, river deposit, and beach deposit and is mainly composed of clay, silt, trace of sand, and organic materials or shell fragments at local points. This deposit can be considered as very soft to soft and very loose to loose soil of brownish gray or gray (dark/light) color, with N values being mostly less than 4 and 10 in maximum. This deposit overlies the volcanic deposit and its thickness in the coastal plain increases toward the north direction and reaches to a maximum depth of about 20 m. As shown in Table 2, laboratory mechanical soil properties tests show the unconfined compressive strength (qu) in the range of 0.08 to 0.75 kg/cm^2, or 0.23 kg/cm^2 on an average. This means that this unit is mostly very soft.

Recent deposits overlie on the coastal plain and extend along the rivers or valleys in the undulating area. Coastal deposits (beach ridges deposits) and marine deposits can be found beneath the recent deposits as far as 8 km from the sea.

(b) Alluvial Fan (Pleistocene) Unit

This deposit is the result of the weathering process of the Tertiary volcanic product. It is composed of tuffaceous sand, conglomerates and lahar deposits and covers most of the undulating area, except lower areas of rivers or valleys where the surface is covered by the Alluvial unit. The color of soils is dominantly reddish/yellowish/light brown to brownish/dark gray and black in some layers, where the consistency of soils is firm to very stiff or loose to dense. N values are in the range of 10 to 20 and the thickness is 5 to 10 m as shown in Figure 10.

(c) Genteng / Banten Tuff (Pliocene) Unit

This deposit contains the sedimentary rocks of the Tertiary volcanic product and is called tuffaceous sand and tuffaceous clay in alternation, in which lahar and lava deposit, lapilli and pumice fragments can be found. This unit is estimated to form the bedrock in the lowland Study Area. The soil consistency is very stiff to moderately cemented or weathered cemented to strongly cemented with N values of around 20 in the upper portion and more than 30 in the lower portion on an average. The main colors are gray to brownish gray and black in some layers. These sedimentary rocks are encountered at increasing depth from 15 m to 20 m toward the north direction.

From the above geological considerations, the following design concepts are tentatively recommended for structures in the lowland plain in the master plan stage:

(i) Side slope:

1:2 for excavated canals and embankments in the Alluvial unit.

1:1.5 for excavated canals and embankments in the Alluvial Fan unit

(ii) Pile foundation (bedrocks):

20 m in depth for sheet piles, foundation piles of drainage facilities, etc.

3. GEOTECHNICAL INVESTIGATION IN THE FEASIBILITY STUDY

3.1 Introduction

Geotechnical investigation have been carried out in the project area of the Ciliwung Floodway, the Western Banjir Canal (WBC) and the downstream reaches of the Cisadane river.

The main objectives of the investigation are to obtain the following information :

(1) Geological conditions along the Western Banjir Canal (WBC) and around the downstream reaches of the Cisadane river for the river improvement works,

(2) Geological conditions along the Ciliwung Floodway tunnel in Bogor, and

(3) Geotechnical feature of foundations, cut slopes and tunnel.

3.2 Geology

3.2.1 General Geology

According to the result of field reconnaissance, the geological literature published by the Geological Research and Development Center of the Directorate General of Geology and Mineral Resources, and previous investigations and studies, the geology in the Study Area is composed of alluvium of the Holocene age (mainly in the lowland plain), terrace deposits of the Pleistocene age (mainly alluvial fan in the Bogor zone and the lowland plain), tuffaceous sedimentary rocks of the Pliocene to Miocene age (mainly in the Bogor zone) and southern volcanoes of the Miocene age.

The geological map and the local stratigraphy in and around the Study Area are given in Figures 1 and 2, respectively.

3.2.2 Geology in the Project Area

(1) Downstream Reaches of the Cisadane River (River Improvement Work)

Most of the subsurface layers in this project area belongs to Alluvial. This deposit unit is actually a mixture of valley deposit, river deposit and beach deposit and mainly consists of clay, silt, sand, gravel, pebble and boulder containing organic material, or shell fragments at the local part. Further this unit can be considered as very soft to soft soil (applicable to clay / silt) and very loose to loose soil (applicable to sound).

(2) Western Banjir Canal Alignment (River Improvement Work)

Alluvial (downstream reaches from Grogol) and Alluvial Fan (Grogol to Manggarai) are the majority to subsurface layers. Alluvial Fan deposit is the result of weathering and redepositing of Quaternary volcanic products and mainly composed of bedded tuff and conglometatic taff and those are interbedded with sandy tuff and pumice taff in some places.

(3) Ciliwung Floodway Route (Tunnel Work)

The Ciliwung Floodway tunnel area is located between the Ciliwung river and the Cisadane river in the hilly area of Bogor. The geology of the tunnel route is mainly composed of Younger Volcanic Rocks of G. Pangrango named in the Geological Map of the Bogor Quadrangle (1986) which consists of old deposits, lahar and lava, andestic basalt with oligoclase-andesine, labradorite, olivine, pyroxene, and hornblende etc., mostly highly weathered and poorly cemented.

3.3 Geotechnical Investigation for Ciliwung Floodway

3.3.1 Work Items, Quantities and Locations

Work items and quantities of the geotechnical investigation works in the field and the laboratory are shown in Table 3. Seven core drillings with SPT, permeability test and LLT have been carried out to obtain geological and geotechnical conditions of the tunnel floodway route and drilling depth is reached to 389 m in total.

A series of laboratory test have been conducted on samples taken from bore holes, which are recovered rock core samples (for rock test) as well as undisturbed samples obtained by use of the thin wall sampling tube (for soil test).

Locations of field work (core drilling) are shown in Figure 11.

The coordinates and elevations of the borehole points are presented as follows :

Borehole	Coordinate (m)		Elevation (m)
No.	X	Y	Z
FLD-1	700,297.500	9,268,442.500	272.864
FLD-2	700,580.500	9,268,366.550	284.075
FLD-3	700,514.103	9,268,334.250	275.159
FLD-4	700,425.511	9,268,266.750	295.932
FLD-5	699,972.600	9,268,200.241	280.431
FLD-6	699,430.012	9,268,052.750	280.422
FLD-7	699,353.101	9,268,027.032	260.411

Note : X ,Y : National Coordinates System
Bessel UTM Zone 48
Z : Mean Sea Level (TTG)

3.3.2 Results of Investigation

Geological profiles which mean summary of drilling logs are shown in Figure 12. Summary of laboratory test results on recovered core samples from borehole are shown in Table 4 (rock test) and Table 5 (soil test) respectively. Summary of LLT results and permeability test results are shown in Table 6 and Table 7 respectively.

All drilling logs with results of SPT, LLT test results, permeability test results and laboratory test results are compiled in the Attached Reference Data.

3.3.3 Geotechnical Evaluation

The rock formation making up the project area is of Quaternary volcanic origin, namely Younger Volcanic Rocks unit all over.

As shown in Figure 12, the following sequence of the rock unit can be distinguished from the top of the series (youngest beds) to the bottom (deepest and oldest occurrence):

- Overburden
- Tuffaceous sandy silt
- Tuff breccia
- Older volcanic deposits (tuffaceous sandy silt, gravely sand)

(1) Overburden

In the most upper portion of Younger Volcanic Rocks unit, the loose overburden layers which are formed mainly from intensively weathered tuff, are composed of soft clayey silt or silty-sandy clay, and partly contains gravels and boulders of andesitic rocks. The thickness of these overburden layers ranges from 10 m in the boreholes of FLD-5 and FLD-6 to 25 m in the top of topographic condition at most.

N-values in the above boreholes range high value of 12 to 22 on the whole, partly more than 50 even the groundwater level is observed at high level and water content of soil samples is around 70 %.

According to the laboratory test results for core samples of the borehole of FLD-6, its soil classification belongs to silts and clays of liquid limit greater than 50 %, namely MH and CH of the Unified Soil Classification symbol adopted by US Bureau of Reclamation. The unit weights in natural state range 1.52 to 1.61 gr/cm^3 and the unconfined compression strength is an order of 0.2 kgf/cm^2.

(2) Tuffaceous Sandy Silt

The tuffaceous sandy silt layers covered by the overburden were observed horizontally in the borehole of FLD-4, FLD-5 and FLD-6 and have a thickness of 10 to 15 m as shown in Figure 12. The layers which contain the pumiceous tuff portion partly, are highly weathered and poorly cemented, and classified to the soft rock layer. However, N-values of the layers are often more than 50.

The coefficient of permeability ranging from an order of 10^{-3} to 10^{-4} cm/sec shows its impervious condition of the layers as a whole.

According to soil tests for the undisturbed samples of the borehole of FLD-4 (2.5-19.8 m), the typical properties of tuffaceous sandy silt layers are same as those of the overburden mostly therefore its soil symbols are classified to MH and CH group also. The unconfined compression strength ranges widely such as 0.14 to 0.98 kgf/cm^2.

(3) Tuff Breccia

The tuff breccia layers below the tuffceous sandy layers appear on the order volcanic deposits with a range of 10 to 25 m in thickness.

The andestic components of these layers varying in size from 0.1 to 10 cm with even large boulders are in a dense matrix of silty sand tuff. Mostly the cementation is poorly developed and rock test results for the core samples of tuff breccia show the unconfined compressive strength as 5 to 15 kgf/cm^2 in the moderately cemented conditions and 200 to 400 kgf/cm^2 in the consolidated components and andesite rocks itself. N-values in the layers are more than 50 and the coefficient of permeability ranges widely from an order of 10^{-2} to 10^{-5} cm/sec probably due to the degree of the cementation and weathering.

(4) Older Volcanic Deposits

The older volcanic deposits layers appear underneath the tuff breccia layers as the oldest and deepest rock unit in this investigation area.

The layers are distinguished from tuff or tuffceous sandy silt in the upper portion with a thickness 20 to 30 m to volcanic breccia or gravely sand in the lower portion.

The older volcanic deposits are moderately to softly consolidated and SPT for N-values could not be conducted fully due to hardness or N-values more than 50 in all.

The RQD (Rock Quality Designation) of the recovered samples obtained in these layers with careful drilling not exceeded 25 %, and probably near 0 % as a whole.

The coefficient of permeability by the borehole permeability tests ranges widely between an order of 10^{-3} and 10^{-5} cm/sec in these layers.

3.3.4 Geotechnical Consideration for Floodway Construction

In view of the topographic condition, the tunnel will be encountered to the tuffaceous sandy silt layers and tuff breccia. As above-mentioned, the both layers are poorly consolidated and loosely cemented and included boulders in places.

N-values by SPT ranges 38 to more than 50 m in the upper layer and lower layer more than 50 all over. The elasticity coefficient (Young's modulus) obtained by the borehole lateral load test (LLD) has a wide range from 150 to more than 10,000 kg/cm^2 probably due to the degree of the cementation as well as the components of rocks.

The drilling works of this investigation were disturbed very often by the borehole collapse and/or the jamming in the gravely and loosely layers of these younger volcanics. The coefficient of permeability also has a wide range from an order of 10^{-2} to 10^{-5} cm/sec.

The groundwater level were observed at a depth of 1.0 to 3.0 m in the boreholes of FLD-1, FLD-2, FLD-3, FLD-5 and FLD-7 and 10.0 to 15.0 m in boreholes of FLD-4 and FLD-6. In addition, the artesian water (confined water) with 0.9 and 2.0 m in a height of water pressure from the ground surface appears to come out at a depth of 15 and 20 m of the boreholes of FLD-5 and FLD-7, discharge of which are about 1.0 and 5.0 l/sec respectively.

Judging from the poorly consolidated condition and the physical properties of the layers such as unconfined compressive strength and elasticity modulus, some difficulties will arise during tunnel construction in the Younger Volcanic Rocks unit considering the relatively thin overburden and a lot of the groundwater/artesian water. The tunnel excavation would be requested a lot of protection works such as steel supports, shotcrete/granite and drainage and a concrete lining with a heavy reinforcement. Although not so much field investigation and laboratory test have been carried out on these soft volcanic rocks, the following parameters are recommended for the design at the feasibility study level :

Wet density	:	1.85 t/m
Strength parameter (drained)	:	C = 10.0 t/m^2
		Ø = 30°
Modulus of elasticity	:	E = 150 kg/cm^2

The cut slopes of the open channels including tunnel inlet and outlet are to be composed of three different layers, namely overburden layers, tuffaceous sandy silt and tuff breccia. According to the geotechnical investigation and field reconnaissance, especially from the observation results of the bluff along the Ciliwung river, these layers in normal cut slopes is strong enough. No special attention except slope protection against erosion for cut slope is necessary to stabilize the slopes and to reduce maintenance works.

Moderately consolidated rock of tuff breccia is expected to exist down to 30 m in depth from the ground surface of the borehole FLD-1, where the intake weir is planned. In the above-mentioned tuff breccia, N-values exceed 50 and permeability coefficient is an order of 10^{-4} cm/sec except about 5 m in depth of surface zone. Tuff breccia core samples were collected from the borehole FLD-1. The confined compressive strength ranges from 23 to 478 kg/cm^2 widely due to the degree of consolidation. These values indicate a rather soft rock condition. Consequently, it is recommended that the surface weathered tuff breccia, about 5 m in depth, are removed from the foundation of the weir to improve the bearing capacity and the impervious condition.

3.4 Geotechnical Investigation for River Improvement Works

3.4.1 Work Items, Quantities and Locations

Work items and quantities of the geotechnical investigation works in the field and the laboratory are shown in Table 8. Sixteen (16) core drillings with SPT , borehole permeability test and LLT have been carried out to obtain geological and geotechnical conditions along the Western Banjir Canal and the downstream reaches of the Cisadane river and drilling depth is reached to 354.0 m in total. A series of laboratory test (soil test) have been conducted on samples taken from the boreholes, which are undisturbed samples obtained by use of the thin wall sampling tube. Locations of field work (core drilling) are shown in Figure 13. The coordinates and elevations of the borehole points are presented as follows :

Borehole	Coordinate (m)		Elevation (m)
No.	X	Y	Z
Western Banjir Canal			
WBC-1	695,722.500	9,324,775.021	0.300
WBC-2	696,257.500	9,323,701.100	0.128
WBC-3	697,740.100	9,321,289.100	2.320
WBC-4	697,997.100	9,320,706.400	3.420
WBC-5	698,599.900	9,319,605.500	3.591
WBC-6	698,969.000	9,318,712.500	4.184
WBC-7	699,155.900	9,318,197.200	2.212
WBC-8	700,317.419	9,315,609.900	3.561
WBC-9	700,277.511	9,314,612.101	5.800
WBC-10	700,815.500	9,314,310.500	7.147
WBC-11	701,687.500	9,314,032.800	9.245
WBC-12	702,925.012	9,313,874.911	11.402
WBC-13	703,409.500	9,313,721.250	11.558
WBC-14	704,475.500	9,313,495.500	8.510
WBC-15	704,555.500	9,313,686.600	9.500
Cisadane River			
CSD-1	680,784.900	9,329,749.500	3.539

Note : X ,Y : National Coordinates System

Bessel UTM Zone 48

Z : Mean Sea Level (TTG)

3.4.2 Results of Investigation

Geological profiles along WBC and the Cisadane river which mean summary of drilling logs are shown in Figure 14.

Summary of laboratory test results on recovered undisturbed samples by use of thin wall samples tube are shown in Table 9. Summary of LLT results and permeability test results are shown in Table 10 and 11.

All drilling logs with results of SPT, LLT test results, permeability test results and laboratory test (soil test) results are compiled in the Attached Reference Data.

3.4.3 Geotechnical Evaluation

The general geological conditions and geological profiles can be seen in Figure 14 and summarized in two (2) parts of geological units, namely Holocene (Alluvial) unit and Pleistocene (Alluvial Fan) unit

(1) Holocene (Alluvial) Unit

This deposit is actually mixed of valley deposit, river deposit and beach deposit and mainly consists of clay, silt and some sand and containing organic material or shell fragment at the local part. The downstream reaches of WBC from Grogol and the Cisadane river between the boreholes of WBC-1 and WBC-7 and CSD-1 area are dominantly covered by this deposit with a depth of 10 to 15 m. This deposit can be considered as the very soft soil (applicable to clay/silt) and the very loose soil (applicable to sand) with N-values of less than 10 and mostly a range from 1 to 3, and with brownish gray or gray (dark/light) colours. From the grain size analysis and the Atterberg limit test, this deposit is classified to CH group of Unified Soil Classification system in all except only WBC-4 (4.5 - 5.0 m) sample which belongs to SM group.

From the geological and geotechnical considerations of the field investigation and laboratory works, the main engineering properties to be adopted for the design works are proposed as follows :

- Wet density (n) : 1.60 t/m^3
- Unconfined compressive strength (q_u) : 2.0 t/m^3
- Elasticity coefficient (Em) : 15 kgf/cm^2
- Compression index (Cc) : 0.57
- Coefficient of consolidation (Cv) : 5×10^{-3} cm^2/sec

- Pile foundation (bedrocks) : 15 - 20 m in depth
- Side slope for excavated canals and embankments : 1 : 2

(2) Pleistocene (Alluvial Fan) Unit

This deposit is the result of weathering and redepositing process of Quaternary volcanic products and consists mainly of clay, silt, sand and gravel. This deposit is widely distributed in the WBC area, underlying the Alluvial unit in the downstream reaches of the Cisadane river and along WBC and as the superfacial layers between Grogol and Manggarali with a depth of 10 to 20 m.

N-values of this deposit ranges from 2 to more than 50 due to the degree of the consistency, firm to very stiff or loose to dense and unconsolidated to consolidated (tuffaceous). The permeability coefficient ranges from an order of 10^{-5} to 10^{-7} cm/sec, impervious condition in general except the intercalated thin sand layers which is an order of 10^{-4} cm/sec.

From the field investigation and laboratory test results, the following engineering properties and design concepts are recommended for structures :

- Wet density (n) : 1.70 t/m^3
- Unconfined compressive strength (q_u) : 2.5 t/m^3
- Elasticity coefficient (Em) : 150 kgf/cm^2
- Compression index (Cc) : 0.34
- Coefficient of consolidation (Cv) : 5.4×10^{-3} cm^2/sec
- Pile foundation (bedrocks) : 15 m in depth
- Side slope for excavated canals and embankments : 1 : 1.5

Table 1 SOIL STRATIGRAPHY IN LOWLAND PLAIN

Geochronology: Period	Geochronology: Epock	Facies	Symbol	General Description
QUARTERNARY	Holocene (Alluvial)	Recent Deposits	*F*	Filled materials consist of SILT, Clay, SAND and garbage. Mainly soft to firm clayey SILT.
			Acl	Slope wash and marsh CLAY and SILT. Brownish to greyish colours, very soft to film, trace of matters, medium plasticity.
		Coastal Deposits	*Ac2*	Sandy SILT to clayey SILT, very soft to soft, brownish GREY to (dark) GREY, trace of organic matters and shell fragments, medium to high plasticity.
			As	Very loose SAND to silty SAND, dark to light GREY, trace of shell fragments, fine to medium sand.
	Pleistocene (Alluvial Fan)	Marine Deposits	*Ac3*	Very soft to medium silty CLAY to CLAY with shell fragments. Dark to light, GREY, high plasticity.
		Volcanic Deposits	*Dc*	Soft to very stiff CLAY, SILK and clayey to sandy SILT. Reddish / yellowish BROWN to brownish / light GREY mottling, medium platicity, contain subrounded gravels (ϕ 5 - 25 mm) in some places.
		Old River Deposits	*Ds & Dg*	Silty SAND, SAND, GRAVELS and their mixture, yellowish / light / dark BROWN to brownish / light / dark GREY and in some places BLACK. Fine to coarse SAND, mainly subrounded gravels (ϕ 5 - 20 mm), Max. ϕ = 50 mm, weakly cemended, Loose to Dense.
TERTIARY	Pliocene (Genteng / Banten Tuff)	Sedimentary Rocks	*Tcl*	Heavily weathered (decomposed) tuffaceous SILT and sandy / clayey SILT, light BROWN to brownish / light GREY, weakly cemented, non to medium plasticity, firm to very stiff.
			Tsl	Tuffaceous silty SAND to SAND (fine-coarse), brownish / yellowish / dark GREY to dark BROWN and BLACK. Trace of subangular-subrounded gravels (max. ϕ 30 mm), heavily weathered, medium to weakly cemented.
			Tc2	Tuffaceous hard SILT and sandy SILT. Dark / light greyish to brownish colours, non-plasticity, weakly cemented to moderately cemented.
			Ts2	Sand, gravelly SAND, silty SAND, tuffaceous, mainly GREY to dark GREY, fine to coarse SAND, partially contain subangular to subrounded gravels (ϕ 5 - 20 mm, max. ϕ = 40 mm), medium to strongly cemented.

Table 2 TYPICAL SOIL TEST RESULT

Facies	Symbol	Soil Classification		INDEX PROPERTIES							MECHANICAL PROPERTIES					
		Visual	Unified	SL (%)	Wn (%)	LL (%)	PI (%)	Gs	γ_t (g/cm^2)	e	qu (kg/cm^2)	Cu (kg/cm^2)	ϕu (o)	Ccu	ϕcu	Cc
Recent Deposit	Ac1	CLAY to SILT	CH MH	21 - 24 (Ave. 23)	38 - 110 (Ave. 64)	51 - 123 (Ave. 82)	30 - 60 (Ave. 46)	2.52 - 2.73 (Ave. 2.65)	1.63 - 1.76 (Ave. 1.72)	1.17 - 2.25 (Ave. 1.68)	0.08 - 0.25 (Ave. 0.15)	-	-	0. 03	23	
Coastal Deposit	Ac2	-	-	22.86	37 - 49.2 (Ave. 43)	45 - 59 (Ave. 52)	14 - 27 (Ave. 20)	2.62 - 2.67 (Ave. 2.65)	1.66	1.39	0.21	-	-	0.03	0.5	0.23
Marine Deposit	Ac3	CLAYEY SILT silty CLAY	MH CH	20 - 47 (Ave. 33)	35 - 99 (Ave. 72)	49 - 141 (Ave. 82)	23 - 94 (Ave. 47)	2.58 - 2.73 (Ave. 2.63)	1.43 - 1.84 (Ave. 1.59)	0.95 - 2.68 (Ave. 1.88)	0.08 - 0.75 (Ave. 0.24)	0.02 - 0.6 (Ave. 0.12)	4 - 10 (Ave.6)	0.02	14	0.19 - 1.45 (Ave. 102)
Volcanic Deposit	Dc	clayey SILT to silty CLAY	MH CH	19 - 36 (Ave. 30)	21 - 101 (Ave. 48)	43 - 114 (Ave. 80)	22 - 71 (Ave. 47)	2.58 - 2.73 (Ave. 2.64)	1.48 - 1.99 (Ave. 1.79)	0.69 - 2.44 (Ave. 1.22)	0.63 - 1.99 (Ave. 1.02)	0.05 - 1.25 (Ave. 0.49)	2 - 7 (Ave. 5)	0.45	7	0.41 - 1.46 (Ave. 0.94)
Sedimentary Rocks	Tc1	SILTY to sandy / silty CLAY	MH CH	26 - 33 (Ave. 29.)	39 - 80 (Ave. 60)	64 - 96 (Ave. 81)	21 - 54 (Ave. 42)	2.50 - 2.70 (Ave .2.62)	1.55 - 1.80 (Ave. 1.64)	1.07 - 2.03 (Ave. 1.69)	0.83 - 1.45 -	0.3	16	0.15	22	0.28 - 0.90 (Ave. 0.54)
	Tc2	CLAY, SILT, sandy SILT silty SAND	CH, MH ML SM	-	32 - 61 (Ave. 51)	46 - 105 (Ave. 68)	5 - 66 (Ave. 31)	2.60 - 2.70 (Ave. 2.65)	-	-	-	-	-	-	-	-
	Ts2	SAND with silt	SM	-	39	-	-	2.69	-	-	-	-	-	-	-	-

Remarks : SL : Shrinkage limit, Wn : Natural moisture content, LL : Liquid limit, PL : Plastic limit, PI : Plasticity index
Gs : Specific gravity, γ_t : Wet density, e : Void ratio, qu : Unconfined compressive strengh
Cu (Ccu) : Cohesion, ϕu (ϕcu) : Internal friction angle, Cc : Compression index

Table 3 ITEMS AND QUANTITIES OF GEOTECHNICAL INVESTIGATION (CILIWUNG FLOODWAY)

WORK ITEM				UNIT	QUANTITY
1. FIELD WORKS (Core Drilling and Testing in Boreholes)					
1.1	Numbers of Core Drilling			Place	7
1.2	Core Drilling Depth			m	389.0
	Borehole No.	FLD - 1	30.0 m		
		FLD - 2	49.0 m		
		FLD - 3	30.0 m		
		FLD - 4	100.0 m		
		FLD - 5	60.0 m		
		FLD - 6	90.0 m		
		FLD - 7	30.0 m		
1.3	Standard Penetration Test			nos	105
1.4	Permeability Test			nos	64
1.5	Borehole Lateral Test			nos	6
1.6	Undisturbed Sampling			nos	23
2. LABORATORY TEST (Soil / Rock Test)					
2.1	Moisture Content Test			nos	23
2.2	Specific Gravity Test			nos	23
2.3	Grading Analysis			nos	23
2.4	Liquid Limit, Plastic Limit			nos	23
2.5	Unconfined Compression Test			nos	23

Table 4 SUMMARY OF ROCK TEST RESULTS (CILIWUNG FLOODWAY)

ROCK SAMPLE Borehole / Depth (m)	TYPE OF ROCK	UNCONFINED COMPRESSION STRENG. (qu) (kg/cm^2)	NATURAL DENSITY (ρd) (gr/cm^3)	NATURAL WATER CONTENT (%)	SATURAT. DENSITY (ρs) (gr/cm^3)	ABSORPT. STR. WTR CONTENT (%)	DRY DENSITY (ρd) (gr/cm^3)	DEGREE OF SATUR.(S) (%)	POROSITY (n) (%)	APPR. SPECIFIC GRAVITY (-)	TRUE SPECIFIC GRAVITY (-)	VOID RATIO (e) (-)
FLD-1												
(5.80 - 6.00)	T.B (Comp)	23.0	1.851	6.2	1.966	17.6	1.743	35.3	30.7	1.743	2.514	0.442
(8.70 - 8.90)	T.B (Comp)	478.1	2.66	0.5	2.672	0.8	2.648	53.3	2.2	2.648	2.709	0.023
(24.60 - 24.85)	T.B (Comp)	288.5	2.273	0.5	2.284	5.7	2.262	8.5	12.8	2.267	2.594	0.147
(28.20 - 28.40)	T.B	28.0	1.787	6.4	1.902	19.5	1.679	32.9	32.8	1.674	2.499	0.488
FLD-3												
(14.00 - 14.20)	ANDESITE	320.7	2.563	5.7	2.709	7.6	2.425	75.0	18.4	2.425	2.973	0.226
(17.55 - 17.85)	T.B	1242.0	2.795	0.4	2.806	0.8	2.784	49.9	2.3	2.784	2.849	0.023
(29.10 - 29.50)	T.B (Comp)	443.8	2.792	0.2	2.796	0.7	2.788	21.1	2.0	2.788	2.844	0.020
FLD-4												
(62.80 - 63.00)	T.S.S	2.5	0.861	58.2	1.362	129.2	0.544	45.1	70.3	0.544	1.833	2.369
FLD-6												
(19.50 - 19.65)	T.B	5.1	1.207	38.1	1.666	66.2	0.874	57.5	57.8	0.874	2.073	1.371
(28.50 - 28.70)	T.B	10.0	1.789	8.6	1.942	22.4	1.648	38.4	36.9	1.648	2.610	0.584
(31.10 - 31.20)	T.B	14.5	1.686	19.2	2.009	33.1	1.415	57.8	46.9	1.415	2.664	0.883
(38.42 - 38.65)	T.S.S	10.4	1.292	23.8	1.599	44.6	1.044	53.3	46.6	1.044	1.955	0.873
(40.00 - 40.20)	T.S.S	11.2	1.372	31.5	1.803	49.5	1.044	63.5	51.7	1.044	2.159	1.069
(44.30 - 44.50)	T.S.S	4.9	1.253	36.2	1.707	57.4	0.920	63.2	52.7	0.920	1.946	1.116

Notes : T.B : Tuff Breccia   T.S.S : Tuffaceous sandy silt with gravels
Comp : Component of Andesite

Table 5 SUMMARY OF SOIL TEST RESULT (CILIWUNG FLOODWAY)

Hole No.			FLD-1	FLD-4						FLD-6	
Depth (m)			3.00-3.20	1.00-1.50	2.50-3.00	8.50-9.00	11.5-12.0	19.35-19.8	23.3-23.85	1.60-2.00	6.50-7.00
Item	Symbol	Unit	*MH	*CH	*CH	*CH	*MH	*CH	*MH	*CH	*MH
Specific Gravity	G	-	2.661	2.602	2.637	2.586	2.674	2.650	2.418	2.739	2.676
Natural Water Content	Wn	%	58.8	57.5	66.2	55.2	67.4	72.5	68.8	78.4	68.3
Unit Weight, Natural State	g n	t/m³	1.606	1.630	1.610	1.690	1.630	1.604	1.396	1.522	1.614
Dry Unit Weight	g d	t/m³	1.011	1.035	0.969	1.089	0.974	0.930	0.827	0.853	0.959
Natural Void Ratio	e	-	1.631	1.515	1.722	1.375	1.746	1.851	1.923	2.211	1.790
Natural Porosity	n	%	62.0	60.2	63.3	57.9	63.6	64.9	65.8	68.9	64.2
Degree of Saturation	Sr	%	95.9	98.8	100	100	100	100	86.5	97.1	100
Saturation of Water Content	Wsat	%	61.3	58.2	66.2	55.2	67.4	72.5	79.5	80.7	68.3
Saturation Unit Weight	g sat	t/m³	1.631	1.637	1.610	1.690	1.630	1.604	1.485	1.542	1.614
Liquit Limit	LL	%	73.3	100.6	112.5	121.3	79.9	133.3	97.0	121.2	112.5
Plastic Limit	PL	%	40.8	35.9	40.7	38.1	41.6	47.5	56.2	49.5	48.8
Plasticity Index (LL-PL)	PI	%	32.5	64.7	71.8	83.2	38.3	85.8	40.8	71.7	63.7
Gravel content (>20mm)	-	%	1.7	-	-	-	-	-	-	-	-
Sand Content 2.0 ~ 0.075 mm	-	%	33.9	13.3	13.1	10.1	24.9	11.6	19.2	15.4	10.0
Silt/clay content (<0.075mm)	-	%	64.4	86.7	86.9	89.9	75.1	88.4	80.8	84.6	90.0
Unconfined Compr. Strength	qu	kgf/cm²	1.17	0.49	0.36	0.98	0.14	0.44	0.71	0.19	0.23

* : Soil Symbol (Unified Soil Classification)

Table. 6 SUMMARY OF LATERAL LOAD TEST (CILIWUNG FLOODWAY)

Location : Ciliwung - Cisadane River : Bogor

No. ITEM	SYMBOL	UNIT	BORE HOLE	FLD - 4		FLD - 5		FLD - 6	
			DEPTH (m)	19.0	26.0	10.0	17.0	15.0	22.0
1. Pressure at Rest	P_o	kg/cm^2		2.0	4.0	1.5	5.0	1.5	1.3
2. Yield Stress	P_y	kg/cm^2		7.0	66.0	5.5	150.0	4.0	6.7
3. Failure Stress	P_l	kg/cm^2		-	-	-	-	6.10	-
4. Subgrade Reaction Coefficient(K-Value)	K_m	kg/cm^3		48.6	1,294.1	57.3	2,173.9	31.8	35.1
5. Elasticity Coefficient (Young's Modulus)	E_m	kg/cm^2		235.1	6,332.4	265.2	10,640.2	153.0	169.9
6. Out Radius($\frac{r1+r2}{2}$)	R_m	cm		3.721	3.764	3.561	3.756	3.706	3.726
(Rock Classification)				(Pumiceous Tuff)	(Tuffaceous Gravelly Siltysand)	(Decomposed Tuff Breccia)	(Tuff Breccia)	(Decomposed Tuff Breccia)	(Decomposed Tuff Breccia)
(N - Value)	(N)			-	-	-	-	(41 - 44)	(> 38)

Note : $K_m = \frac{\Delta P}{\Delta \gamma}$ (slope of linear portion of P-r curve), $E_m=(1+v').R_m.K_m$, $v' = 0.3$ (Poisson's ratio).

Table 7 SUMMARY OF PERMEABILTY TEST RESULT
(CILIWUNG FLOODWAY)

PERMEABILITY COEFFICIENT: k (cm/sec) AT DEPTH : D (m)																				
FLD-1			FLD-2			FLD-3			FLD-4			FLD-5			FLD-6			FLD-7		
D	Test	k	D	Test	k	D	Test	k	D	Test	k	D	Test	k	D	Test	k	D	Test	k
5	C	6.49E-02	5	C	6.78E-02	5	C	8.20E-04	5	F	3.57E-04	5	F	1.26E-04	5	F	0.00	5	C	2.28E-05
5-10	L	1.56E-04	10	C	1.65E-02	10	C	7.43E-04	10	F	2.11E-04	10	C	3.24E-03	10	F	0.00	10	C	6.55E-06
10-15	L	2.25E-04	15	C	1.42E-02	13.5-15.9	L	1.92E-04	15	C	5.53E-03	15	C	2.72E-02	15	F	5.38E-05	15	C	9.57E-06
15-20	L	1.10E-05	20	C	6.56E-03	16.0-20.0	L	1.28E-04	20	F	4.78E-05				20	F	1.90E-04	15-20	L	8.87E-05
20-25	L	NP	25	C	2.49E-03	20-25	L	1.03E-04	25	F	3.75E-04				25	F	5.01E-04	20-25	L	1.47E-04
25-30	L	9.78E-05	30	C	2.14E-03	25-30	L	1.08E-04	30	C	4.97E-03				25-30	L	1.45E-04	25-30	L	1.31E-04
			35	C	4.31E-04				35	C	1.54E-03				30-35	L	2.19E-04			
			40	C	1.22E-03				40	F	1.50E-05				35-40	L	1.17E-04			
			45	C	9.49E-03				45		-				40-45	C	5.49E-05			
									50	F	3.78E-05				45-50	C	3.68E-05			
									55	F	1.63E-05				50-55	C	2.42E-04			
									60	F	2.01E-05				55-60	C	2.38E-04			
									65	F	7.03E-05				-					
									70		-				65-70	C	5.87E-05			
									75	F	6.86E-05				70-75	C	5.12E-05			
									80	C	1.47E-03				75-80	C	7.25E-05			
									85	C	1.23E-03				80-85	C	3.68E-05			
									90	F	2.29E-05									
									95	C	1.98E-04									
									100	C	5.05E-05									

Remarks Test : F ; Falling head test
C ; Constant head test
L ; Lugeon test

Table 8 ITEMS AND QUANTITIES FOR GEOTECHINICAL INVESTIGATION (WBC & CISADANE RIVER)

WORK ITEM				UNIT	QUANTITY
1. FIELD WORKS (Core Drilling and Testing in Boreholes)					
1.1	Numbers of Core Drilling			Place	16
1.2	Core Drilling Depth			m	354.0
	Borehole No.	WBC - 1	20.0 m		
		WBC - 2	20.0 m		
		WBC - 3	22.0 m		
		WBC - 4	25.0 m		
		WBC - 5	23.0 m		
		WBC - 6	24.0 m		
		WBC - 7	22.0 m		
		WBC - 8	20.0 m		
		WBC - 9	20.0 m		
		WBC - 10	22.0 m		
		WBC - 11	20.0 m		
		WBC - 12	20.0 m		
		WBC - 13	21.0 m		
		WBC - 14	20.0 m		
		WBC - 15	25.0 m		
		CSD - 1	30.0 m		
1.3	Standard Penetration Test			nos	177
1.4	Permeability Test			nos	68
1.5	Borehole Lateral Test			nos	6
1.6	Undisturbed Sampling			nos	36
2. LABORATORY TEST (Soil / Rock Test)					
2.1	Moisture Content Test			nos	36
2.2	Specific Gravity Test			nos	36
2.3	Grading Analysis			nos	36
2.4	Liquid Limit, Plastic Limit			nos	36
2.5	Unconfined Compression Test			nos	36
2.6	Consolidation Test			nos	36

Table 9 SUMMARY OF LABORATORY SOIL TEST (WBC/CISADANE : 1/6)

Hole No.			WBC-1			WBC-2		WBC-3		
Depth (m)			2.00-2.60	8.00-8.60	16.6-17.0	9.00-9.70	13.0-13.70	4.00-4.55	8.50-9.00	12.5-13.0
Item	Symbol	Unit	* CH	* CH	* CH	* CH	* CH	* CH	* CH	* CH
Specific Gravity	G	-	2.442	2.678	2.655	2.697	2.628	2.671	2.676	2.737
Natural Water Content	Wn	%	135.0	26.5	25.6	85.6	100.6	60.8	82.9	75.7
Unit Weight, Natural State	γ_n	t/m^3	1.320	1.865	1.898	1.450	1.417	1.696	1.511	1.579
Dry Unit Weight	γ_d	t/m^3	0.562	1.474	1.512	0.781	0.706	1.055	0.826	0.899
Natural Void Ratio	e	-	3.347	0.816	0.756	2.452	2.721	1.533	2.240	2.045
Natural Porosity	n	%	77.0	44.9	43.1	71.0	73.1	60.5	69.1	67.2
Degree of Saturation	Sr	%	98.5	86.9	89.7	94.1	97.2	100	99.1	100
Saturation of Water Content	Wsat	%	137.1	30.5	28.5	90.9	103.5	60.8	83.7	75.7
Saturation Unit Weight	γ_{sat}	t/m^3	1.332	1.924	1.942	1.492	1.438	1.696	1.517	1.579
Liquit Limit	LL	%	178.5	125.7	136.6	103.3	133.8	64.7	126.6	97.6
Plastic Limit	PL	%	36.5	28.4	43.3	28.3	30.7	21.0	29.8	25.4
Plasticity Index (LL-PL)	PI	%	142.0	97.3	93.3	75.0	103.1	43.7	96.8	72.2
Gravel content (>20mm)	-	%	-	-	-	2.5	-	-	-	-
Sand Content 2.0 ~ 0.075 mm	-	%	7.7	4.3	10.2	26.0	14.1	22.6	22.8	25.8
Silt/clay content (<0.075mm)	-	%	92.3	95.7	89.8	71.5	85.9	77.4	77.2	74.2
Unconfined Compr. Strength	q_u	kgf/cm^2	0.08	0.08	0.36	0.04	0.05	0.24	0.48	0.21
Sensitivity	St		1.64	1.22	1.20	1.12	1.49	1.29	1.54	1.18
Consolidation Test	e_o	-	3.333	2.522	2.152	2.965	2.709	1.524	2.229	2.035
	Cc	-	1.14	0.75	0.61	0.67	0.90	0.36	0.85	0.54
	Cv	cm^2/sec	1.14E-03	3.36E-03	6.45E-03	8.06E-04	2.11E-03	5.83E-03	4.78E-03	5.72E-03

* : Soil Symbol (Unified Soil Classification)

Table 9 SUMMARY OF LABORATORY SOIL TEST (WBC/CISADANE : 2/6)

Hole No.			WBC-4		WBC-5		WBC-6			
Depth (m)			4.50 - 5.00	7.50 - 8.00	10.5 -10.85	15.0 -15.40	2.50 - 3.00	4.00 - 4.40	6.00 - 6.40	10.0-10.45
Item	Symbol	Unit	* SM	* CH	* CH	* CH	* CH	* CH	* CH	*MH
Specific Gravity	G	-	2.763	2.653	2.478	2.506	2.664	2.696	2.549	2.657
Natural Water Content	Wn	%	35.2	91.8	72.5	78.3	56.5	61.6	79.9	84.5
Unit Weight, Natural State	γ_n	t/m³	1.831	1.411	1.540	1.510	1.624	1.620	1.503	1.532
Dry Unit Weight	γ_d	t/m³	1.354	0.736	0.893	0.847	1.037	1.002	0.835	0.831
Natural Void Ratio	e	-	1.040	2.605	1.776	1.960	1.568	1.690	2.052	2.199
Natural Porosity	n	%	51.0	72.3	64.0	66.2	61.1	62.8	67.2	68.7
Degree of Saturation	Sr	%	93.5	93.4	100.0	100.0	96.1	98.3	99.3	100.00
Saturation of Water Content	Wsat	%	37.7	98.2	72.5	78.3	58.9	62.7	80.5	84.5
Saturation Unit Weight	γ_{sat}	t/m³	1.864	1.458	1.540	1.510	1.648	1.631	1.508	1.532
Liquit Limit	LL	%	NP	107.0	109.0	94.0	74.3	80.7	122.3	80.1
Plastic Limit	PL	%	NP	28.7	35.2	38.8	27.5	33.6	34.3	40.8
Plasticity Index (LL-PL)	PI	%	-	78.4	73.8	55.2	46.8	47.2	88.0	39.3
Gravel content (>20mm)	-	%	-	-	-	-	-	-	-	-
Sand Content 2.0 ~ 0.075 mm	-	%	62.2	21.4	11.7	18.1	18.0	27.2	13.4	13.0
Silt/clay content (<0.075mm)	-	%	37.8	78.6	88.3	81.9	82.0	72.8	86.6	87.0
Unconfined Compr. Strength	q_u	kgf/cm²	0.26	0.04	0.13	0.11	0.05	0.13	0.48	0.35
Sensitivity	St		1.20	1.14	1.17	1.16	1.62	1.46	1.54	1.29
Consolidation Test	e_o	-	1.034	1.567	1.767	1.950	2.128	1.945	2.042	2.189
	Cc	-	0.11	0.65	0.30	0.31	0.48	0.42	0.56	0.73
	Cv	cm²/sec	1.03E-02	4.08E-03	8.33E-03	1.19E-02	3.58E-03	2.33E-03	6.06E-03	6.24E-03

* : Soil Symbol (Unified Soil Classification)

Table 9 SUMMARY OF LABORATORY SOIL TEST (WBC/CISADANE : 3/6)

Item	Symbol	Unit	WBC-7			WBC-8			WBC-9	
Hole No.			WBC-7			WBC-8			WBC-9	
Depth (m)			2.70 - 3.00	4.00 - 4.50	5.00 - 5.50	2.50 - 3.00	5.00 - 5.50	8.00 - 9.00	2.00 - 2.50	5.00 - 5.50
			CH	CH	CH	CH	CH	CH	CH	MH
Specific Gravity	G	-	2.566	2.584	2.671	2.664	2.456	2.526	2.527	2.654
Natural Water Content	Wn	%	48.9	55.4	70.3	62.9	71.7	62.0	39.3	54.2
Unit Weight, Natural State	γ_n	t/m³	1.690	1.631	1.508	1.694	1.557	1.656	1.784	1.671
Dry Unit Weight	γ_d	t/m³	1.135	1.05	0.885	1.040	0.907	1.022	1.281	1.084
Natural Void Ratio	e	-	1.261	1.462	2.017	1.562	1.708	1.470	0.973	1.449
Natural Porosity	n	%	55.8	59.4	66.9	61.0	63.1	59.5	49.3	59.2
Degree of Saturation	Sr	%	99.5	97.9	93.1	100	100	100	100	99.2
Saturation of Water Content	Wsat	%	49.1	56.6	75.5	62.9	71.7	62.0	39.3	54.6
Saturation Unit Weight	γ_{sat}	t/m³	1.693	1.643	1.554	1.694	1.557	1.656	1.784	1.675
Liquit Limit	LL	%	126.6	136.5	94.6	110.4	121.4	166.7	132.2	138.6
Plastic Limit	PL	%	24.1	21.9	31.4	33.9	38.6	33.1	31.1	34.2
Plasticity Index (LL-PL)	PI	%	102.5	114.6	63.2	76.5	82.8	133.6	101.2	104.3
Gravel content (>20mm)	-	%	-	-	-	-	-	-	-	-
Sand Content 2.0 ~ 0.075 mm	-	%	14.7	16.5	17.4	16.4	11.4	2.8	9.1	18.5
Silt/clay content (<0.075mm)	-	%	85.3	82.6	82.6	83.6	88.6	97.2	90.9	75.5
Unconfined Compr. Strength	q_u	kgf/cm²	0.11	0.20	0.90	0.58	0.27	0.46	0.56	0.18
Sensitivity	St		1.14	1.09	1.20	1.26	1.37	1.50	1.44	1.27
Consolidation Test	e_o	-	1.254	1.454	2.428	1.414	1.699	1.098	0.676	2.038
	Cc	-	0.30	0.39	0.73	0.37	0.49	0.34	0.21	0.50
	Cv	cm²/sec	4.56E-03	2.85E-03	5.92E-03	2.56E-03	2.91E-03	5.40E-03	6.00E-03	3.95E-03

* : Soil Symbol (Unified Soil Classification)

Table 9 SUMMARY OF LABORATORY SOIL TEST (WBC/CISADANE : 4/6)

Hole No.			WBC-9	WBC-10			WBC-11			WBC-12
Depth (m)			7.00 - 7.50	2.00 - 2.60	4.00 - 4.50	6.45 - 7.00	2.00 - 2.35	5.00 - 5.50	8.00 - 8.75	2.00 - 2.60
Item	Symbol	Unit	CH	CH	CH	CH	CH	CH	MH	CH
Specific Gravity	G	-	2.520	2.629	2.665	2.690	2.542	2.413	2.505	2.629
Natural Water Content	Wn	%	56.2	38.6	43.6	52.9	46.9	68.5	77.6	52.3
Unit Weight, Natural State	γ_n	t/m³	1.720	1.692	1.664	1.679	1.683	1.489	1.513	1.669
Dry Unit Weight	γ_d	t/m³	1.101	1.221	1.159	1.098	1.146	0.884	0.852	1.096
Natural Void Ratio	e	-	1.289	1.154	1.300	1.449	1.219	1.731	1.940	1.400
Natural Porosity	n	%	56.3	53.6	56.5	59.2	54.9	63.4	66.0	58.3
Degree of Saturation	Sr	%	100.0	88.0	89.4	98.1	97.8	95.5	100	98.3
Saturation of Water Content	Wsat	%	56.2	43.9	48.8	53.9	48.0	71.7	77.6	53.2
Saturation Unit Weight	γ_{sat}	t/m³	1.720	1.756	1.724	1.690	1.695	1.517	1.513	1.679
Liquit Limit	LL	%	104.5	144.3	115.5	108.8	87.5	129.5	129.0	137.5
Plastic Limit	PL	%	29.3	24.1	28.3	30.7	30.2	34.4	44.6	34.9
Plasticity Index (LL-PL)	PI	%	75.2	120.2	87.2	78.1	57.3	95.1	84.4	102.6
Gravel content (>20mm)	-	%	-	-	-	-	-	-	-	-
Sand Content 2.0 ~ 0.075 mm	-	%	2.8	4.9	4.4	11.0	27.3	21.2	15.4	3.3
Silt/clay content (<0.075mm)	-	%	97.2	95.1	95.6	89.0	72.7	78.8	84.6	96.7
Unconfined Compr. Strength	q_u	kgf/cm²	0.46	3.09	1.51	0.15	0.28	0.12	0.71	0.14
Sensitivity	St		1.90	1.39	1.35	1.33	1.14	1.29	1.63	1.11
Consolidation Test	e_o	-	1.281	1.147	1.293	1.441	1.136	1.722	2.258	1.392
	Cc	-	0.22	0.22	0.22	0.37	0.27	0.51	0.48	0.28
	Cv	cm²/sec	6.46E-03	9.78E-03	9.88E-03	4.96E-03	2.33E-03	4.54E-03	2.95E-03	6.17E-03

* : Soil Symbol (Unified Soil Classification)

Table 9 SUMMARY OF LABORATORY SOIL TEST (WBC/CISADANE : 5/6)

Hole No.			WBC-12			WBC-13			WBC-14	WBC-15
Depth (m)			5.40 - 6.00	6.45 - 7.00	11.5 - 12.0	2.20 - 2.70	5.00 - 5.50	11.5 - 12.0	8.40 - 9.00	5.00 - 5.45
Item	Symbol	Unit	CH	CH	CH	CH	CH	MH	MH	CL
Specific Gravity	G	-	2.702	2.619	2.622	2.602	2.679	2.732	2.668	2.564
Natural Water Content	Wn	%	60.3	50.1	73.0	50.1	57.3	63.7	71.2	59.0
Unit Weight, Natural State	γ_n	t/m³	1.601	1.696	1.630	1.621	1.707	1.603	1.515	1.728
Dry Unit Weight	γ_d	t/m³	0.999	1.13	0.942	1.080	1.085	0.979	0.885	1.087
Natural Void Ratio	e	-	1.705	1.318	1.783	1.409	1.469	1.790	2.014	1.359
Natural Porosity	n	%	63.0	56.9	64.1	58.5	59.5	64.2	66.8	57.6
Degree of Saturation	Sr	%	95.5	99.6	100	92.5	100	97.2	94.3	100
Saturation of Water Content	Wsat	%	63.1	50.3	73.0	54.1	57.3	65.5	75.5	59.0
Saturation Unit Weight	γ_{sat}	t/m³	1.63	1.70	1.63	1.67	1.71	1.21	1.55	1.73
Liquit Limit	LL	%	153.0	119.5	137.0	143.0	102.7	69.7	69.5	49.2
Plastic Limit	PL	%	33.3	28.8	25.9	37.0	34.5	35.6	37.8	22.7
Plasticity Index (LL-PL)	PI	%	119.7	90.7	111.1	106.0	68.2	34.1	31.7	26.5
Gravel content (>20mm)	-	%	-	-	-	-	-	-	-	-
Sand Content 2.0 ~ 0.075 mm	-	%	7.1	11.3	2.8	2.2	12.4	17.9	10.8	32.0
Silt/clay content (<0.075mm)	-	%	92.9	88.7	97.2	97.8	87.6	82.1	89.2	68.0
Unconfined Compr. Strength	q_u	kgf/cm²	0.22	0.65	0.42	0.70	0.39	0.29	0.11	0.49
Sensitivity	St		1.12	1.33	1.33	1.12	1.24	1.08	1.15	1.20
Consolidation Test	e_o	-	1.697	1.311	1.364	1.046	1.461	1.781	1.996	1.352
	Cc	-	0.44	0.35	0.50	0.24	0.25	0.33	0.52	0.30
	Cv	cm²/sec	4.89E-03	4.68E-03	6.97E-03	6.11E-03	5.52E-03	5.77E-03	6.78E-03	4.87E-03

* : Soil Symbol (Unified Soil Classification)

Table 9 SUMMARY OF LABORATORY SOIL TEST (WBC/CISADANE : 6/6)

Item	Symbol	Unit	CSD - 1			
Hole No.			CSD - 1			
Depth (m)			1.00 - 1.45	3.00 - 3.50	5.45 - 6.00	9.20 - 9.65
			CH	CH	CH	CH
Specific Gravity	G	-	2.648	2.612	2.679	2.712
Natural Water Content	Wn	%	35.0	57.2	68.8	60.7
Unit Weight, Natural State	γ_n	t/m³	1.778	1.691	1.649	1.683
Dry Unit Weight	γ_d	t/m³	1.317	1.076	0.977	1.047
Natural Void Ratio	e	-	1.010	1.428	1.742	1.590
Natural Porosity	n	%	50.2	58.8	63.5	61.4
Degree of Saturation	Sr	%	91.7	100	100	100
Saturation of Water Content	Wsat	%	38.1	57.2	68.8	60.7
Saturation Unit Weight	γ_{sat}	t/m³	1.820	1.690	1.649	1.680
Liquit Limit	LL	%	74.0	78.3	95.1	108.8
Plastic Limit	PL	%	15.0	26.1	36.4	24.6
Plasticity Index (LL-PL)	PI	%	59.0	52.2	58.7	63.2
Gravel content (>20mm)	-	%	-	-	-	-
Sand Content 2.0 ~ 0.075 mm	-	%	28.4	16.3	39.4	15.4
Silt/clay content (<0.075mm)	-	%	71.6	83.7	60.6	84.6
Unconfined Compr. Strength	q_u	kgf/cm²	0.27	0.27	0.45	0.08
Sensitivity	St		1.22	1.54	1.27	1.62
Consolidation Test	e_o	-	1.004	1.420	1.733	1.582
	Cc	-	0.14	0.35	0.55	0.49
	Cv	cm²/sec	9.68E-03	9.68E-03	6.36E-03	6.70E-03

* : Soil Symbol (Unified Soil Classification)

Table. 10 SUMMARY OF LATERAL LOAD TEST (WBC / CISADANE)

Location : Western Banjir Canal - Jakarta

No.	ITEM	SYMBOL	UNIT	BORE HOLE	WBC - 5			WBC - 11		
				DEPTH (m)	5.0	10.0	15.0	5.0	10.0	15.0
1.	Pressure at Rest	P_o	kg/cm^2		0.18	0.38	0.50	0.00	0.50	0.40
2.	Yield Stress	P_y	kg/cm^2		0.50	2.20	8.17	0.43	17.9	15.9
3.	Failure Stress	P_l	kg/cm^2		-	-	-	1.46	-	-
4.	Subgrade Reaction Coefficient(K-Value)	K_m	kg/cm^3		0.71	6.16	16.40	2.54	28.60	42.63
5.	Elasticity Coefficient (Young's Modulus)	E_m	kg/cm^2		3.77	35.27	82.45	11.92	143.10	214.70
6.	Out Radius$(\frac{r1+r2}{2})$	R_m	cm		4.092	4.402	3.866	3.603	3.849	3.874
	(N - Value)	(N)			(1)	(35-42)	(>46)	(6)	(40-46)	(40-42)

Note : $K_m = \frac{\Delta P}{\Delta \gamma}$ (slope of linear portion of P-r curve), $E_m = (1+v').R_m.K_m$, $v' = 0.3$ (Poisson's ratio).

Figure 11 SUMMARY OF PERMEABILITY TEST RESULT
(WESTERN BANJIR CANAL AND CISADANE RIVER)

DEPTH	PERMEABILITY COEFFICIENT: k (cm / sec)									
(m)	WBC-1	WBC-2	WBC-3	WBC-4	WBC-5	WBC-6	WBC-7	WBC-8	WBC-9	WBC-10
5	1.01E-06	1.62E-06	9.69E-07	1.53E-06	4.60E-06	4.77E-07	1.09E-06	7.16E-07	7.52E-07	4.64E-06
10	1.25E-05	1.58E-06	9.11E-07	1.62E-06	1.77E-06	7.57E-06	1.07E-06	2.42E-05	7.94E-07	6.55E-05
15	1.65E-05	2.07E-06	9.13E-07	1.28E-05	1.24E-06	1.84E-05	2.99E-06	2.80E-05	7.34E-06	1.39E-05
20	2.02E-06	2.44E-06	5.48E-07	1.78E-05	1.48E-06	2.86E-05	7.82E-06	2.96E-05	1.82E-06	3.15E-06
25	-	-	-	3.10E-05	-	-	-	-	-	-

DEPTH	PERMEABILITY COEFFICIENT: k (cm / sec)					
(m)	WBC-11	WBC-12	WBC-13	WBC-14	WBC-15	CSD-1
5	1.38E-05	7.34E-05	7.91E-05	4.03E-06	1.26E-05	9.39E-08
10	6.75E-06	2.45E-05	3.15E-05	1.02E-05	1.26E-05	1.43E-07
15	5.06E-06	1.52E-05	6.75E-06	8.98E-06	2.93E-05	5.84E-07
20	2.08E-05	6.18E-07	7.34E-06	8.66E-07	1.45E-05	1.73E-06
25	-	-	-	-	3.78E-05	2.03E-04
30	-	-	-	-	-	5.56E-07

Remarks : Falling head test

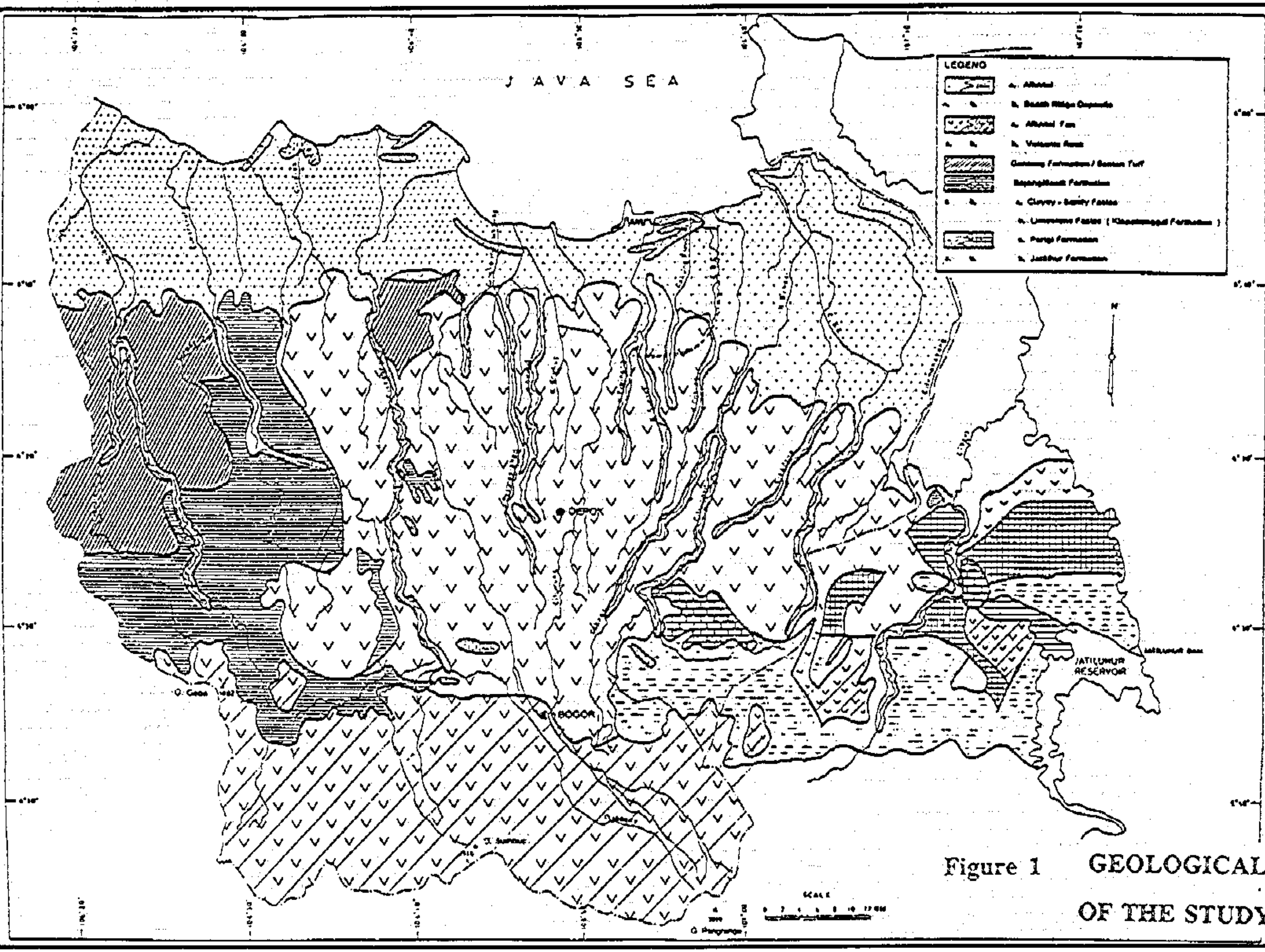

Figure 1 GEOLOGICAL MAP OF THE STUDY AREA

Scale (10^6 TH)	Age		Symbol	Formation & Lithology Unit	Lithology	Sedimentary Environment
	Quaternary	Holocene	Qa	Alluvial	Pebbles, Gravel, Sands, Silt, Mud and Plant remains.	Fluviatil
	Quaternary	Holocene		Errosion Beds / Beach Ridges Deposits	Coarse Sand, Well Sorted, with mollusc shells.	
	Quaternary	Pleistocene	Qav	Alluvial Fan	Bedded Fine tuff, Conglometatic tuff, Interbedded with Sandy tuff and Pumice tuff.	Terrestic
	Quaternary	Pleistocene	Qv	Younger Volcanic Rock	Breccia, Lahar, Pillow lava, Tuffaceous breccia interbedded with Fine tuff.	Terrestic
	Quaternary	Pleistocene	Qvas	Sudamanik Andesites	Hornblende, pyroxene andesites, phorphyritic	
	Tertiary	Pliocene	Qpvb	Banten tuff	Tuff (glass, lithic, crystal) Pumice tuff, Pumiceous breccia and Tuffaceous sandstone	Terrestrial to Tidal
	Tertiary	Pliocene	Tpss	Serpong Formation	Alternating Conglomerate, Sandstone, Siltstone, Claystone with Plant material, Pumice conglomerate, Pumice tuff.	Fluviatile (Braided old river)
				UNCONFORMITY		
5	Tertiary	Miocene – Late	Tpg	Genteng Formation	Pumice tuff, Tuffaceous, sandstone, Andesite breccia Conglomerate, Pebble sandstone with in intercalation of Tuffaceous claystone, rich in silicified wood.	Litoral to Terrestic
				UNCONFORMITY		
10 – 15	Tertiary	Miocene – Middle	ATmdb	Dago Besalt	Intrudes the Bojongmanik, Klapanunggal and Jatiluhur Formation.	
	Tertiary	Miocene – Early	Tmb	Bojong manik Formation (Western Part)	Alternation of Sandstone and Sandy clay with intercalation of Limestone in the lower part and Tuffaceous sandstone and Tuff, In the upper post, in some places Lignite, intecalation were found.	Shallow neritic to Brackish water
	Tertiary	Miocene – Early	Tmk	Klapanunggal Formation (Eastern Part)	Reef Limestone.	
20	Tertiary	Miocene – Early	Tmj	Jatiluhur Formation	Marl and Claystone with a Calcareous sandstone intercalation.	
				UNCONFORMITY		
	Tertiary	Miocene – Early	Tmrs	Rengganis Formation	Fine course Sandstone, Conglomerate and Claystone.	Marine
	Tertiary	Oligocene				

Figure 2 LOCAL STRATIGRAPHIC LOG

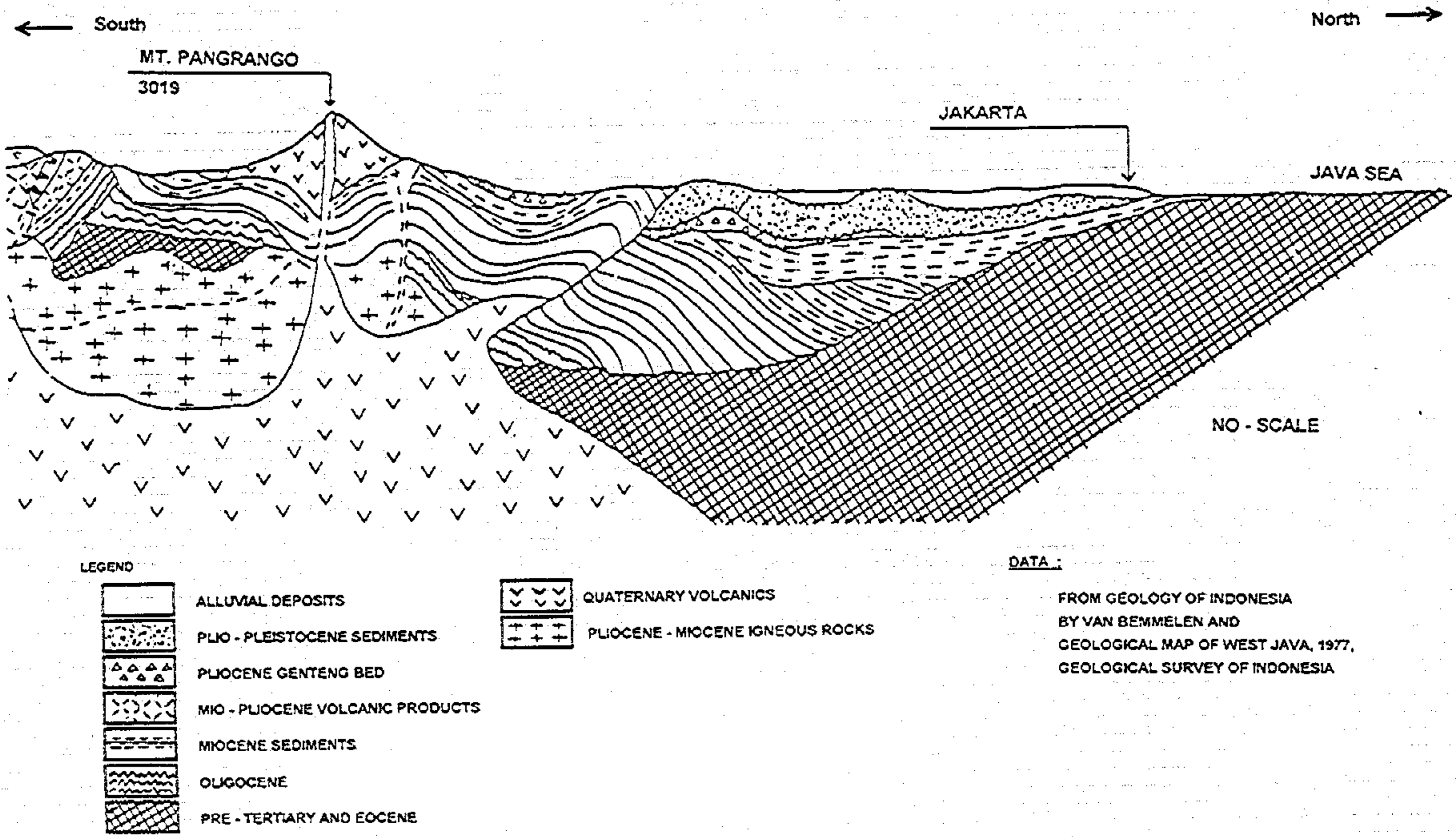

Figure 3 GENERALIZED GEOLOGICAL CROSS-SECTION FROM SOUTH TO NORTH IN THE STUDY AREA

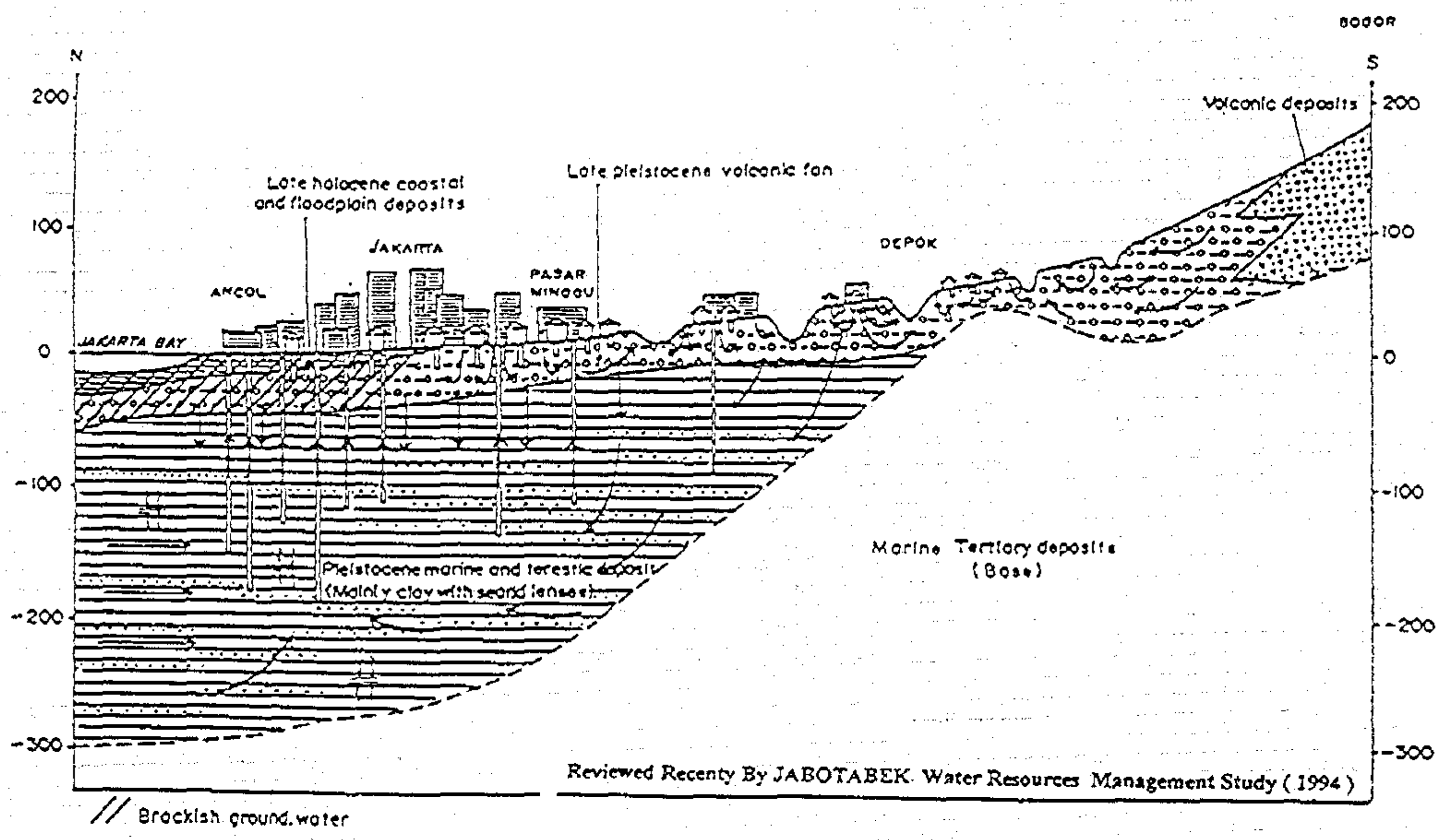

Figure 4 HYDRO-GEOLOGICAL MAP AND SCHEMATIZED NORTH-SOUTH CROSS-SECTION

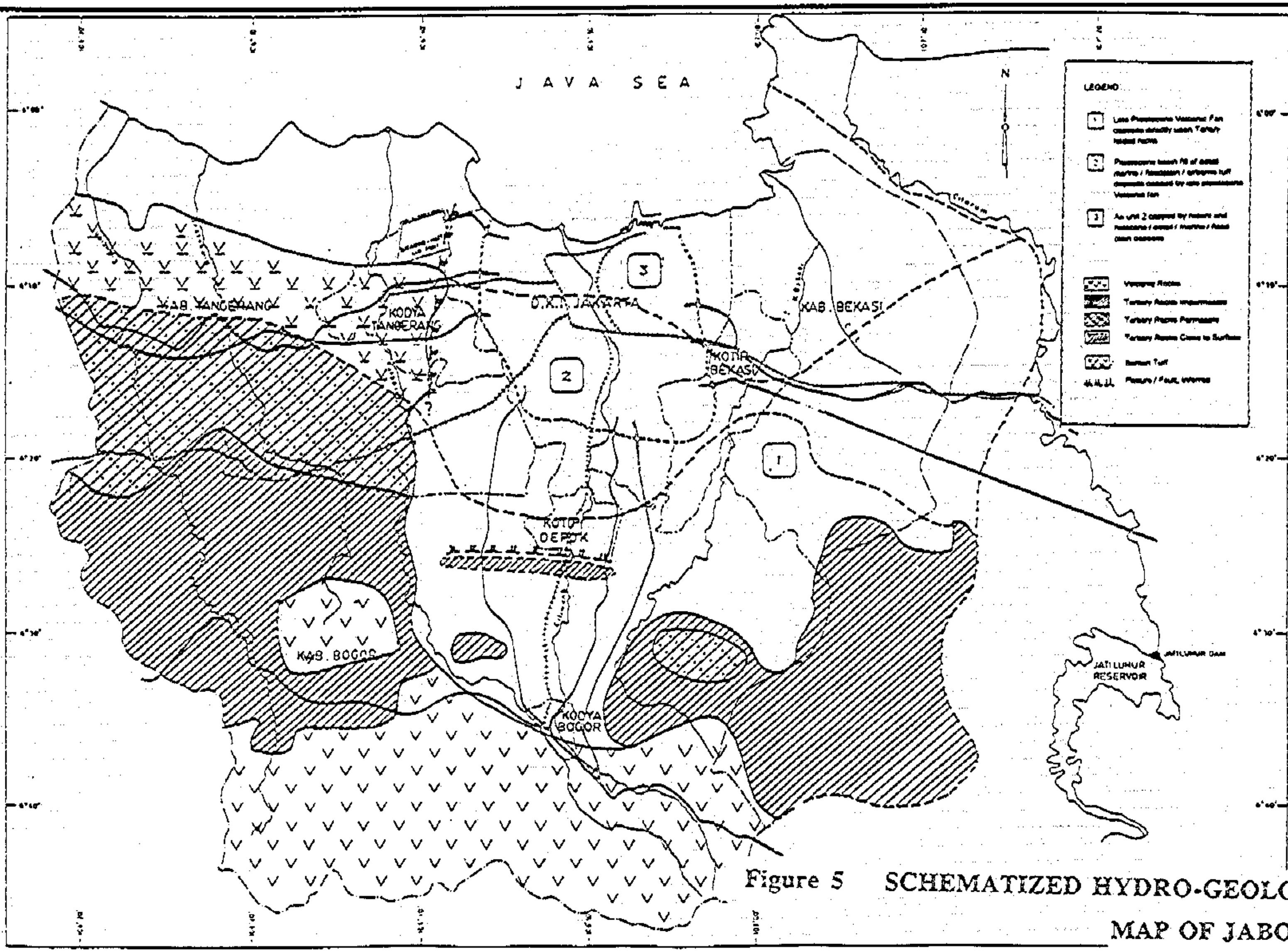

Figure 5 SCHEMATIZED HYDRO-GEOLOGICAL MAP OF JABOTABEK

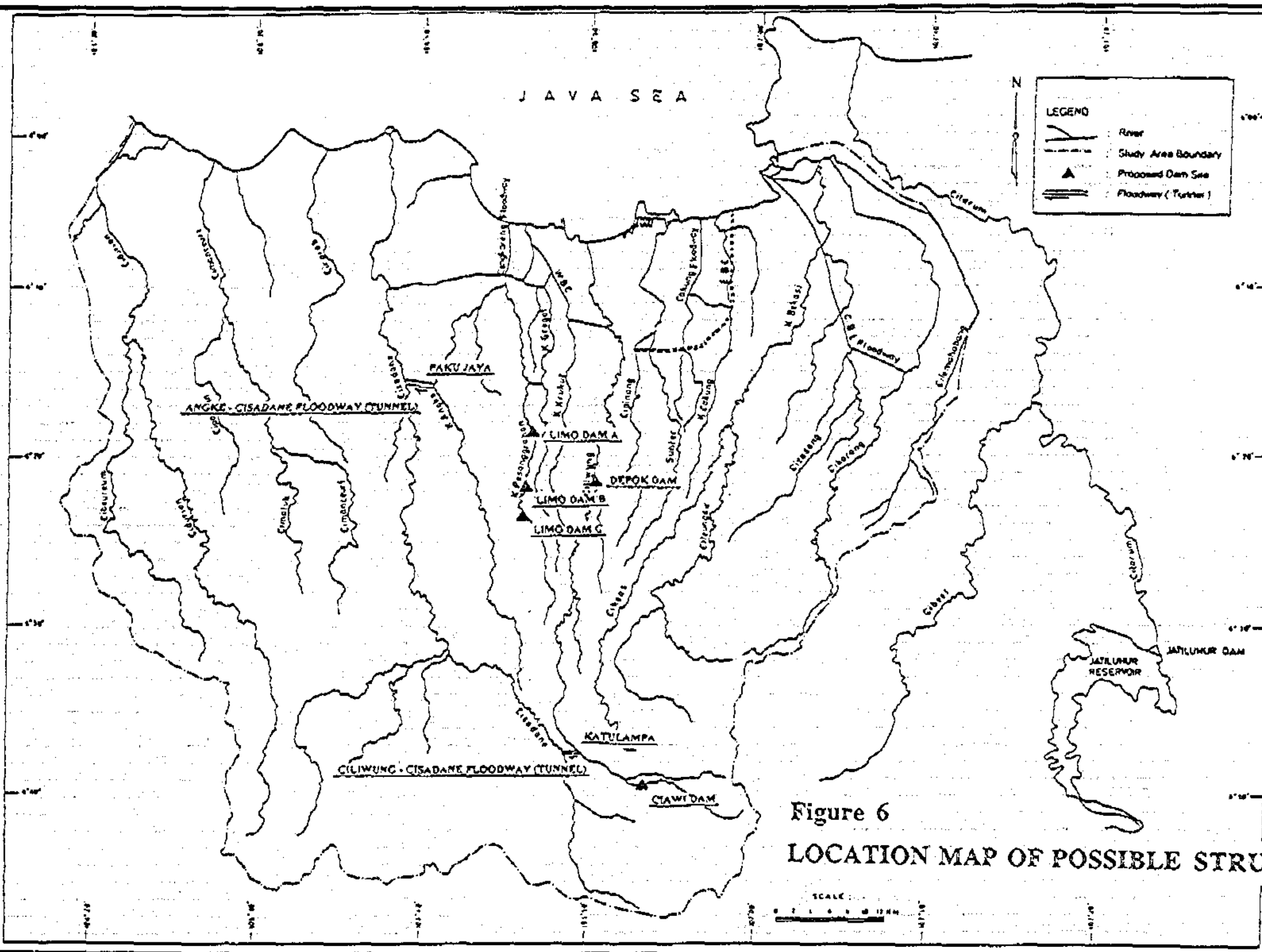

Figure 6

LOCATION MAP OF POSSIBLE STRUCTURES

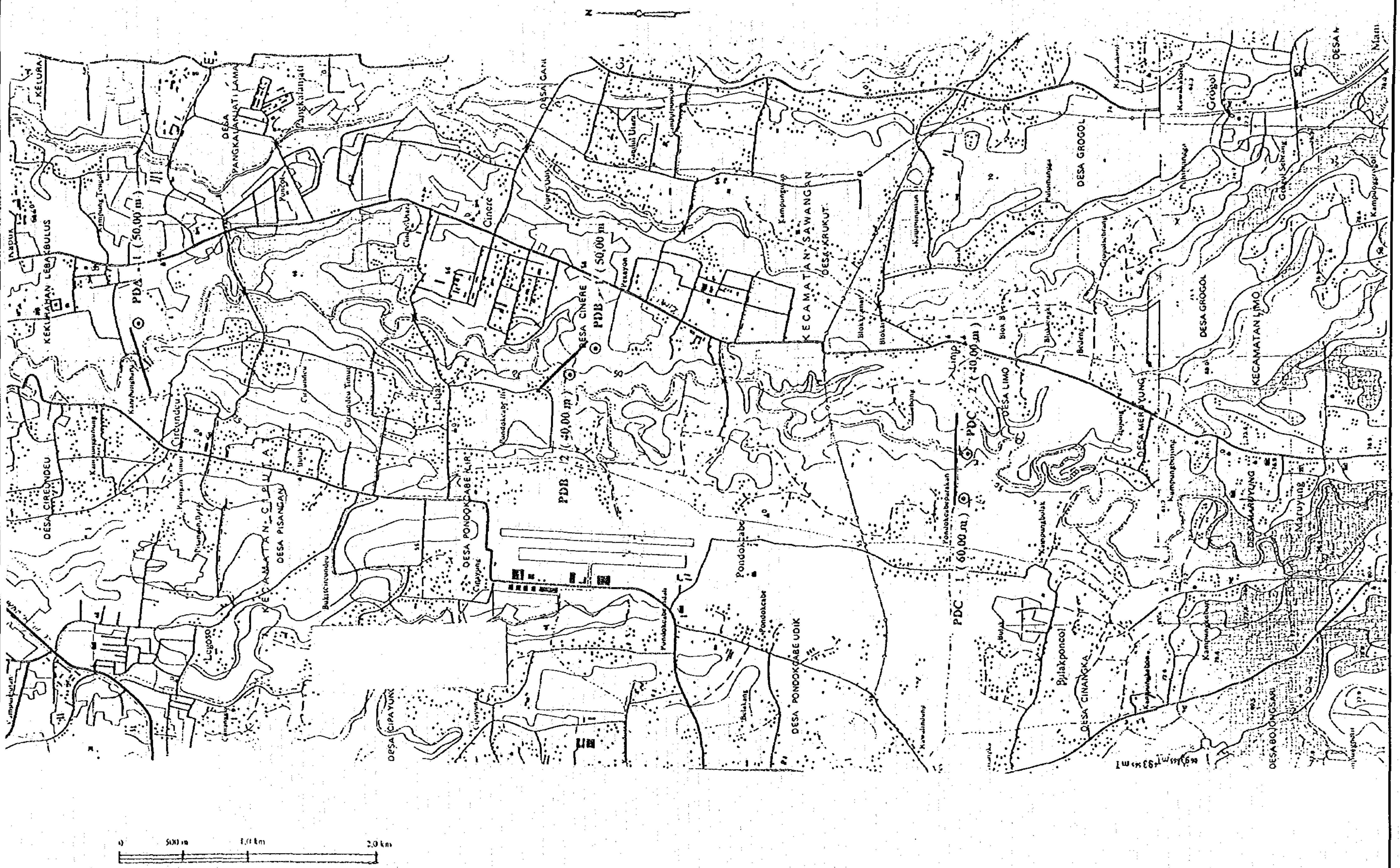

Figure 7 LOCATION MAP OF LIMO DAMS AND DRILLING WORKS

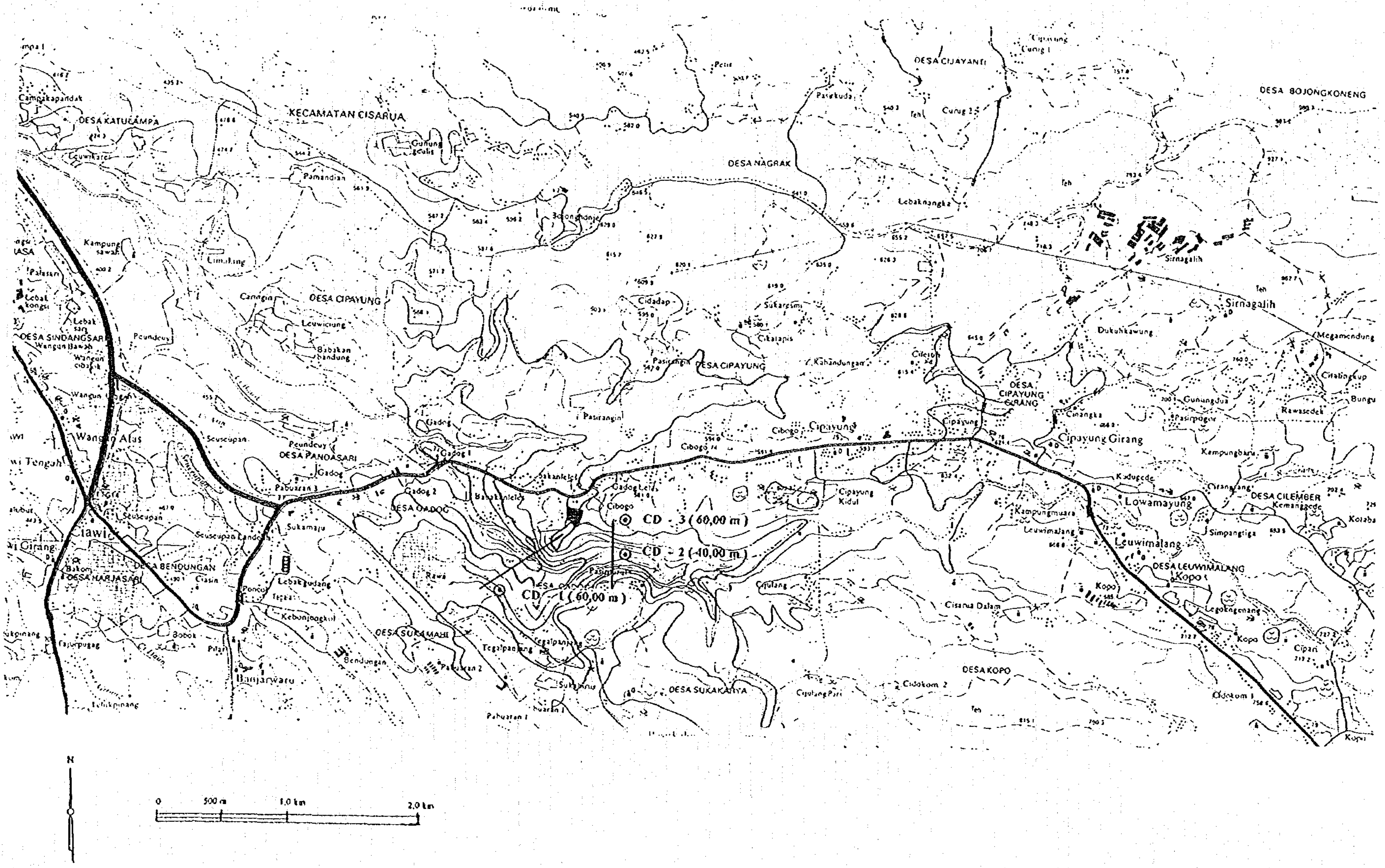

Figure 8 LOCATION MAP OF CIAWI DAM AND DRILLING WORKS

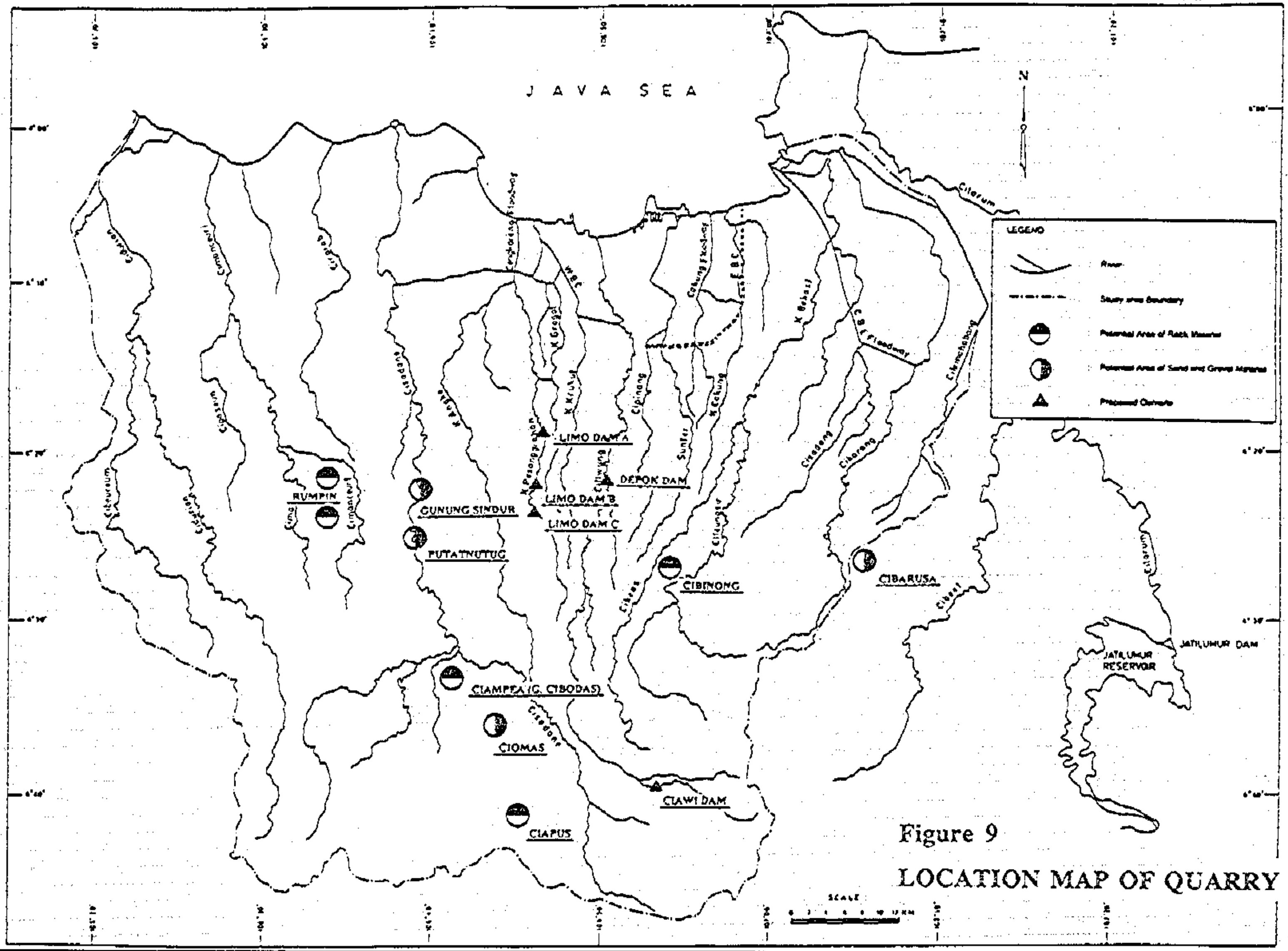

Figure 9

LOCATION MAP OF QUARRY SITES

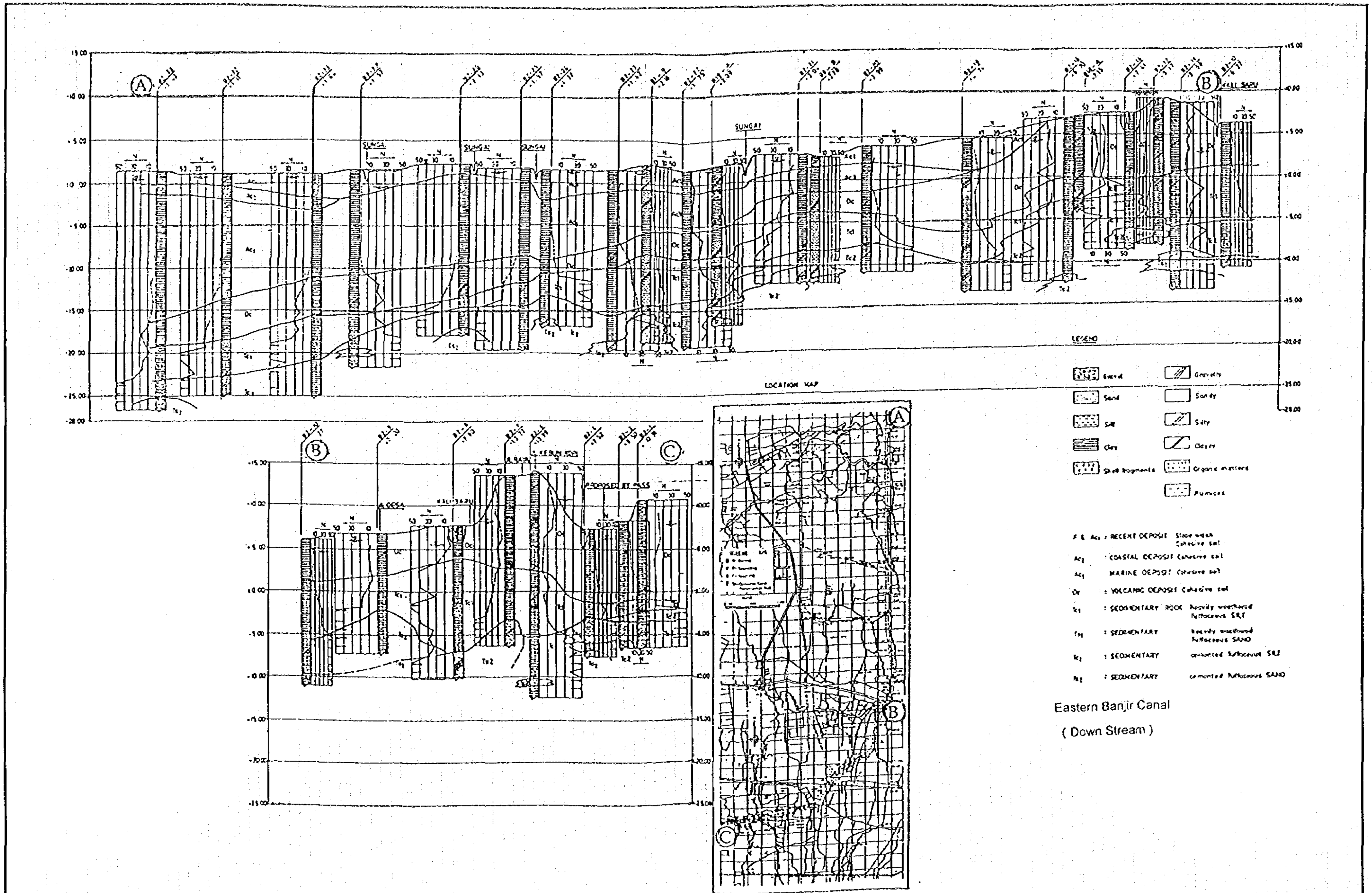

Figure 10 TYPICAL GEOLOGICAL SECTION

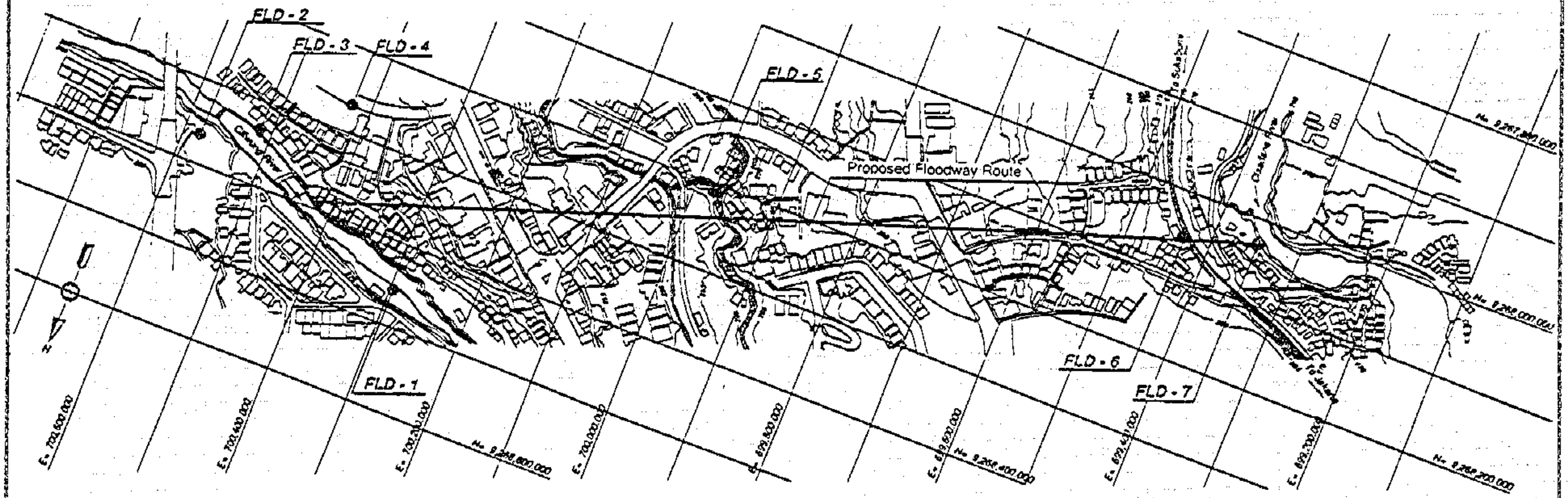

Figure 11 LOCATION OF DRILLING (CILIWUNG FLOODWAY)

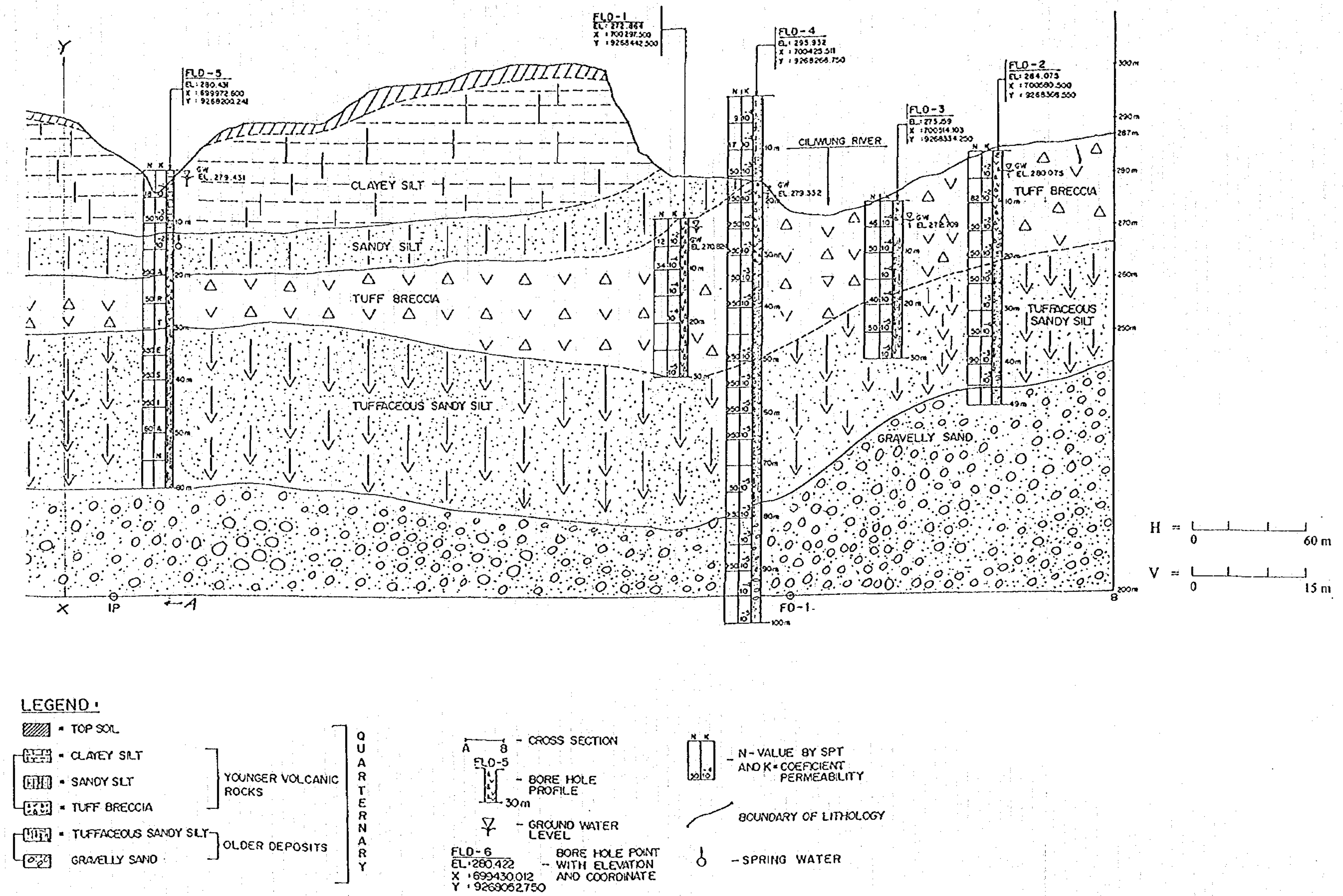

Figure 12 GEOLOGICAL PROFILES (FLD: CILIWUNG FLOODWAY : 1 / 4)

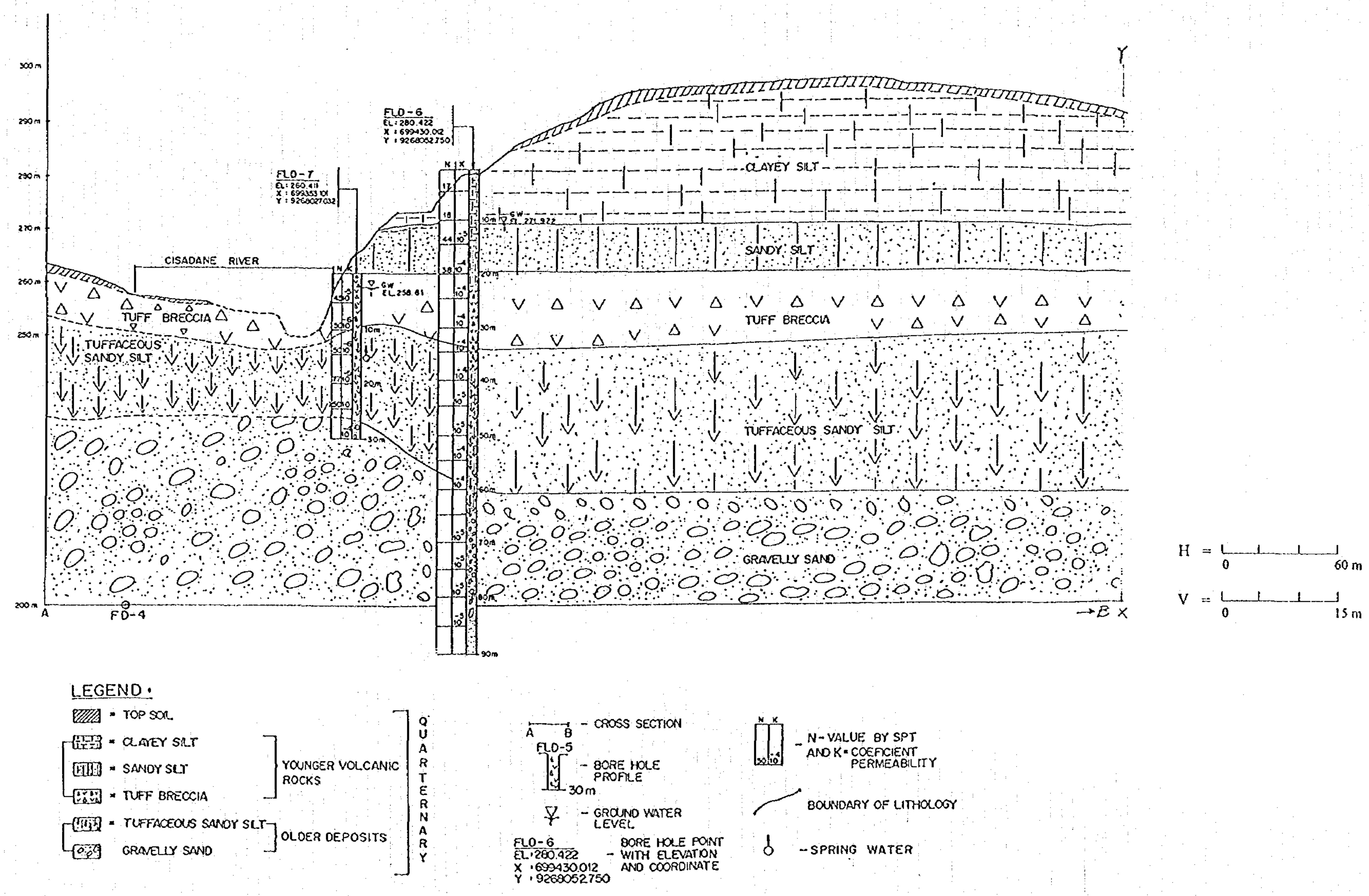

Figure 12 GEOLOGICAL PROFILES (FLD: CILIWUNG FLOODWAY : 2 / 4)

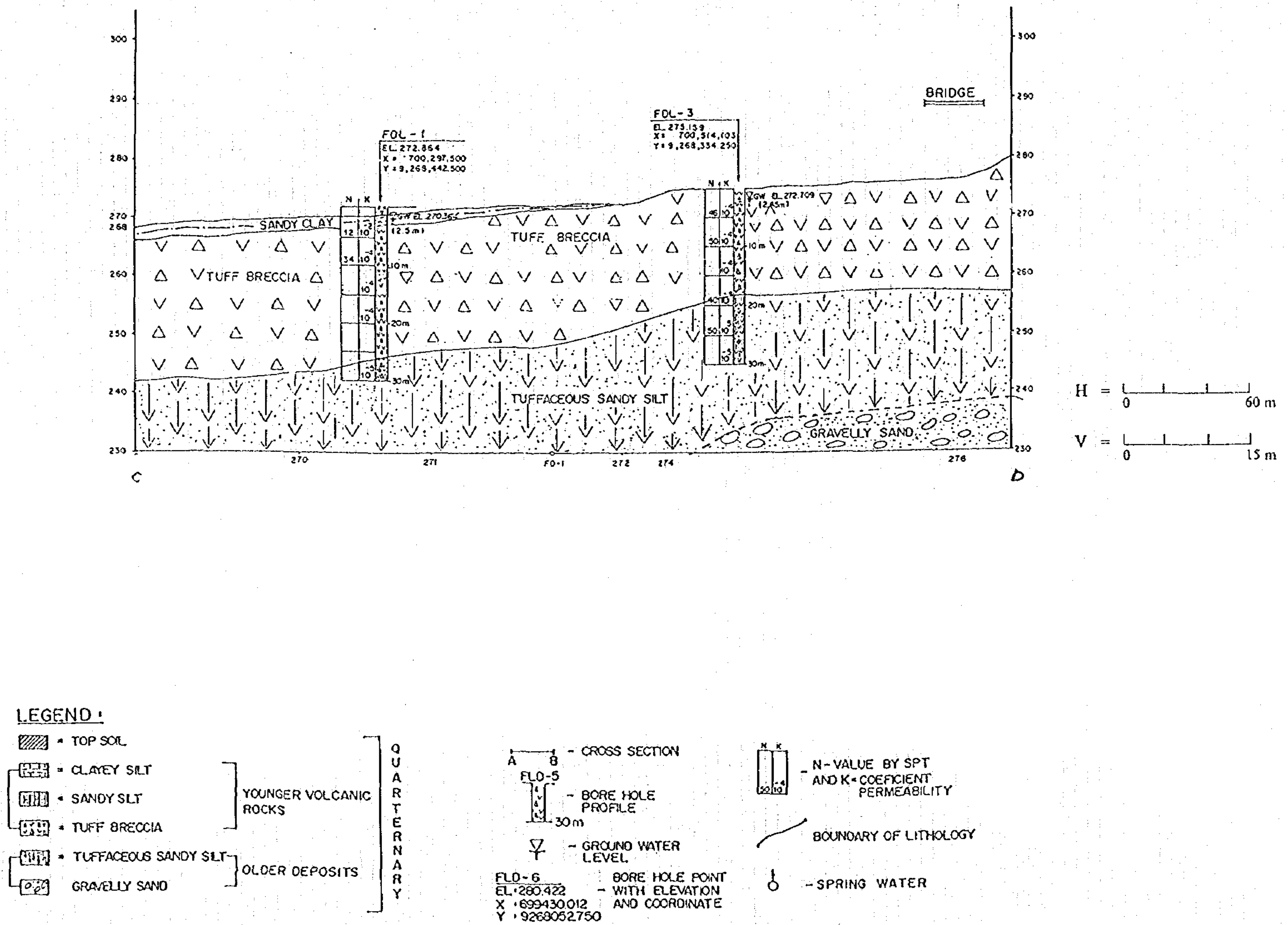

Figure 12 GEOLOGICAL PROFILES (FLD: CILIWUNG FLOODWAY : 3 / 4)

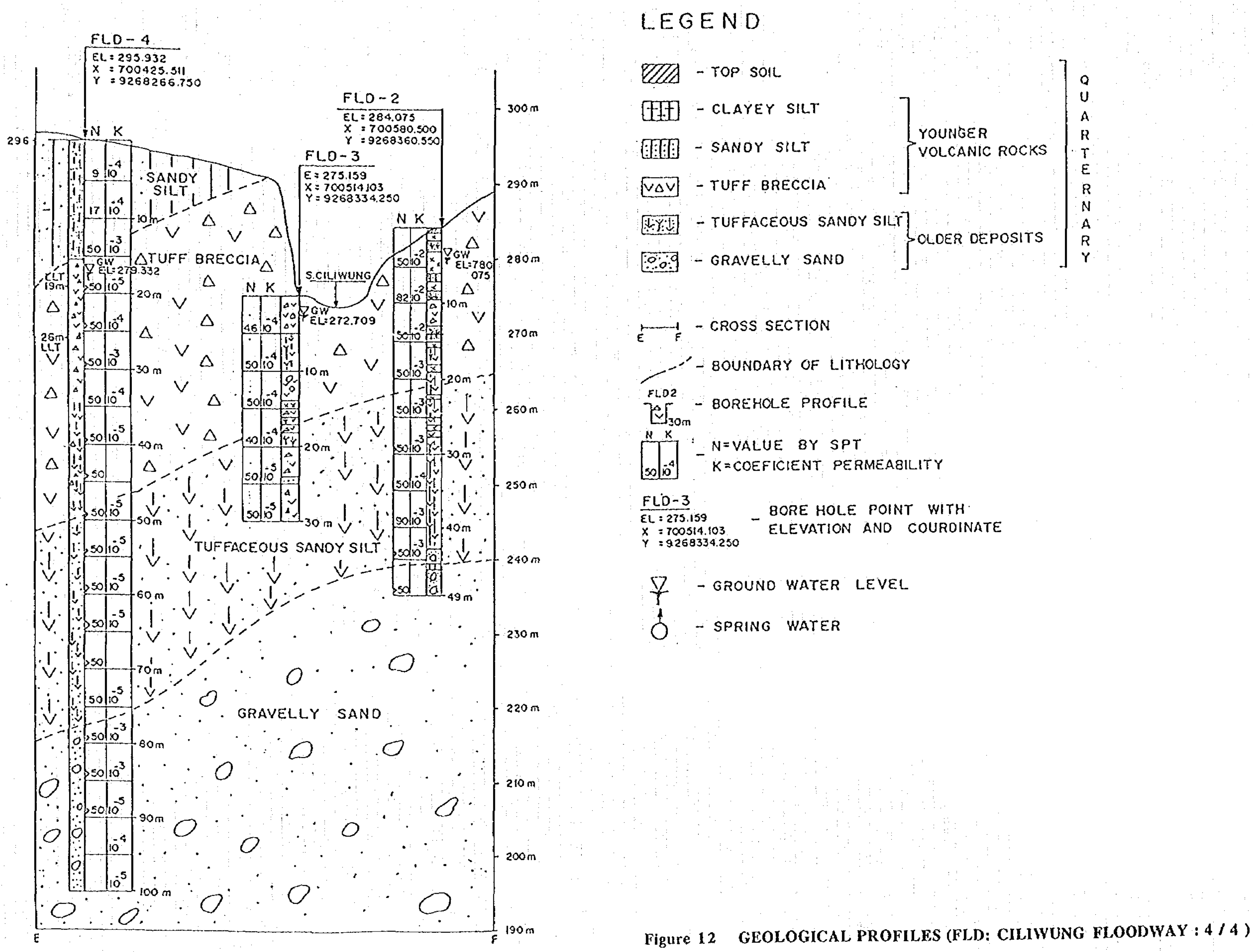

Figure 12 GEOLOGICAL PROFILES (FLD: CILIWUNG FLOODWAY : 4 / 4)

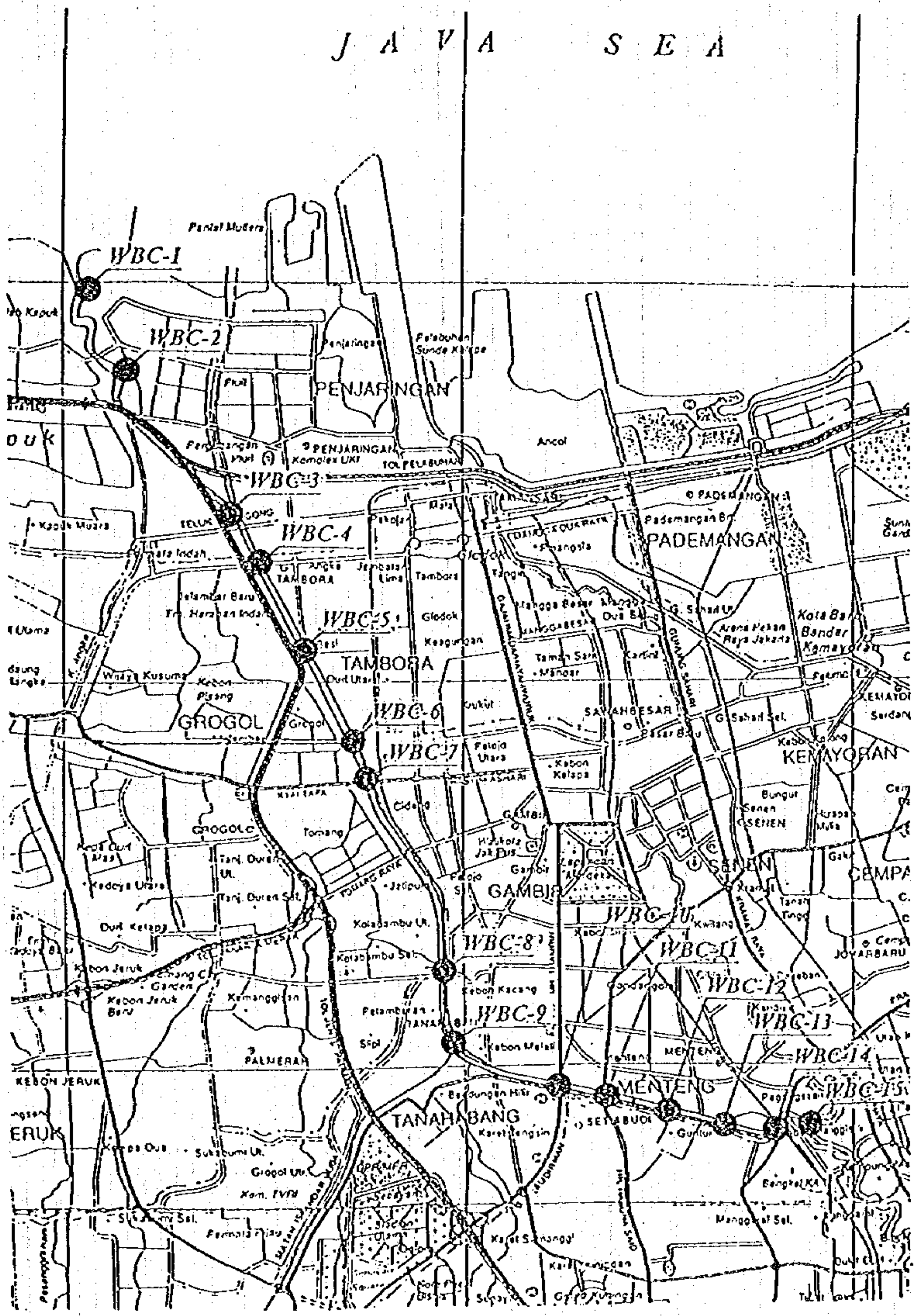

Figure 13 LOCATION OF DRILLING (1 / 2)
(WBC: WESTERN BANJIR CANAL)

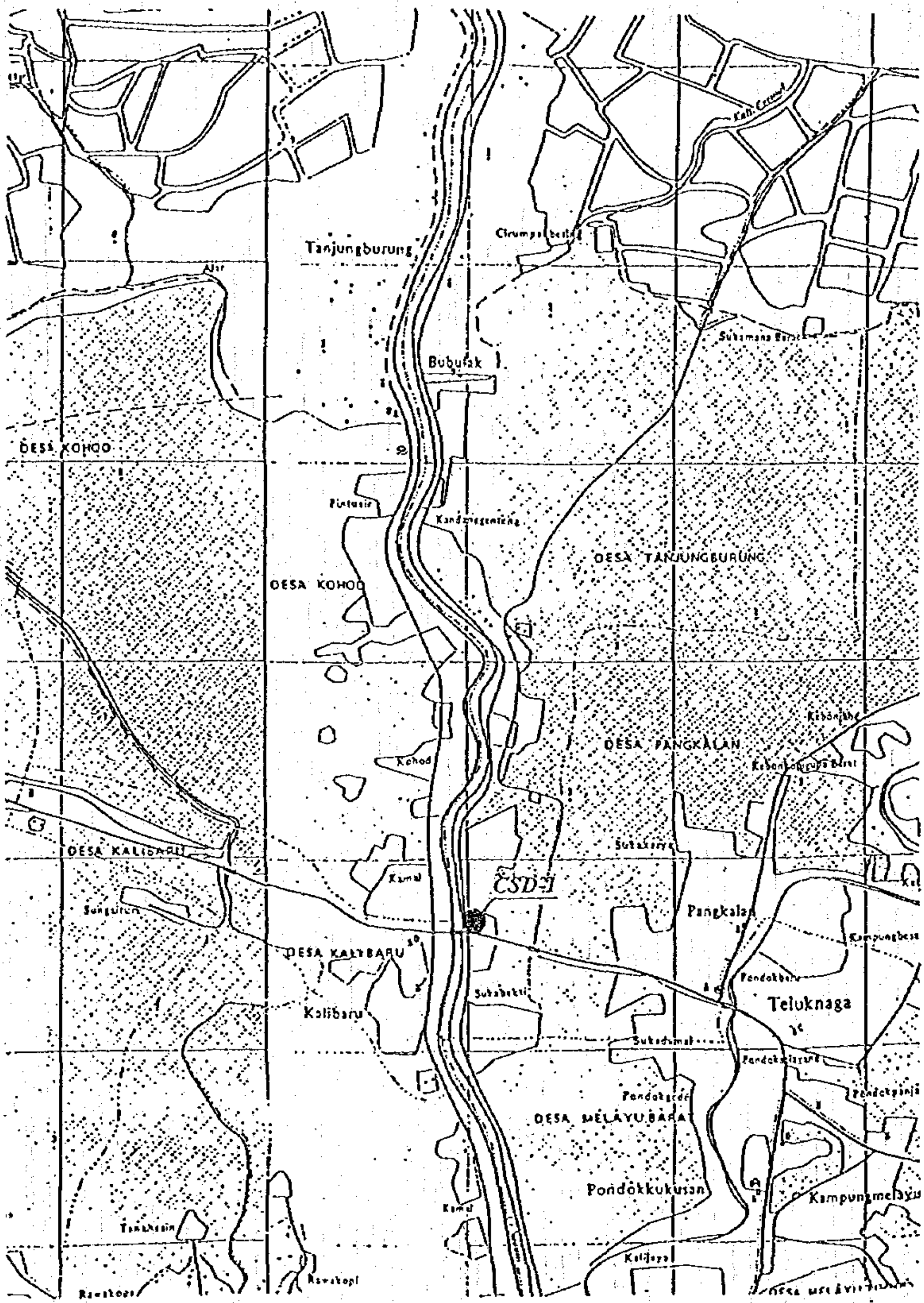

Figure 13 LOCATION OF DRILLING (2 / 2)
(CSD: CISADANE RIVER)

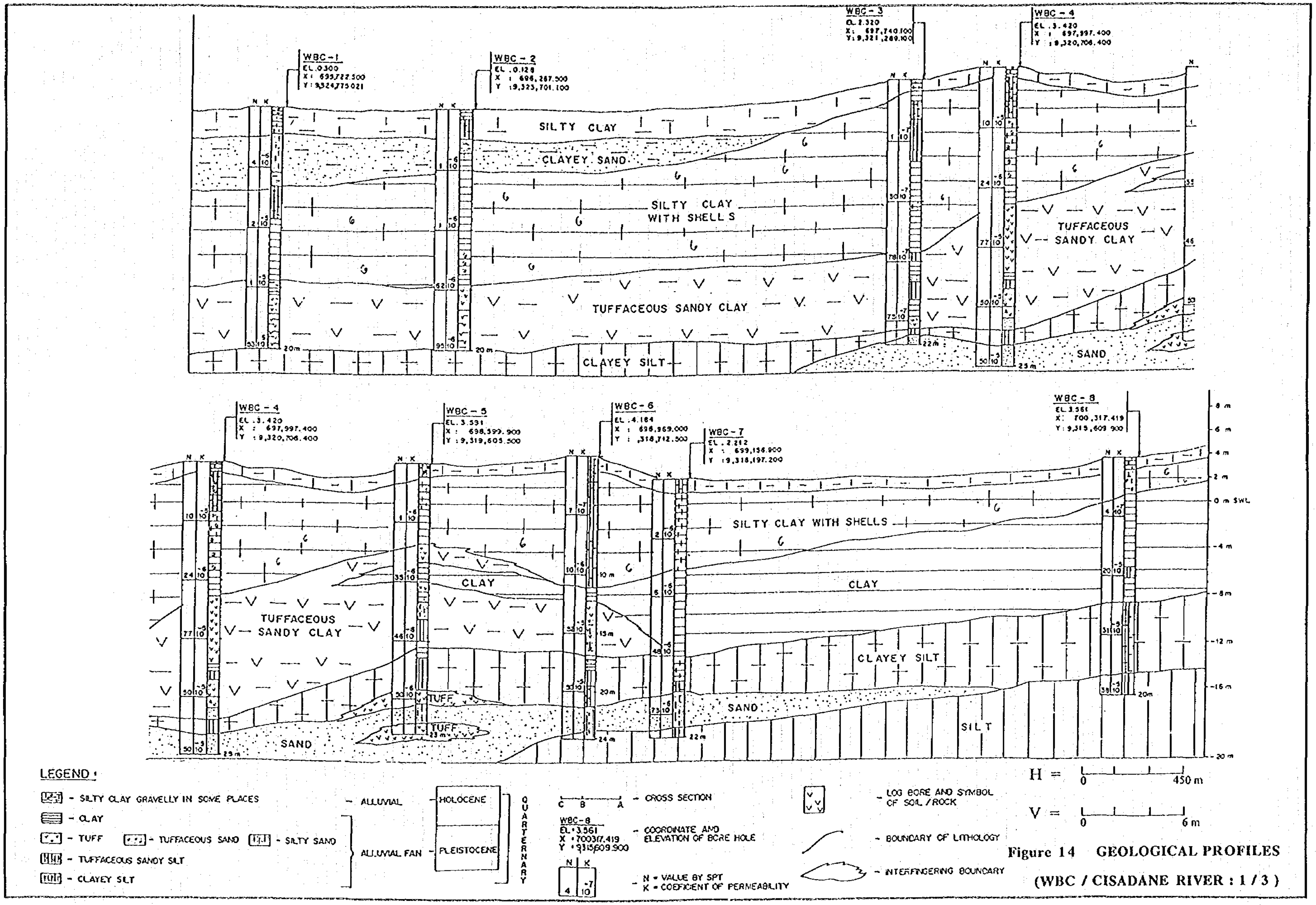

Figure 14 GEOLOGICAL PROFILES

(WBC / CISADANE RIVER : 1 / 3)

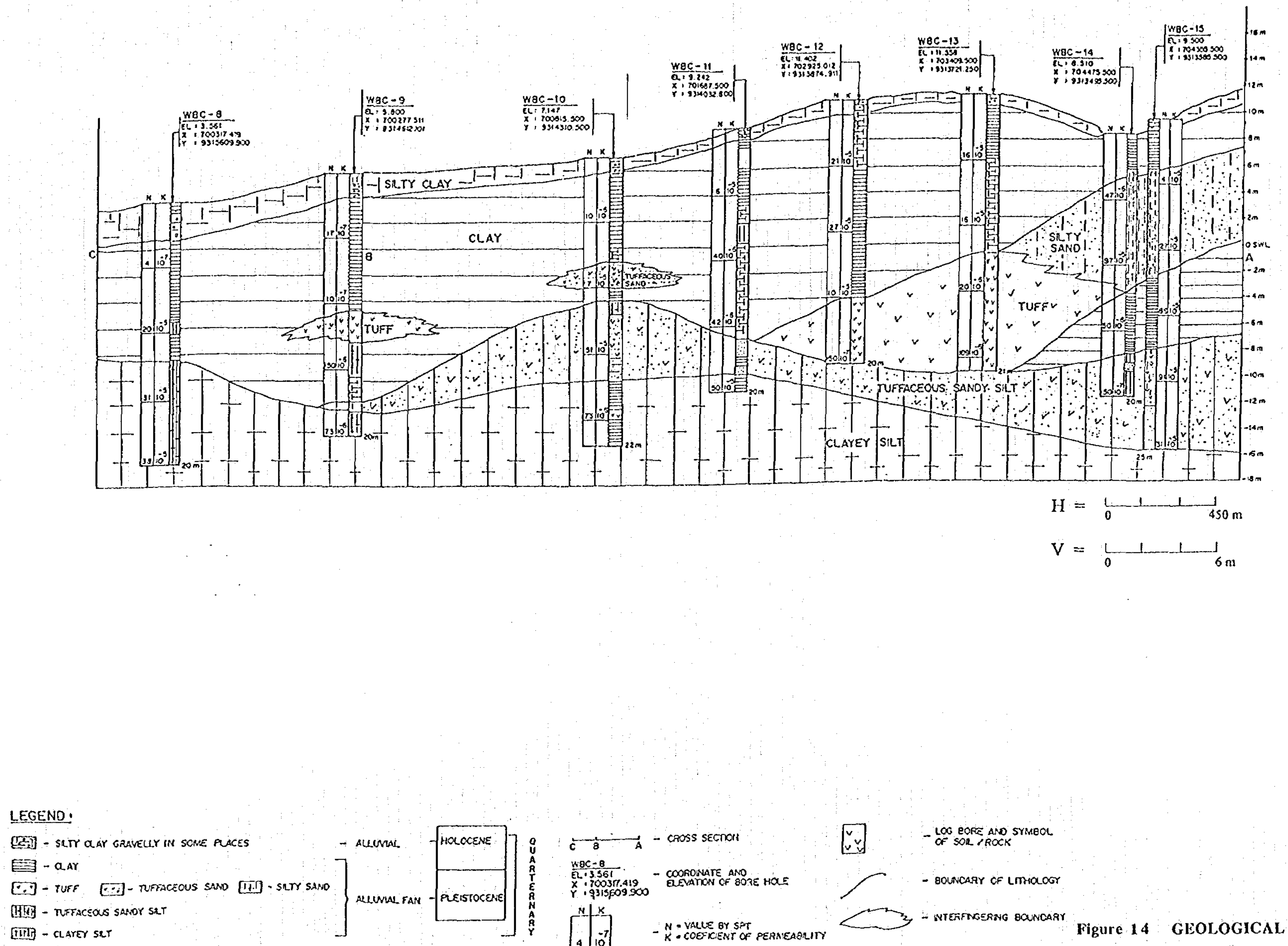

Figure 14 GEOLOGICAL PROFILES
(WBC / CISADANE RIVER : 2 / 3)

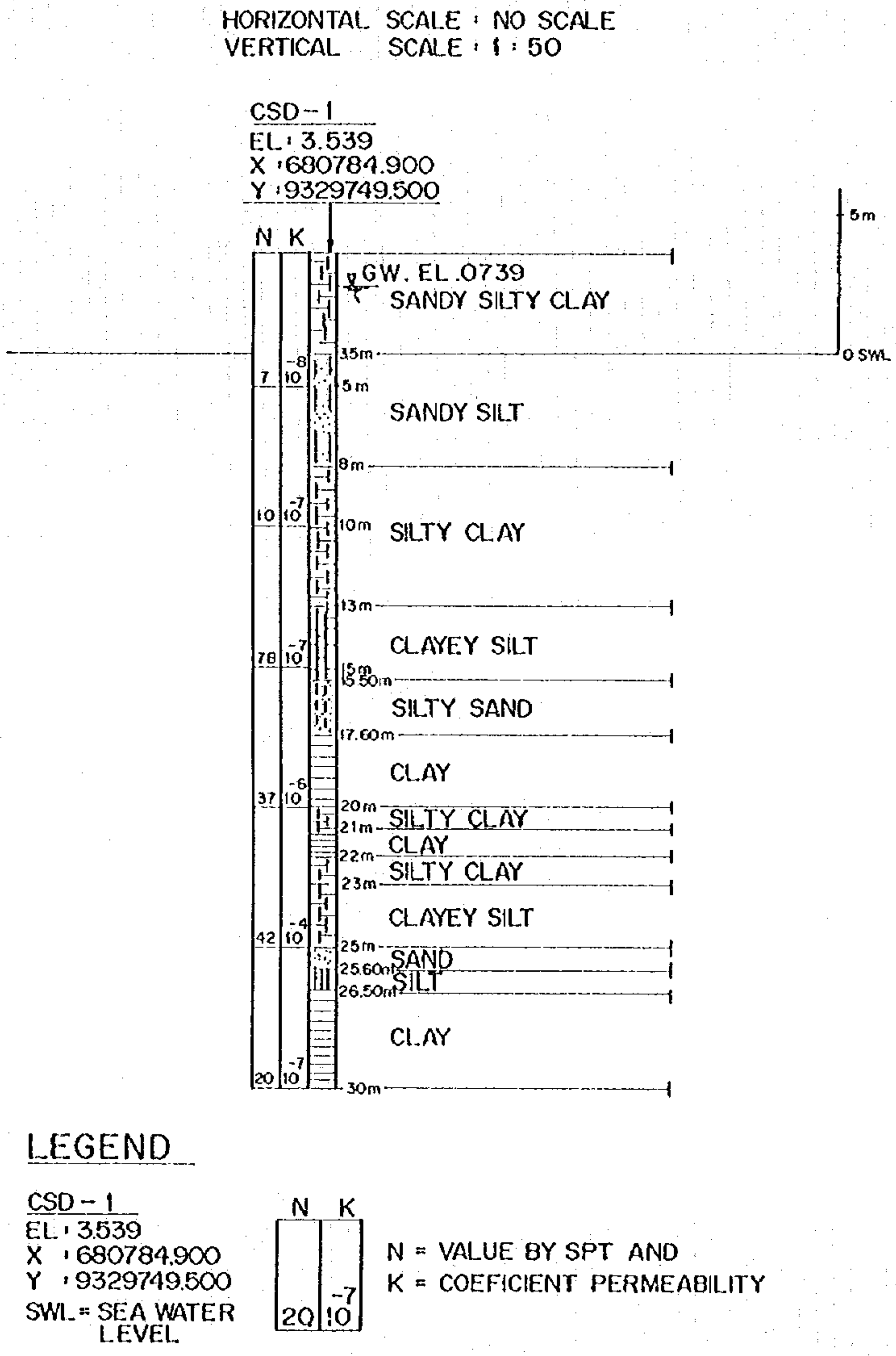

Figure 14 GEOLOGICAL PROFILES (WBC / CISADANE RIVER : 3 / 3)

ANNEX 3

RIVER SURVEY

THE STUDY
ON
COMPREHENSIVE RIVER WATER MANAGEMENT PLAN
IN
JABOTABEK

ANNEX 3 : RIVER SURVEY

Table of Contents

List of Tables

List of Figures

1 GENERAL

This ANNEX 3 (River Survey) compiles the outlines of survey works executed in the Master Plan and Feasibility Studies. All drawings are compiled in attached Data Book.

The contents of this Annex are as follows:

- Chapter 2 describes the outline of river survey conducted in the Master Plan stage; and
- Chapter 3 describes the outline of river and sounding surveys conducted in the Feasibility Study stage.

2 MASTER PLAN STAGE

2.1 General

River profile and cross-sectional survey have been carried out for the objective rivers in the Study Area. The coverage of the survey works for each river has been determined based on the overall viewpoint on flood control in the Study Area. Major existing ponds (Situ-situ) are included in the scope of survey from the viewpoint of comprehensive flood control in the Study Area.

The objective rivers and the work quantities of the survey are shown in Table 1. The objective Situ-situ are shown in Table 2. The locations of the objective rivers and Situ-situ are shown in Figure 1.

The survey works were conducted by a local contractor under the supervision of the Study Team in the period from July to October 1995.

2.2 Method

The metric system is used as the unit. National coordinate datum (ID74) is referred to for the horizontal location. The elevation is measured as the elevation above the mean sea level (Titik Tinggi Geodesi = TTG). Since the practice of elevation expression in Jakarta area is by the elevation above the datum of PP or NWP or the mean sea level (TTG) depending on the project.

Basically the cross sectional profile of the river has been surveyed based on each cross section post and the coordinates and elevation of each cross section post are measured by using GPS (Global Positioning System). The locations and elevations of existing 15 ponds (Situ-situ) have been measured by using GPS.

2.3 Quantity of Works

Quantity of works are as shown below:

Work Item	Unit	Quantity
Monumentation of cross-section posts	points	1752
Control point survey by GPS	points	1752
Cross-sectional survey	sections	876
Longitudinal profile	km	802
Cross-sectional profile	sections	876

2.4 Result

Drawings of cross sections of rivers are prepared with the vertical scale of 1:100 and horizontal scale of 1:500. Locations of cross section are prepared on the topographic map with scale of 1:2,5000 and 1:50,000 depending on the availability of the map.

Final results are as follows:

- Location map of cross-section with a scale of 1:50,000 :1set
- Cross-section with a scale of V=1:100, H=1:500 :1set
- Longitudinal profile with a scale of V=1:100, H=1:50,000 :1set

3 FEASIBILITY STUDY STAGE

3.1 River Survey

3.1.1 Outline

River profile and cross-sectional survey has been carried out for the objective rivers of priority projects for the feasibility study.

The objective rivers are the Western Banjir Canal in the whole reaches, the Cisadane River in the reaches downstream of Pasar Baru Barrage located in Tangerang city, and the Ciliwung and Cisadane Rivers in the reaches near the inlet and outlet facilities of the proposed Ciliwung Floodway.

The general survey quantities are as follows:

Name	Number of cross section	Interval (m)	Length (km)	Width (m)
Cisadane River	42	500	21.1	350
Western Banjir Canal	87	250	17.5	250
Ciliwung Floodway	32	50	1.4	300
Total	161		40.0	

The survey works were conducted by a local contractor under the supervision of the Study Team in the period from June to August 1996.

The location of objective rivers are shown in Figure 2.

3.1.2 Method

The metric system is used as the unit.

National coordinates system Bessel UTM Zone 48 is referred to for the horizontal location. The mean sea level (TTG) is referred to for the elevation.

Cross-sectional profile of the river is surveyed based on each cross section post. Each cross section elevation is surveyed by direct leveling method using automatic leveling instrument and those profiles are drawn at a scale of H=1:500, V=1:100.

Fifteen bridges of Western Banjir Canal, two barrages of Western Banjir Canal and Cisadane River are surveyed by using total station system method and profiles of bridges, barrages are drawn at a scale of H=1:500, V=1:100.

Locations of cross-sections are shown on the topographic map with a scale of 1:5,000.

3.1.3 Result

Drawings as survey result are as follows:

(1) Location map of cross-sections with a scale of 1:5,000.
(2) Cross sectional profiles with a scale of V=1:100, H=1:500.
(3) Longitudinal profiles with a scale of V=1:100, H=1:5,000.
(4) Profiles of bridges and barrages with a scale of V=1:100, H=1:500.

3.2 Sounding Survey

3.2.1 Outline

Sounding survey has been carried out for the objective offshore of rivers of priority projects for the feasibility study.

The objective offshore are 2 km offshore of the Western Banjir Canal and 1 km offshore of the Cisadane River. The objective area of sounding survey is 1.7 km^2 in total as shown in Figure 2.

The sounding survey works were conducted by a local contractor under the supervision of the Study Team in the period from June to August 1996.

3.2.2 Method

The metric system is used as the unit. National coordinates system Bessel UTM Zone 48 is referred to for the horizontal location. The mean sea level (TTG) is referred to for the elevation.

The elevation of the sea bed is measured by using echo-sounder and cross-sectional profiles are drawn at a scale of H=1:500, V=1:100.

3.2.3 Result

Final results are cross-sectional profiles of sea bed.

Table 1 WORK QUANTITY OF RIVER SURVEY WORKS

Name of river system	Length (km)	Survey interval (km)	Number of section	Survey width (meters)
Cidurian River				
- Main	58	1.0	59	250
- Cibeureum	26	1.0	26	
- others (2nos)	4	1.0	4	
Cimanceuri River				
- Main	50	1.0	51	250
-Cipaseun	23	1.0	23	
- Cimatuk	14	1.0	14	
- others (2nos)	4	1.0	4	
Cirarab River				
- Main	40	1.0	41	250
- others (2nos)	6	1.0	6	
Cisadane River				
- Main (lower)	61	1.0	68	250
- Main (upper)	42	2.0	27	
- others (2nos)	6	1.0	7	
- Mookervaart Canal	15	1.0	15	
Cengkareng Floodway				
- Cengkareng Floodway	7	0.5	15	100
- K. Angke (lower)	48	1.0	45	
- K. Angke (upper)	-	-	-	
- K. Pasaanggrahan (lower)	28	0.7	40	
- K. Pasaanggrahan (lower)	18	2.0	9	
Western Banjir Canal				
- K. Grogol	19	0.5	39	100
- Banjir Canal	17	0.5	35	
- K. Krukut	14	0.5	29	
- Ciliwung (lower)	23	0.9	25	
- Ciliwung (upper)	36	2.0	18	
Eastern Banjir Canal				
- K. Cipinang	6	0.5	13	100
- K. Sunter	6	0.5	13	
- K. Buaran	6	0.5	13	
- K. Cakung	8	0.5	17	
Cikarang-Bekasi-Laut				
Floodway	28	1.0	29	250
- CBL	31	1.0	32	
- K. Bekasi	8	1.0	8	
- Cileungsir	8	1.0	8	
- Cikeas	25	1.0	26	
- Cisadang	40	1.0-1.2	37	
- Cikarang (lower)	27	1.0	28	
- Cikarang (upper)	50	1.0	50	
- Cilemahabang				
Total			876	

Table 2 EXISTING PONDS (SITU-SITU) SURVEYED

No.	Location and Name of situ-situ		Area (Ha)
1	TANGERANG	Patrasana	350.00
2		Garugak	180.00
3		Pengondokan	15.00
4		Rancailat	67.98
5		Kelapa Dua	37.56
6		Cihuni	32.34
7		Gabus	9.72
8		Bulakan	30.00
9		Setingin	26.41
10		Cilongok	23.08
11	BOGOR	Cikaret	29.50
12		Gunung Putri	18.75
13		Kemuning	12.65
14		Jampang	12.65
15	BEKASI	Cibeureum	40.00

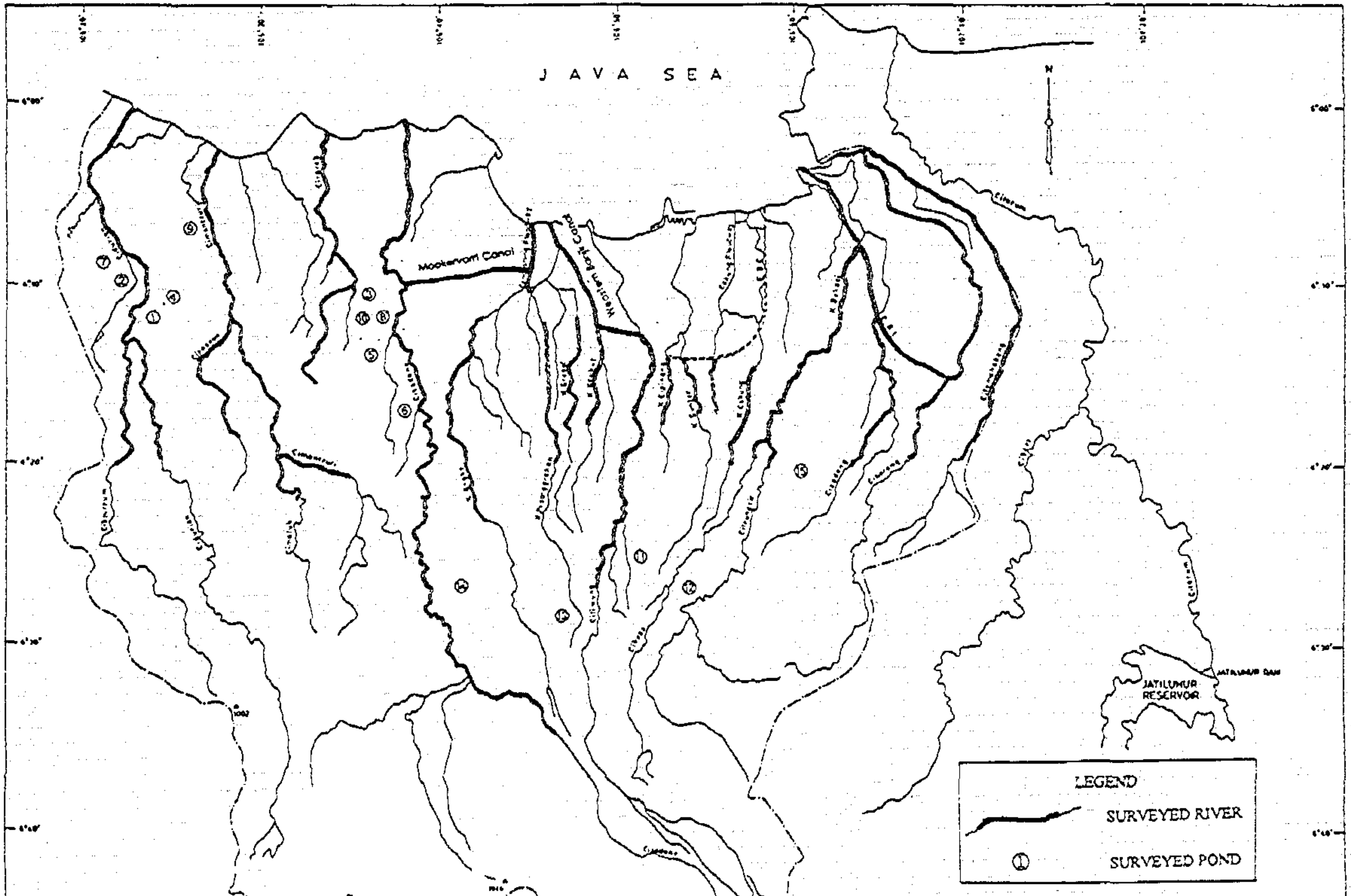

Figure 1 LOCATION OF RIVERS AND PONDS

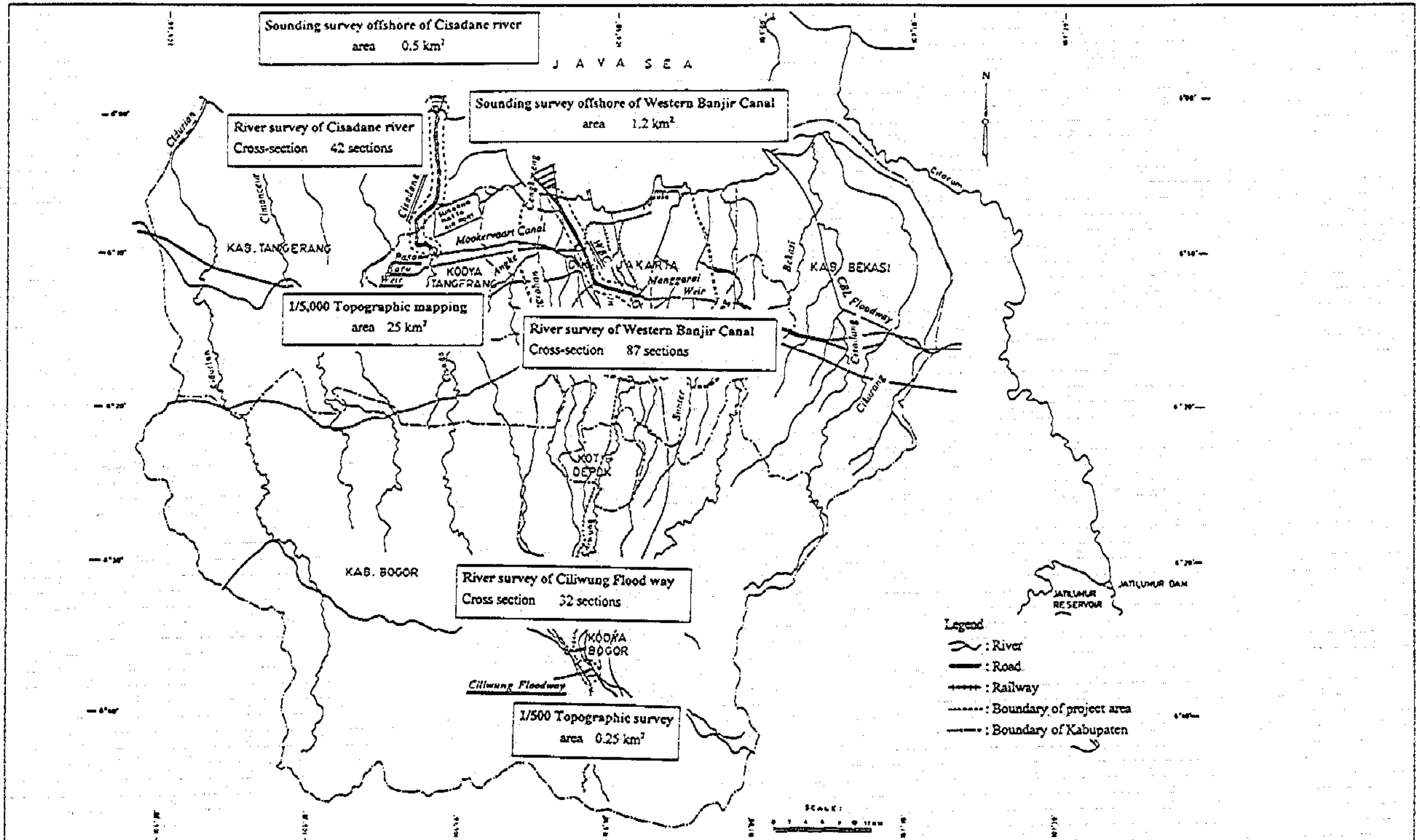

Figure 2 LOCATION OF TOPOGRAPHIC SURVEY