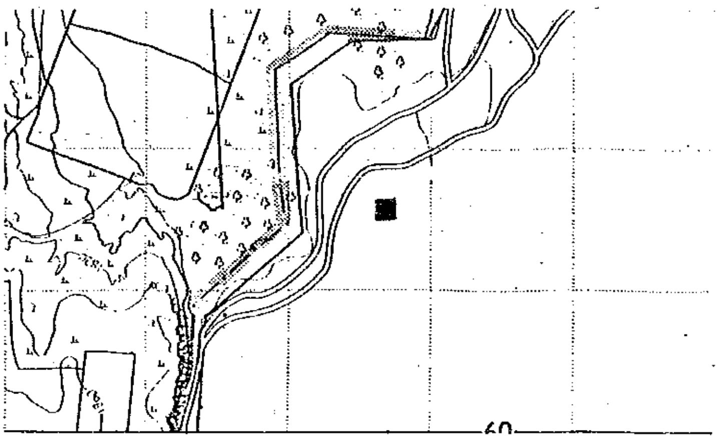
SURVEY MARK DESCRIPTION

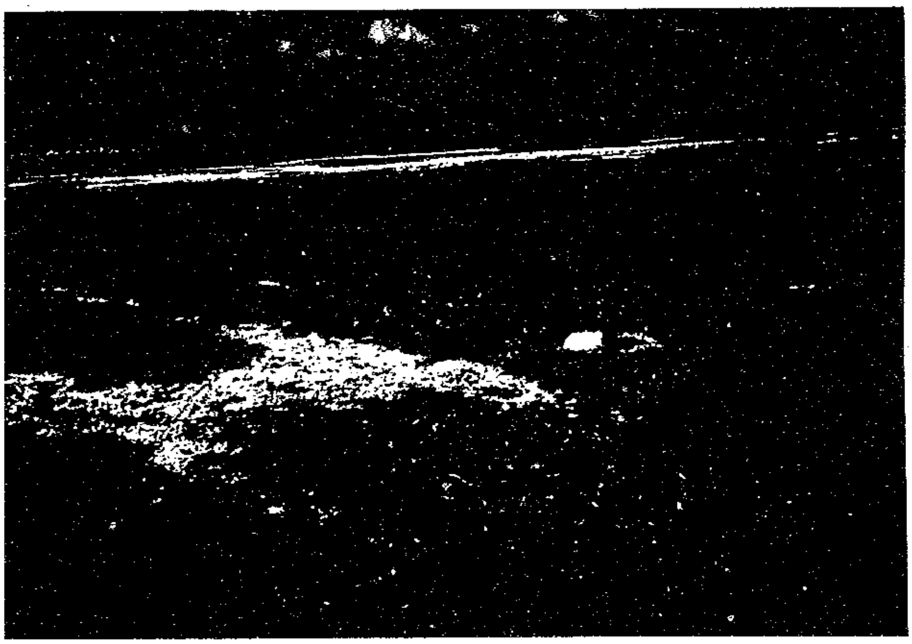
COUNTRY: KENYA **JOB No.** MALEWA DAM **POINT No.** JWBM 17

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 961 572.27	EASTING: 173 742.88	HEIGHT: 1 758.77

LOCATION DIAGRAM



METHOD OF APPROACH

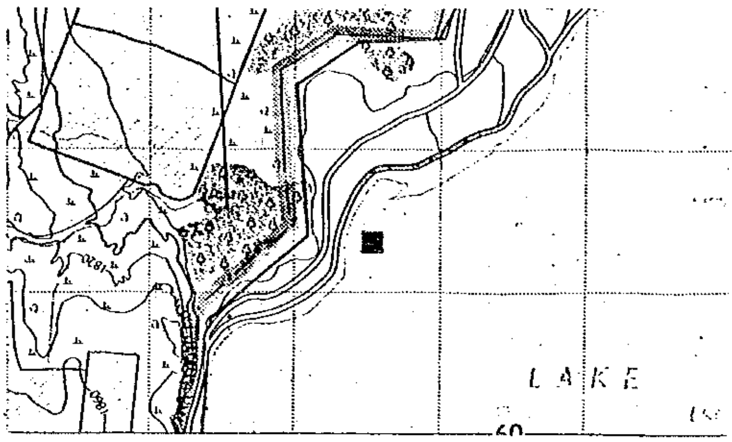


SURVEY MARK DESCRIPTION

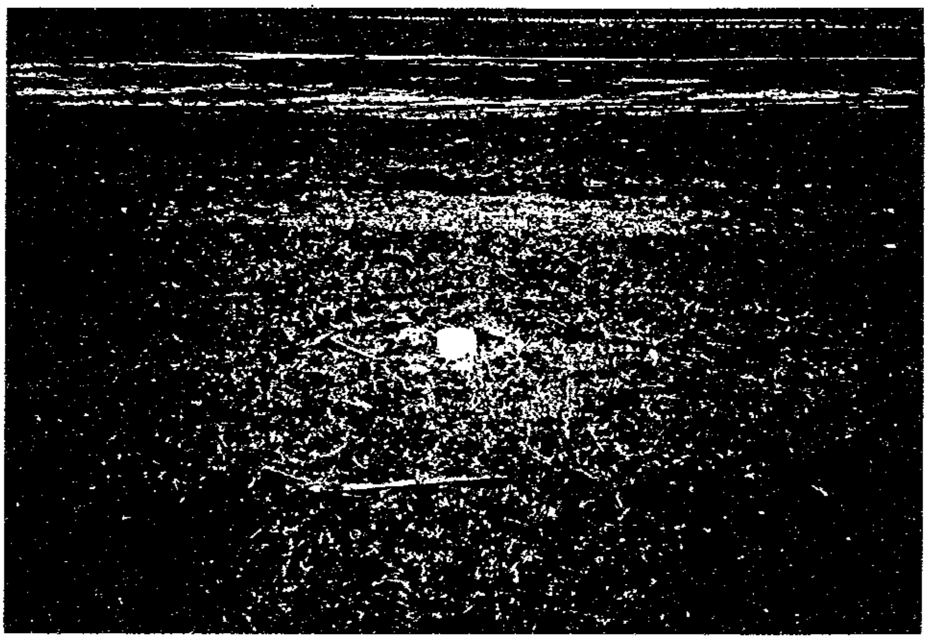
COUNTRY: KENYA **JOB No.** MALEWA DAM **POINT No.** JWBM 18

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 961 404.29	EASTING: 173 495.43	HEIGHT: 1 758.82

LOCATION DIAGRAM



METHOD OF APPROACH

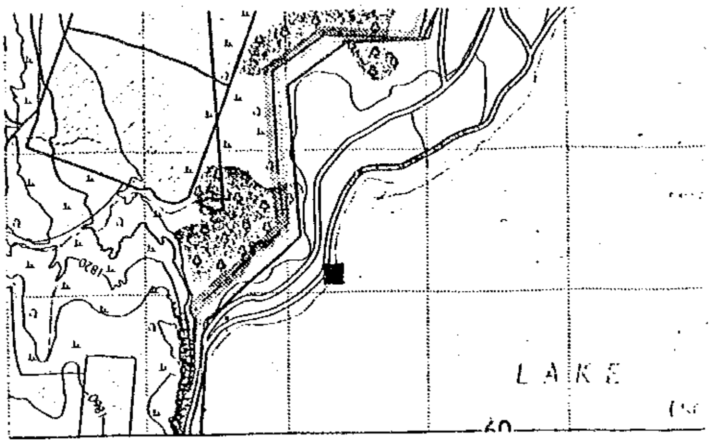


SURVEY MARK DESCRIPTION

COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 19

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 961 164.51	EASTING: 173 309.18	HEIGHT: 1 759.34

LOCATION DIAGRAM



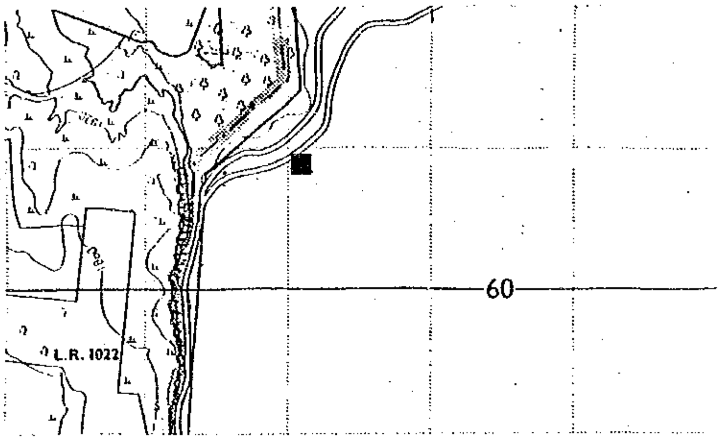
METHOD OF APPROACH

SURVEY MARK DESCRIPTION

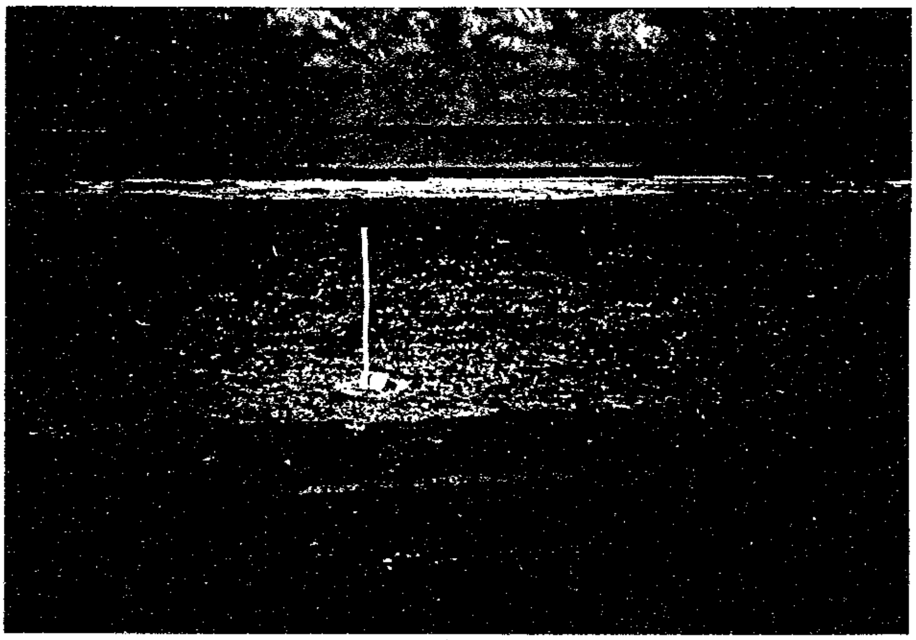
COUNTRY: KENYA **JOB No.** MALEWA DAM **POINT No.** JWBM 20

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 960 921.57	EASTING: 173 120.48	HEIGHT: 1 759.28

LOCATION DIAGRAM



METHOD OF APPROACH

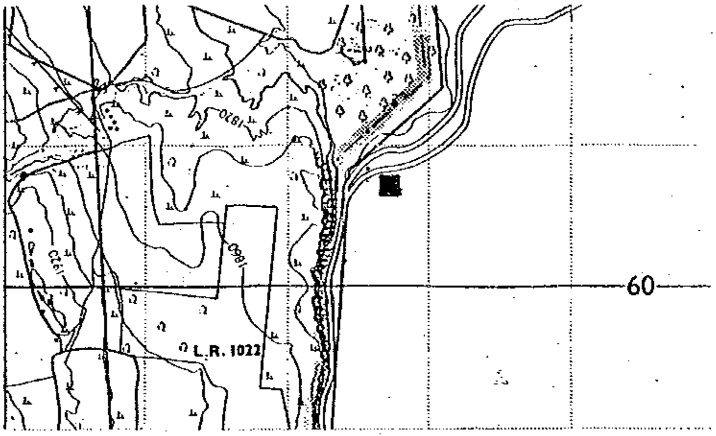


SURVEY MARK DESCRIPTION

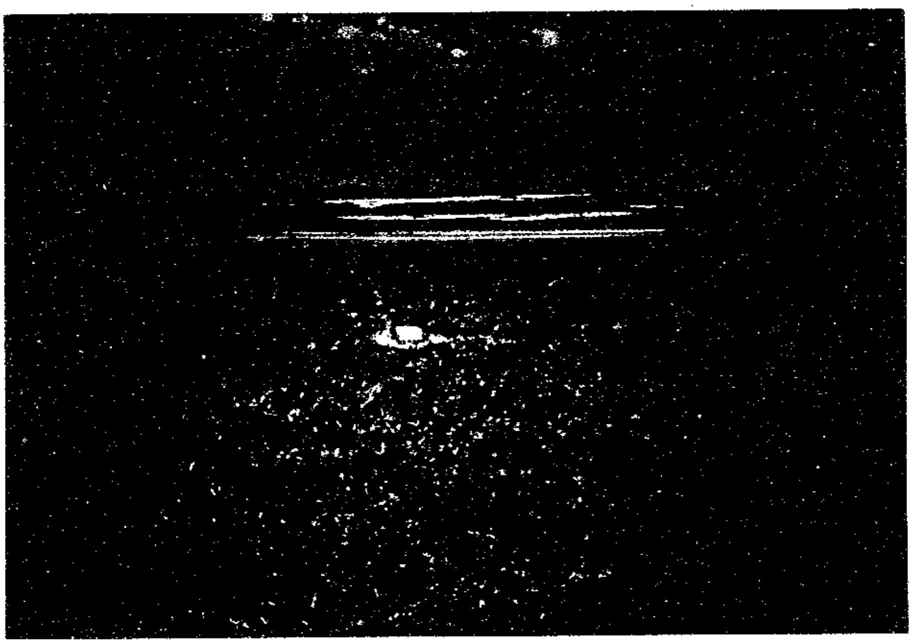
COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 21

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 960 767.85	EASTING: 172 757.81	HEIGHT: 1 759.45

LOCATION DIAGRAM



METHOD OF APPROACH

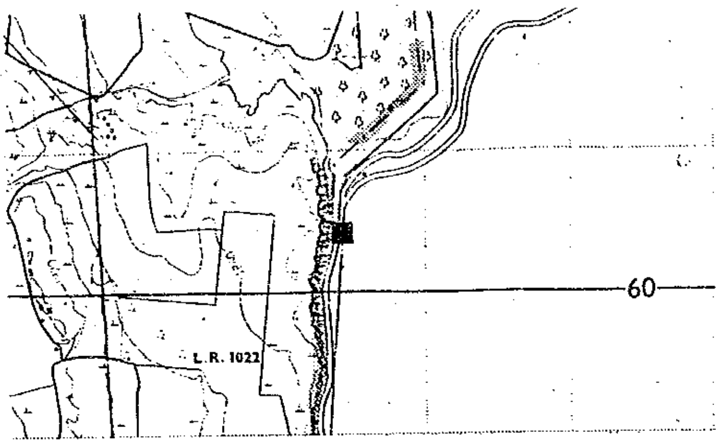


SURVEY MARK DESCRIPTION

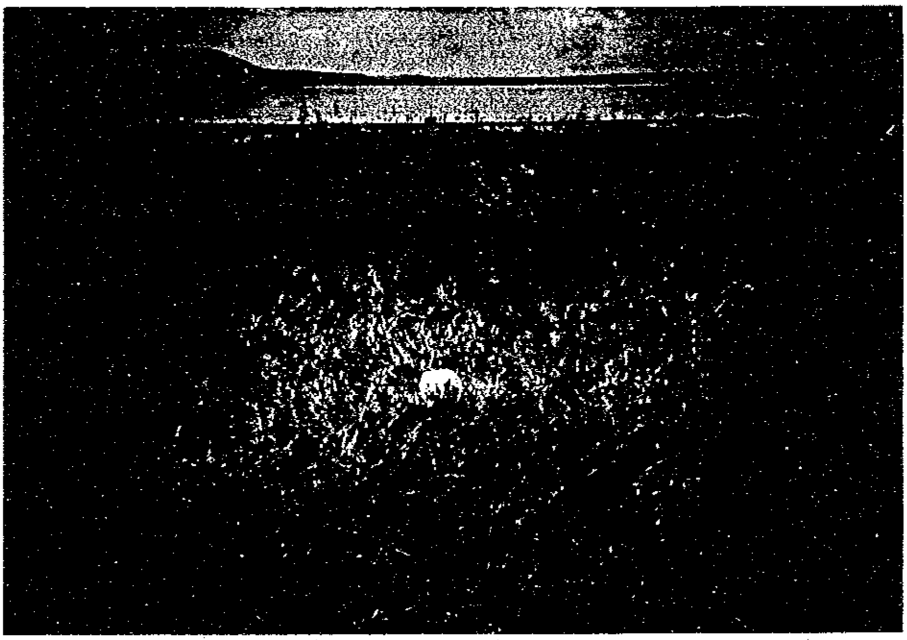
COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 22

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 960 439.00	EASTING: 172 419.66	HEIGHT: 1 758.69

LOCATION DIAGRAM



METHOD OF APPROACH

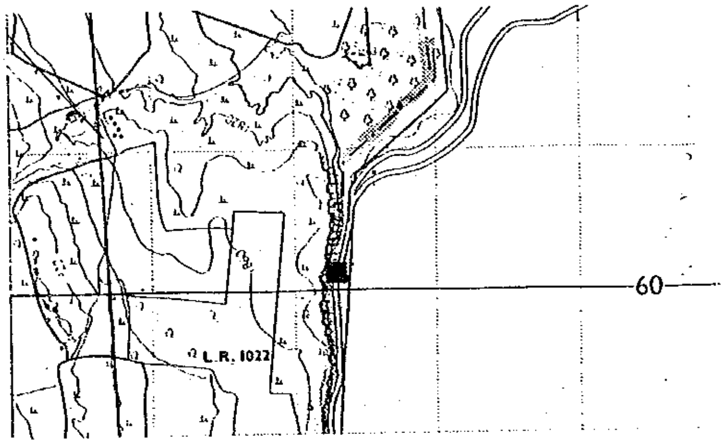


SURVEY MARK DESCRIPTION

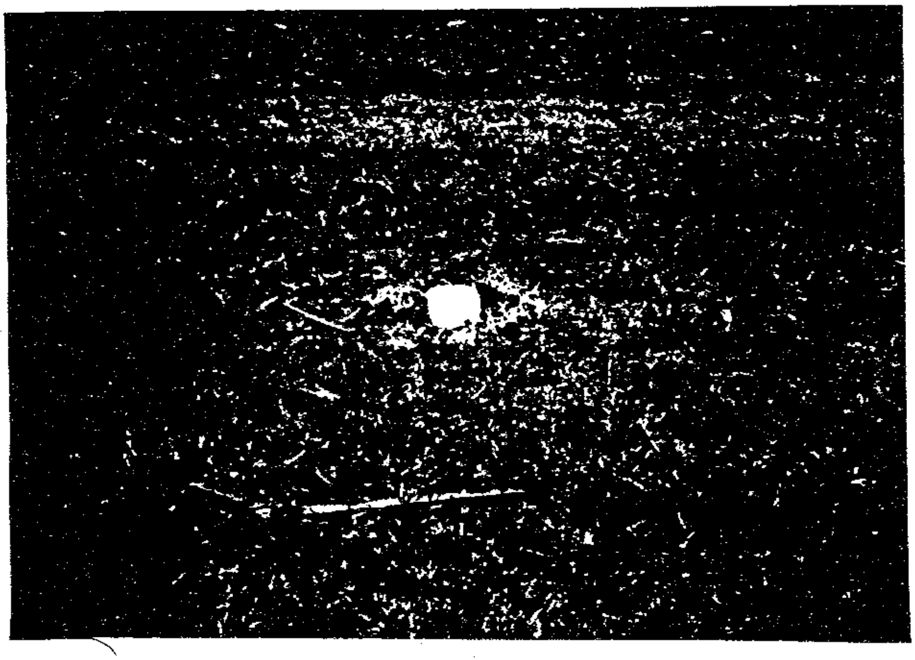
COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 23

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 960 105.87	EASTING: 172 325.50	HEIGHT: 1 758.97

LOCATION DIAGRAM



METHOD OF APPROACH

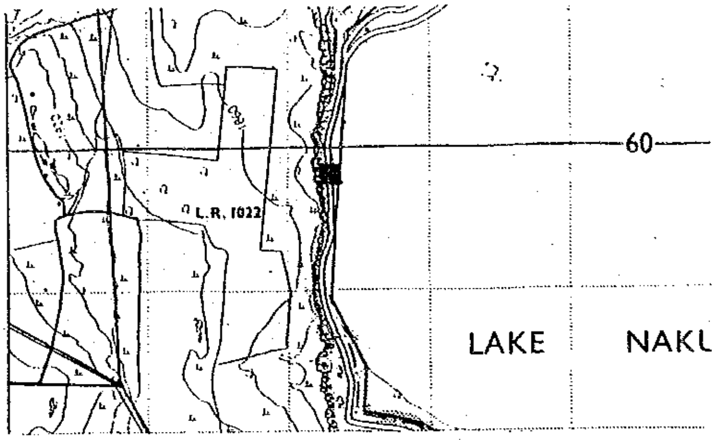


SURVEY MARK DESCRIPTION

COUNTRY: KENYA **JOB No.** MALEWA DAM **POINT No.** JWBM 24

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 959 827.89	EASTING: 172 300.38	HEIGHT: 1 759.57

LOCATION DIAGRAM



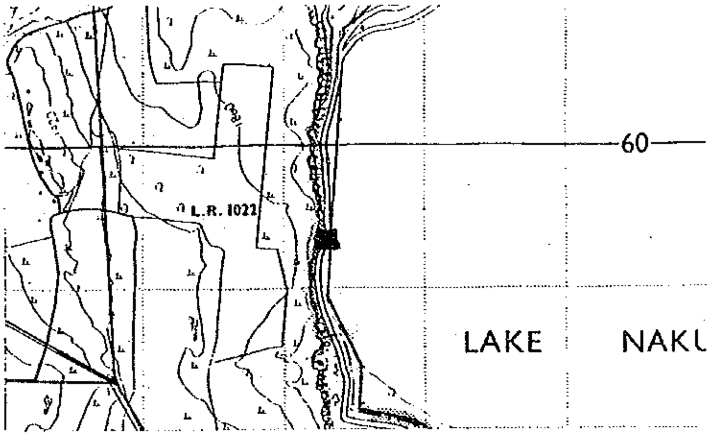
METHOD OF APPROACH

SURVEY MARK DESCRIPTION

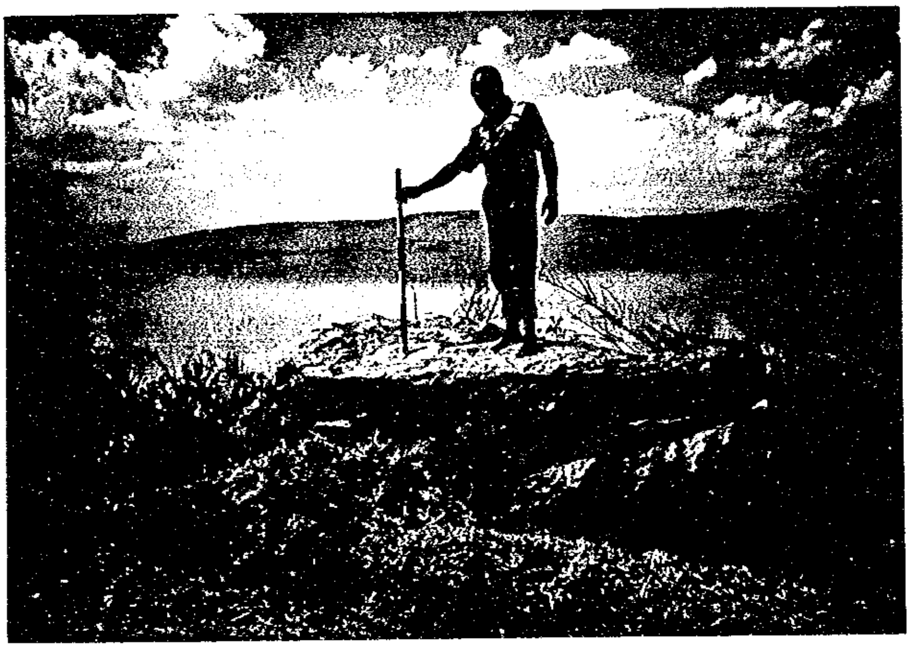
COUNTRY: KENYA **JOB No.** MALEWA DAM **POINT No.** JWBM 25

TYPE: BENCH MARK	DESCRIPTION: ROCK	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 959 331.32	EASTING: 172 297.82	HEIGHT: 1 761.79

LOCATION DIAGRAM



METHOD OF APPROACH

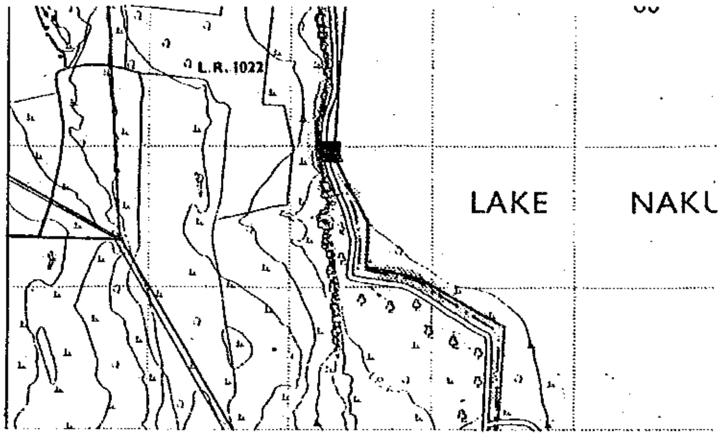


SURVEY MARK DESCRIPTION

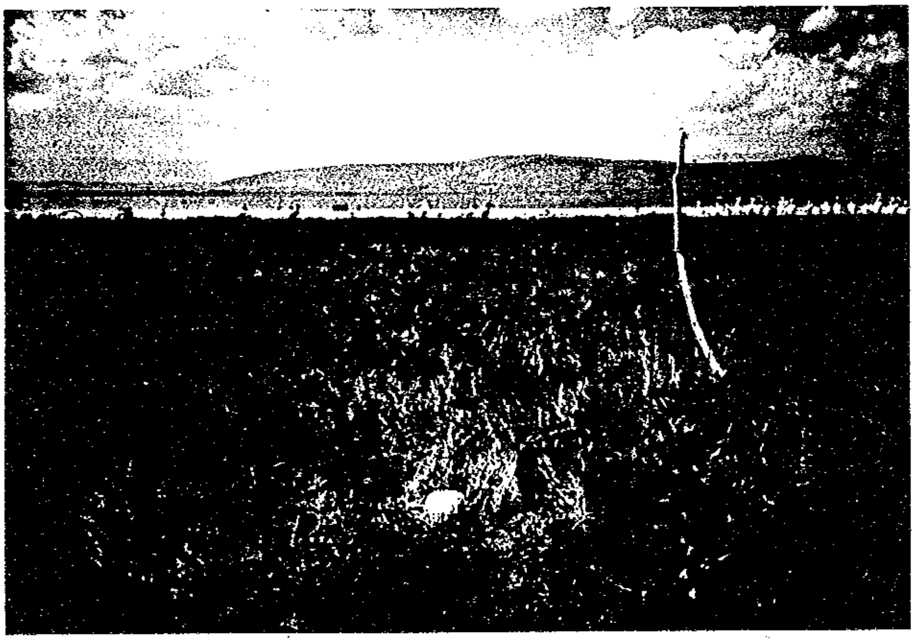
COUNTRY: KENYA **JOB No.** MALEWA DAM **POINT No.** JWBM 26

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 958 955.93	EASTING: 172 284.69	HEIGHT: 1 758.75

LOCATION DIAGRAM



METHOD OF APPROACH

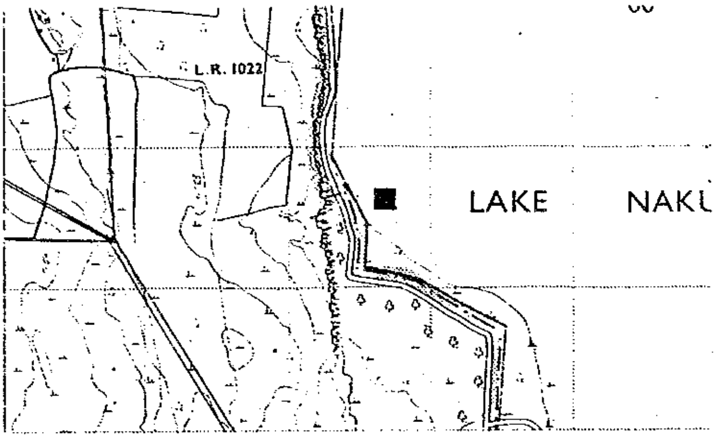


SURVEY MARK DESCRIPTION

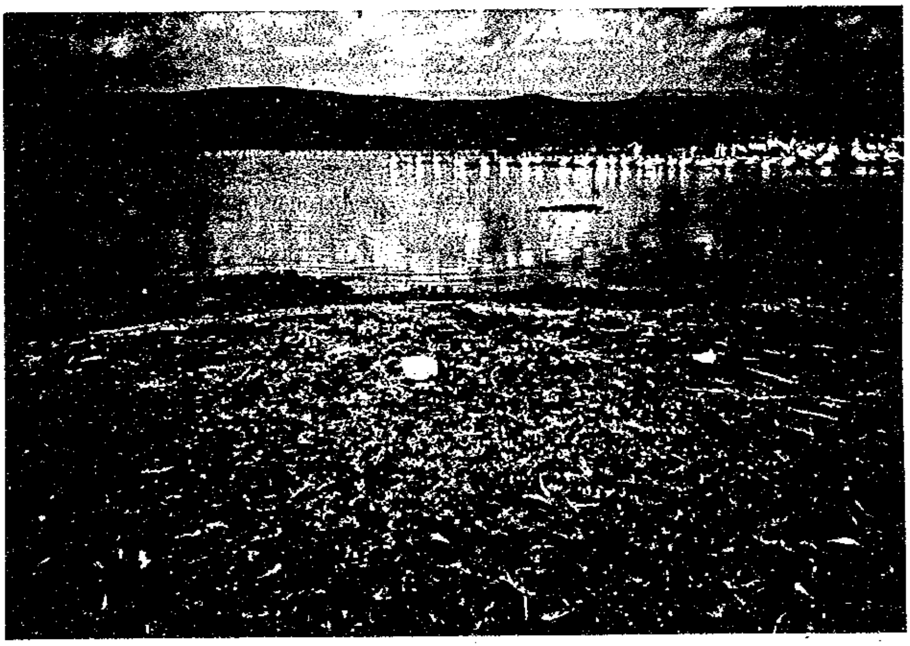
COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 27

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 958 571.78	EASTING: 172 603.97	HEIGHT: 1 758.92

LOCATION DIAGRAM



METHOD OF APPROACH

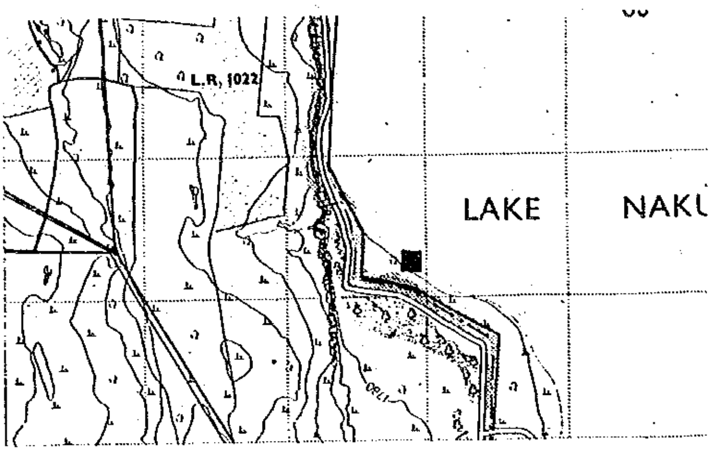


SURVEY MARK DESCRIPTION

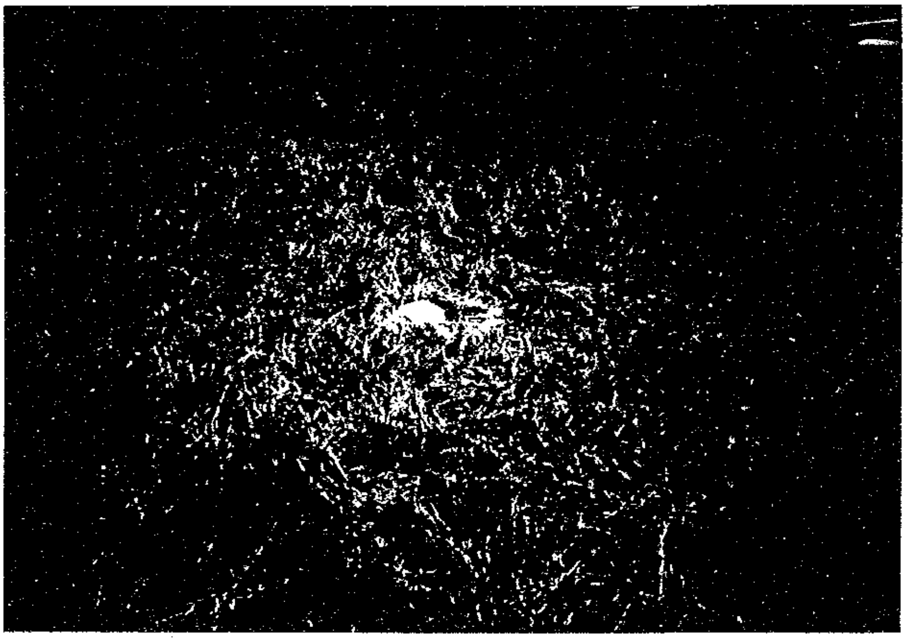
COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 28

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 958 192.85	EASTING: 172 913.54	HEIGHT: 1 758.94

LOCATION DIAGRAM



METHOD OF APPROACH

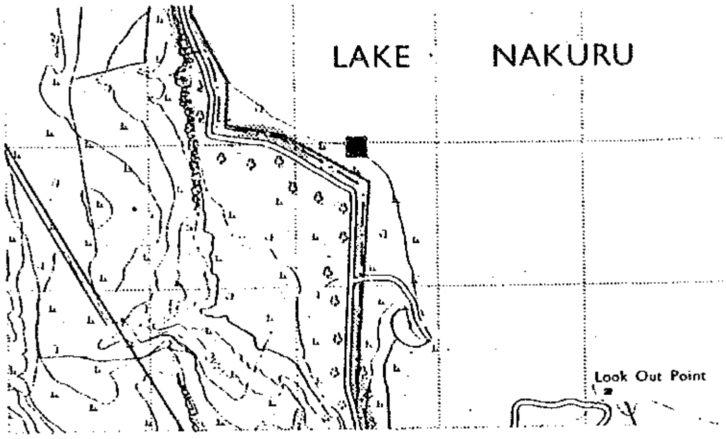


SURVEY MARK DESCRIPTION

COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 29

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 957 979.21	EASTING: 173 404.16	HEIGHT: 1 758.72

LOCATION DIAGRAM



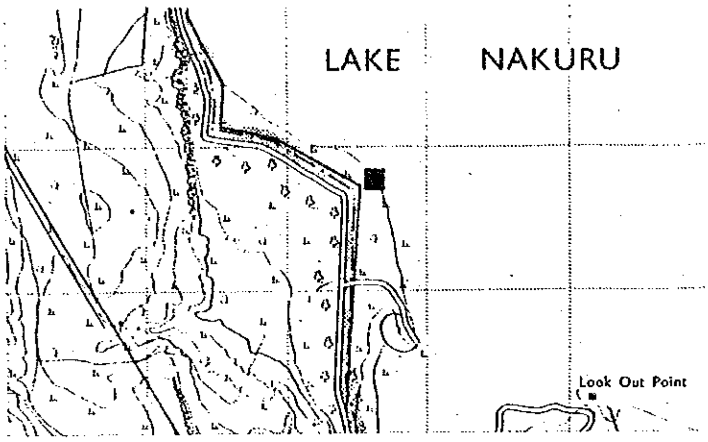
METHOD OF APPROACH

SURVEY MARK DESCRIPTION

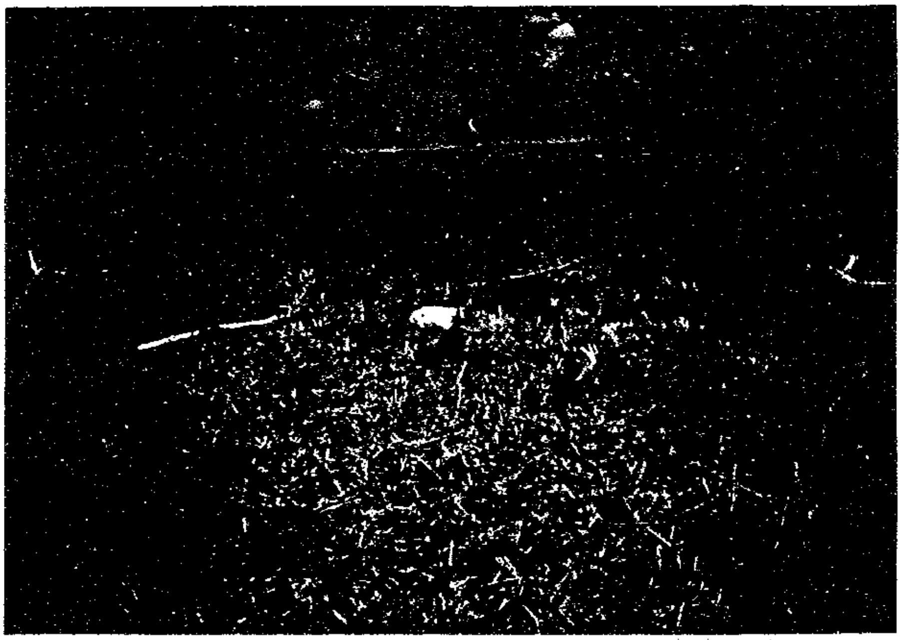
COUNTRY: KENYA **JOB No.** MALEWA DAM **POINT No.** JWBM 30

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 957 764.55	EASTING: 173 650.21	HEIGHT: 1 758.83

LOCATION DIAGRAM



METHOD OF APPROACH

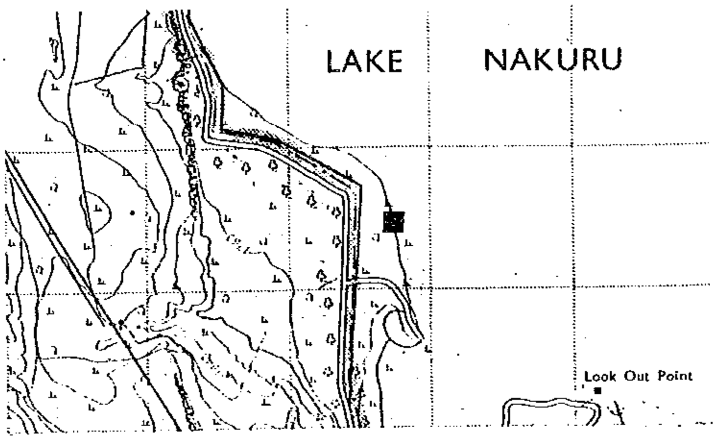


SURVEY MARK DESCRIPTION

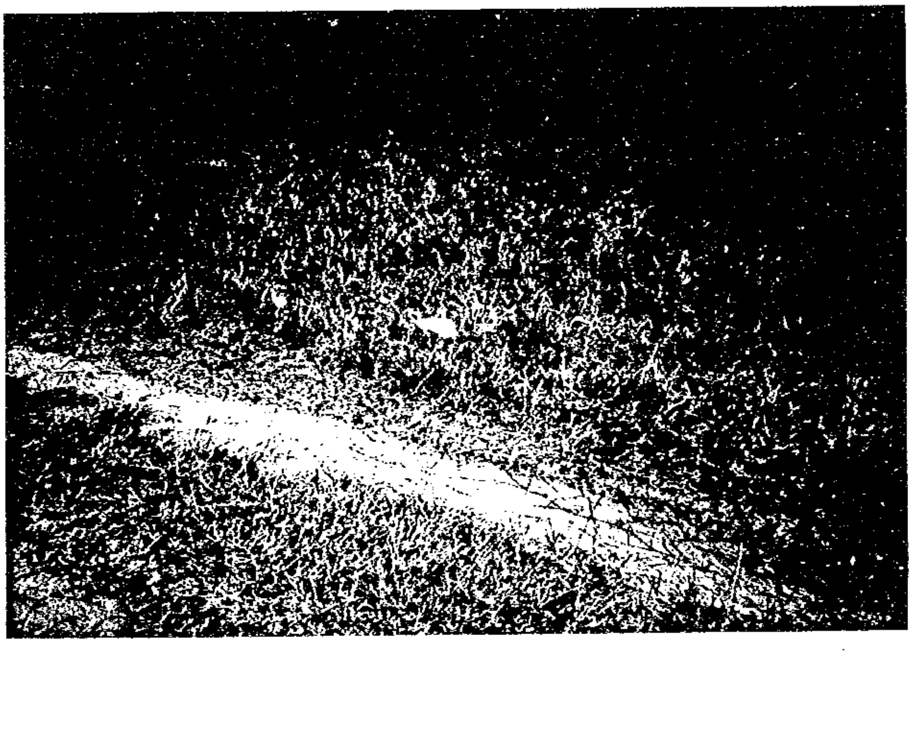
COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 31

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 957 500.22	EASTING: 173 779.10	HEIGHT: 1 759.06

LOCATION DIAGRAM



METHOD OF APPROACH

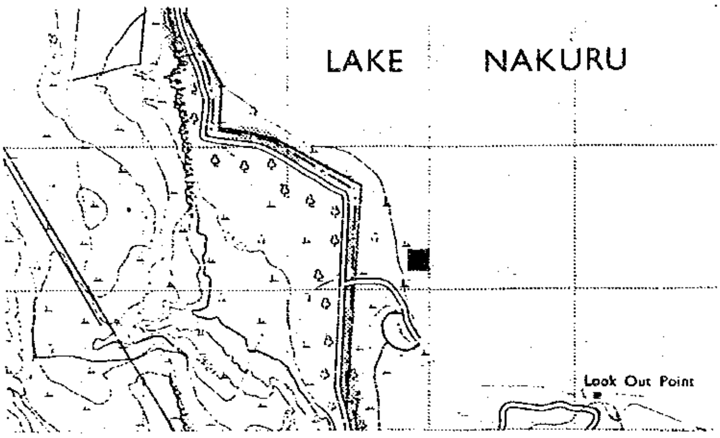


SURVEY MARK DESCRIPTION

COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 32

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 957 216.42	EASTING: 173 917.48	HEIGHT: 1 758.85

LOCATION DIAGRAM



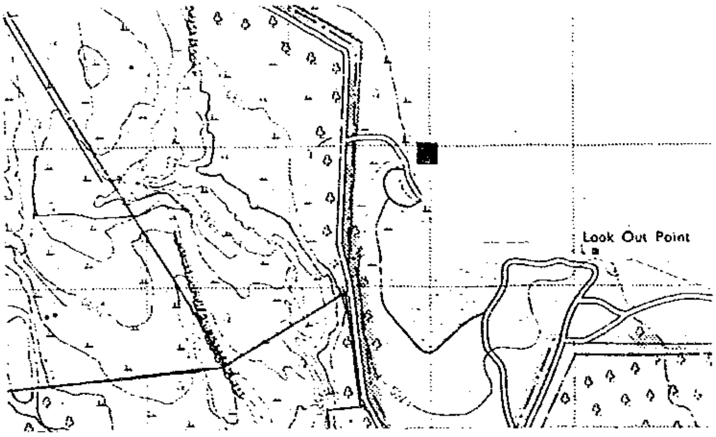
METHOD OF APPROACH

SURVEY MARK DESCRIPTION

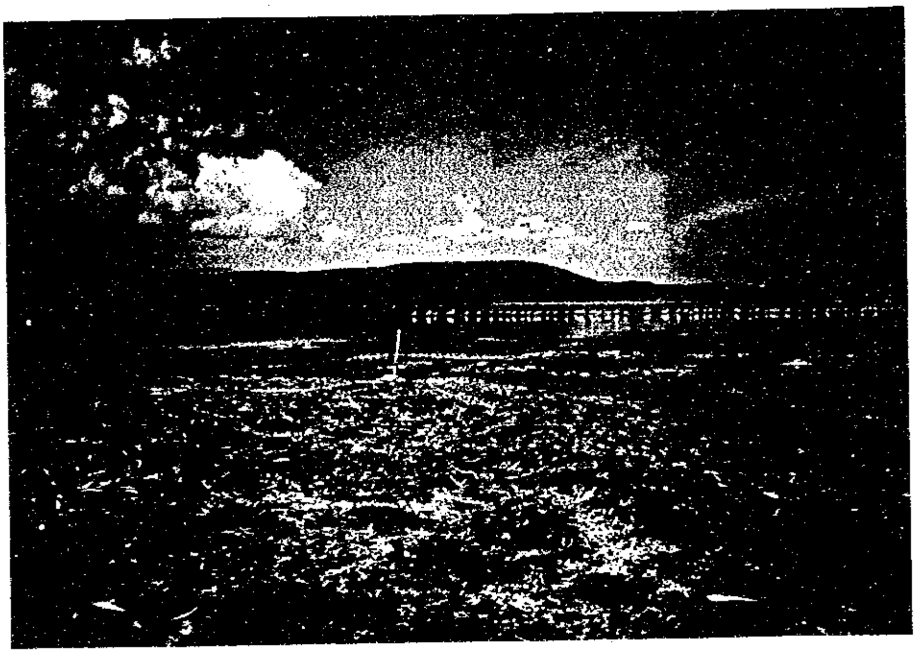
COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 33

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 956 957.38	EASTING: 174 043.80	HEIGHT: 1 758.98

LOCATION DIAGRAM



METHOD OF APPROACH

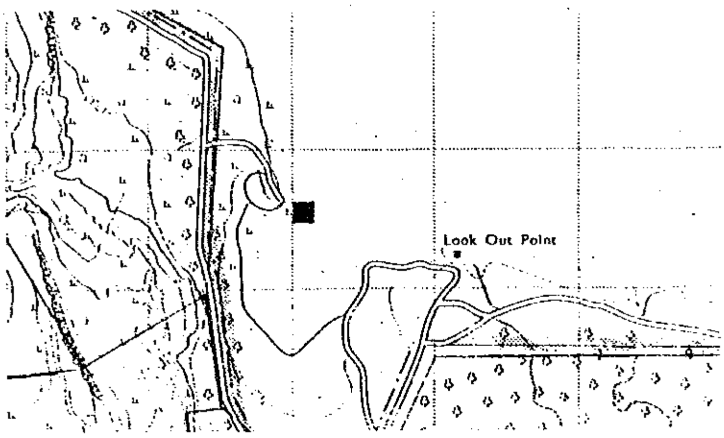


SURVEY MARK DESCRIPTION

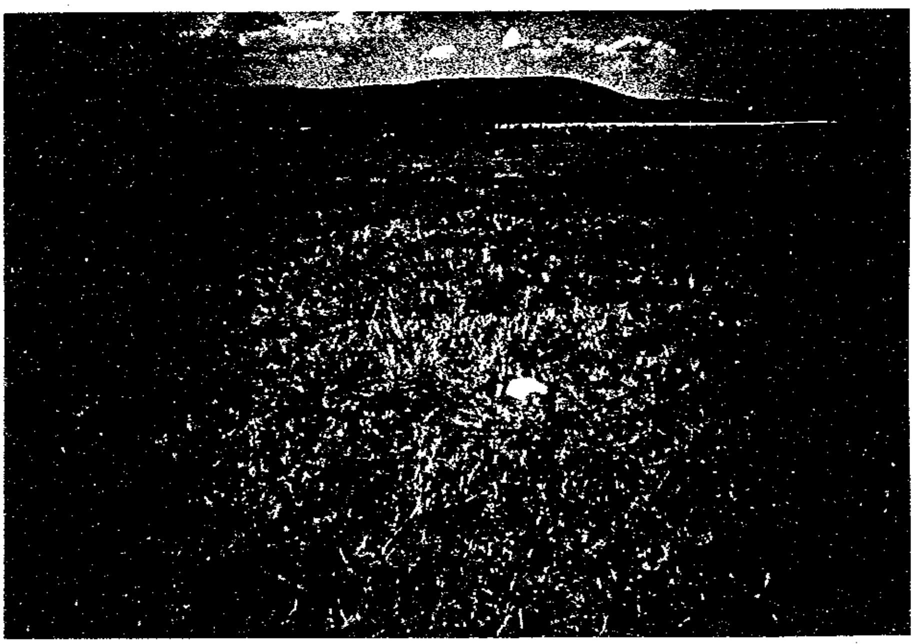
COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 34

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 956 662.79	EASTING: 174 117.77	HEIGHT: 1 758.87

LOCATION DIAGRAM



METHOD OF APPROACH

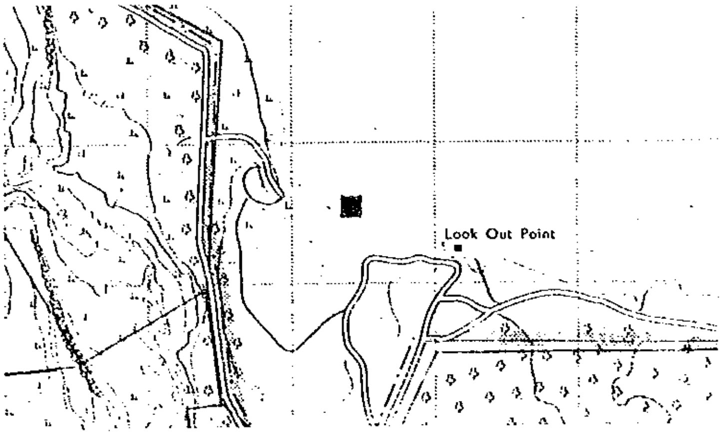


SURVEY MARK DESCRIPTION

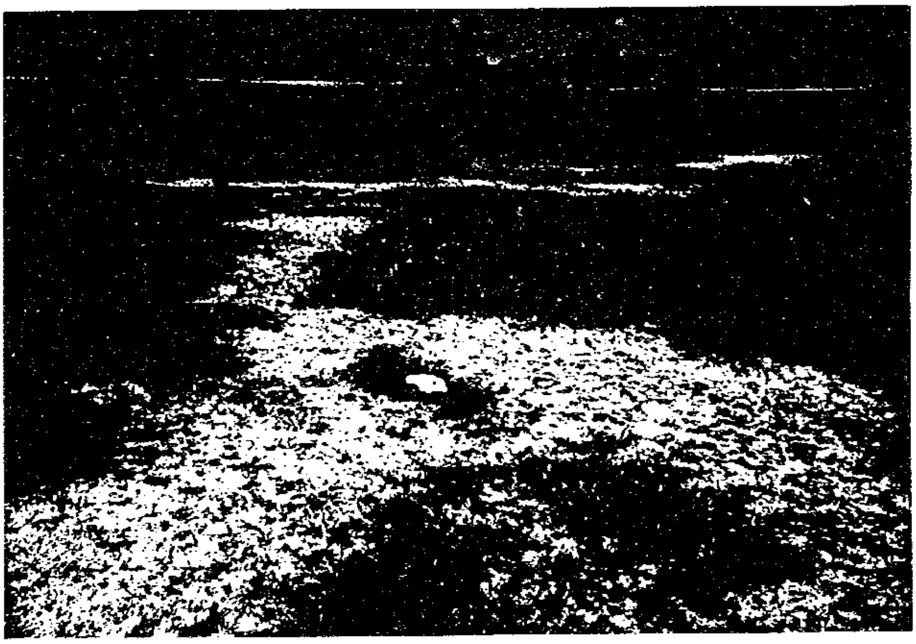
COUNTRY: KENYA JOB No. MALEWA DAM POINT No. JWBM 35

TYPE: BENCH MARK	DESCRIPTION: 50cm CONCRETE	PHOTO NO.
MAP SHEET No. 119/3	DATE: JUNE, 1990	SURVEYOR: Y. KOKUFU
NORTHING: 9 956 492.25	EASTING: 174 409.49	HEIGHT: 1758.71

LOCATION DIAGRAM



METHOD OF APPROACH



ANNEX B

GEOLOGICAL INVESTIGATION

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX

Abbreviation and Local Terms

1. Abbreviation of Measures

1.1 Length

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

1.2 Area

m^2, sq.m	=	square meter
ha	=	hectare
km^2, sq.km	=	square kilometer

1.3 Volume

lit, l	=	liter
lcd	=	liter per capita per day
cu.m, m^3	=	cubic meter
cu.m/day, m^3/day	=	cubic meter per day
MCM	=	million cubic meter

1.4 Weight

mg	=	milligram
mg/l	=	milligram per liter
g	=	gramme
kg	=	kilogram
t	=	ton

1.5 Time

s, sec	=	second
min	=	minute
h, hr	=	hour
d	=	day
yr	=	year

1.6 Money

Kshs.	=	Kenya Shilling(unit of Kenya currency, US$1.00 = Ksh 23.0 = ¥ 150)
US$, $	=	US dollar
¥	=	Japanese Yen

1.7 Electric Measures

kV	=	kilovolt
kW	=	kilowatt
MW	=	megawatt
kWh	=	kilowatt hour
kVA	=	kilovolt ampere

1.8 Other Measures

mmho	=	micromho = conductance
ppm	=	parts per million
ppb	=	parts per billion
MPN	=	most probable number
‰	=	mill
%	=	per cent
PS	=	0.736 kW
°	=	degree
'	=	minute
"	=	second
℃	=	degree centigrade
n.a.	=	not available
COD	=	Chemical Oxygen Demand
T-N	=	Total Nitrogen
I -	=	Inorganic -
O -	=	Organic -
T-P	=	Total - Phosphorus
DO	=	Dissolved Oxygen
pH	=	Exponent of hydrogen ion concentration

1.9 Derived Measures Based on the Same Symbols

cu.m/sec, m^3/s	=	cubic meter per second
cu.m/day, m^3/day	=	cubic meter per day
t/ha	=	ton per hectare
lpcd	=	liter per capita per day

2. Other Abbreviations

BS	=	British Standards
JIS	=	Japanese Industrial Standards
ASTM	=	American Society for Testing and Material
GNP	=	gross national products

GDP	=	gross domestic product
GRDP	=	gross regional domestic product
El.	=	elevation
FWL	=	flood water level
FSL	=	full supply level
MSL	=	minimum supply level
HWL	=	normal operation level
LWL	=	minimum operation level
f.o.b	=	free on board
c.i.f.	=	cost, insurance and freight
ICB	=	international competitive bid
LCB	=	local competitive bid

3. Abbreviation of Organizations

MOA	=	Ministry of Agriculture
MENR	=	Ministry of Environment & Natural Resources
MOF	=	Ministry of Finance
MOLD	=	Ministry of Livestock Development
MOLG	=	Ministry of Local Government
MOTW	=	Ministry of Tourism & Wildlife
MOTC	=	Ministry of Transport & Communication
MORD	=	Ministry of Regional Development
MOWD	=	Ministry of Water Development
NES	=	National Environmental Secretariat
NWCPC	=	National Water Conservation & Pipeline Corporation
SOK	=	Survey of Kenya
KWS	=	Kenya Wildlife Service
NMC	=	Nakuru Municipal Council
NTC	=	Naivasha Town Council

ASTU	=	Anti-Stock Theft Unit
KYSTC	=	National Youth Service Training Center
GMB	=	Gilgil Military Barracks
KMB	=	Kenyatta Military Barracks
WWF	=	World Wide Fund for Nature
JICA	=	Japan International Cooperation Agency
OECF	=	Overseas Economic Cooperation Fund, Japan

I. INTRODUCTION

This report presents findings of geological investigation and their foundation engineering interpretation for the dam scheme in the Malewa river system, that is a part of the Greater Nakuru Water Supply Project.

The preliminary geological investigation (Phase 1 Study) has formed the first part of the two-stage investigation schedule, which will be followed by the second part for detailed investigation, and has aimed at selecting a promising dam site out of alternatives to be found on Malewa river and Turasha river. The investigation has comprised field geological reconnaissance, geological mapping and exploratory drilling with borehole permeability test, taking four and a half months of time from February to June, 1989.

The detailed geological investigation (Phase 2 Study) to follow has carried out in five months from October, 1989 to February, 1990 for obtaining more detailed information of sub-surface conditions of the dam site selected in the preliminary stage.

Findings of the preliminary investigation and the detailed investigation are presented chiefly in Chapter III to IV and Chapter V of this report respectively.

Through the investigation period in both phases, the exploratory drilling with borehole permeability test has been performed by Mowlem Construction Co., Nairobi, according to the specification prepared and under supervision made by the JICA Study Team. The field reconnaissance and the geological mapping have been made by the geologist of the Study Team.

For the completion of this geological study, the Study Team is much obliged to Mr. Mwai, Chief Geologist of NWCPC and Mr. Waweru, Geologist of MOWD, who have provided great support and assistance to the Study Team.

II. INVESTIGATION

2.1 Preliminary Geological Investigation

Items and quantities of the preliminary geological investigation are as shown in Table B.2.1, comprising 24.5 km^2 of geological mapping for alternative dam sites and reservoir areas, 360 m in total length of exploratory core drilling and borehole permeability test at 71 sections (stages) of the drilled holes.

The core drilling with the borehole test has been made in two alternative sites of Malewa dam and Turasha dam, using three sets of hydraulic-feeding rotary drilling rigs, i.e., Long Year 34, Joy 12 and Mobil B61. Core samples taken through the drilling, arranged in core boxes in order, are stored in a warehouse of MOWD. Locations of the drilling are shown in Figs. B.2.1 and B.2.2. Drilling logs are presented in Figs. B.2.3 and B.2.4.

Standard penetration test according to the USBR Specification (Ref. Earth Manual) to evaluate strengths of unconsolidated deposits and completely weathered rock zones has not been performed for their too minor thicknesses to remain as any part of the dam foundation.

Two different methods have been applied to the borehole permeability test depending on geological conditions encountered, that is, the Lugeon test for beds consolidated well for effective packer setting and the constant head test for loose beds which may have collapsed without protection with casing. Coefficients of permeability and Lugeon values have been estimated from results of the test to give the figures in Table B.2.2, using the water pressures corrected for the friction loss of energy according to a test result as shown in Fig. B.2.5.

2.2 Detailed Geological Investigation

Items and qualities of the detailed geological investigation are as shown in Table B.2.3 comprising 560 m in total length of exploratory core drilling and borehole permeability test at 112 sections (stages) of the drilled holes.

The core drilling with the borehole test was concentrated on the Malewa damsite proposed through the preliminary study, using three sets of the same drilling rigs as in the preliminary investigation. Core samples are stored in a warehouse of MOWD. Locations of the drilling are shown in Fig. B.2.1. Drilling logs are presented in Figs. B.2.3.

Standard penetration test was not performed for the same reason as in the preliminary investigation.

The same Specification as for the preliminary investigation has been applied to the borehole permeability test and calculation of coefficients of permeability and Lugeon values from the results of the test. Presented in Table B.2.4 are the coefficients of permeability and Lugeon values that has been calculated using the water pressures corrected for the friction loss of energy according to the test result as shown in Fig. B.2.5.

III. GEOLOGY

3.1 Regional Geology

The project area is situated in the Rift Valley of Kenya, which consists of a main rift, also called Gregory rift, traversing the country from north to south, and a branch rift named Kavirondo, trending from east to west through Lake Victoria. The main rift is a part of the Great Rift System developing from Syria to Mozambique, and has a feature of trough with complex faultings of general orientation from north to south.

Since Miocene epoch to Recent period, this zone has been a stage of repeated volcanism followed by faulting movements. The volcanic activity have often taken the form of fissure eruption, that is, emission of lava and pyroclastic flows from long fissures in the ground. The large scale eruptions along fissures parallel with the axis of the rift and the normal faultings of the similar trend may indicate action of horizontal tensile force in the direction right angle to the rift, that is due to the reverse movements of the plates on the east and west sides of the rift as if to split it. The past geological studies have distinguished three events of major faulting activities which occurred subsequent to volcanic activities in Miocene, Pliocene and early Pleistocene, through which the Rift Valley has grown to the present form. The Rift Valley is intersected with varied tectonic structures, e.g., faults oblique to its axis and secondary minor troughs right angle to it, as represented by the Kavirondo Rift.

Reflecting the age and the geological environment of its formation, the entire stratigraphic sequence in the Rift Valley consists of Tertiary to Recent volcanic and pyroclastic rocks, with intercalations of lake sediments which are also tuffaceous in part. In the contemplated Malewa and Turasha reservoir areas which are located near the eastern margin of the main rift valley, the bedrock is composed of trachytes, welded tuffs and massive tuffs of the Pliocene Kinangop Tuff Group interbedded with the lake sediments.

Reference is to be made to Table B.3.1 for the regional stratigraphy.

3.2 Site Geology, Malewa Dam Scheme

3.2.1 Topography

The reservoir area is located in a flat hill zone with slopes of low angles, composed of sub-horizontally bedded lava and pyroclastic flows. The gently undulating terrain is dissected by the Malewa river to the depth of 50 m to 60 m from the surface of the flat hills, forming a meandering gorge. The Malewa river bed is at El. 2,082 m at the contemplated dam site, and the width of the valley there is 190 m at the top of the gorge at El. 2,145 m. Stratigraphic sequences of gently dipping pyroclastic beds are well exposed on the steep slopes of the valley sides, with well cemented welded tuffs forming small cliffs and soft lake sediments forming flatter parts of the slopes.

3.2.2 Geology of Reservoir Area

Stratigraphy of the reservoir area is summarised as follows:

Age	Lithological Unit	Constituents
Quaternary up to Recent	Colluvium	Silt, sand, pebbles, cobbles, boulders. Partially riverbed deposits.
Upper Tertiary up to Pliocene (Kinangop Tuffs)	Massive tuffs and lake sediments	Taff, lapilli tuff, tuffaceous siltstone, sandstone and conglomerate, with diatomite.
	Welded tuff	Welded tuff

The geological map of the reservoir is shown in Fig. B.3.1 and geological profile is shown in Fig. B.3.2.

The terrain of the reservoir and surrounding area is composed of a series of pyroclastic rocks which are stratigraphically classified as members of a Pliocene Kinangop Tuffs, comprising welded tuffs and massive tuffs interbedded with the lake sediments, being covered with colluvial deposits, the Quaternary overburden on the flat slopes. Detailed lithological descriptions of these geological units are presented below:

(1) Lithological description

(a) Welded Tuff

The welded tuff is wide-spread over the reservoir area, and can be distinguished into several different flow beds. All the flow beds are almost commonly dark grey coloured and include scoria fragments of pebble to cobble size. The welded tuff is the hardest rock in the reservoir area, and often forms long continuous cliffs. Joints of both trends vertical and parallel to the flow structure are observed on outcrops on the cliffs. Interval of the joints are several metres in general.

(b) Massive Tuffs and Lake Sediments

This geological unit is also widely developed in the reservoir area. The massive tuffs, comprising lapilli tuffs and fine tuffs, seem to have had originally similar lithological components to the welded tuff, and be distinguished from the latter only for the lack of welding. The massive tuffs are less cemented than the welded tuff and rarely have joints. The lake sediments consist of alternating layers, less than one metre in thickness, of tuffaceous siltstone, tuffaceous sandstone, conglomerate and a minor quantity of diatomite, which are poorly consolidated and vulnerable to weathering. The large part of the lake sediment is composed of the tuffaceous sandstone of varied particle sizes, which is partly lithic and hard. The conglomerate includes pebble-sized gravels in tuffaceous sandstone matrix.

(c) Colluvium

The colluvial deposit of silt, sand, pebbles, cobbles and boulders of the welded tuff, covers the gentle slopes in the reservoir area, with the maximum thickness of several metres.

(2) Geological structure

The Pliocene series of the pyroclastic rocks with the lake sediments generally show sub-horizontal bedding with the west-northwest dips of less than 10 degrees, which, however, locally varies because of the undulation. All faults identified in the reservoir area are minor and have no foundation engineering significance.

3.2.3 Geology of Dam Site

Stratigraphy of the contemplated dam site is summarised as follows:

Age	Lithological Unit	Constituent
Quaternary up to Recent	Colluvium	Silt, sand, pebbles, cobbles boulders.
	River deposits	Clay, silt, sand pebbles, cobbles and boulders.
Upper Tertiary up to Pliocene	Upper non-welded Layer	Non-welded tuff (lapilli tuff)
	Welded tuff	Welded tuff
	Lower non-welded Layer	Non-welded tuff (lapilli tuff)
	Massive tuffs	Tuff, lapilli tuff.
	Lake sediments	Tuffaceous siltstone, sandstone, conglomerate, diatomite.

Similar to the geology of the reservoir area, the bedrock of the dam site is composed of pyroclastic rocks of the Pliocene Kinangop Tuffs, including the welded tuffs and non-welded layers, the massive tuffs with intercalations of the lake sediments and the Quaternary overburden of the colluvial deposits and the river deposits.

The geological map of the Malewa damsite is shown in Fig. B.3.3. The geological profile along the Malewa dam axis is shown in Fig. B.3.4 and other geological profiles of the Malewa damsite are shown in Figs. B.3.5 through B.3.9.

Accounts of the member beds are as follows:

(1) Lithological description

(a) Lake sediments

The lake sediment layers have been identified at five different horizons, as numbered from 1 to 5 in descending order. The sediments of these layers, however, show similar lithological features of alternating tuffaceous siltstones, tuffaceous sandstones, conglomerates, and minor diatomites with intercalations of pumice tuff and lapilli tuff. Each of these layers is not thicker than one metre, and their boundaries are often gradational. Soft and vulnerable to weathering, samples of yellowish coloured weathered lake sediments has been taken in the boreholes MB-1 and MB-3, while fresh core samples are grey to greenish grey as has been recovered from the borehole MB-2. The tuffaceous sandstone is the major member of the lake sediments, with cross-beddings and occasionally lithic and hard portions as observed in the core samples from MB-2. Conglomerate is as described for the reservoir geology.

(b) Welded tuff

The welded tuffs have been identified at three different horizons, as numbered from 1 to 3 in descending order. While the horizons Wtf1 and Wtf2 are dark grey and characterized by pebble to cobble size scoria fragments as commonly observed in this area, the horizon Wtf3 contains smaller pumice fragments instead of scoria in the dark grey matrix which is more compact than in Wtf1 and Wtf2. Clear joints are developed at several metre intervals, in the directions both vertical and horizontal. The vertical joints predominate in Wtf2.

(b) Upper and lower non-welded layer

The welded tuff layers are associated by non-welded layers both in the upper and the lower parts. Whereas the lithological components are similar to those in the welded tuffs, the marginal non-welded layers are more poorly cemented. Transition to the welded tuff layers is gradational.

(c) Massive tuffs

Four different horizons of the massive tuffs have been identified in the dam site and numbered from 1 to 4 in descending order. This unit is composed of lapilli tuffs and finer tuffs, characterized by pebble to cobble sized scoria included. The massive tuffs of different horizons show nearly the same lithologic features, which are also not much different from the welded tuff except for the feature of welding.

(d) River deposits

The river deposits, composed of clay, silt, sand and pebbles to boulders of the welded tuff, are estimatedly not thicker than one metre.

(e) Colluvium

The colluvial deposits covering gentle slopes consist of silt, sand and gravels. Boulders of the welded tuff are often one to two metres in diameter. The thickness of these deposits has been measured at 4.45 m in the borehole MB-2, and is estimated at several metres in general.

(2) Geological structure

As described for the reservoir geology, the Pliocene beds in the dam site are also sub-horizontally stratified with the dip of less than 10 degrees to west-northwest, or from the left bank to the right bank downstream, with some undulations. Minor faults of no practical significance have been found at the dam site.

(3) Weathering

The bedrock is moderately to slightly weathered to considerable depths in the both abutments, while weathering is hardly observed in the rocks under the river bed. The lowest groundwater tables observed in the boreholes on the both banks were nearly at the level of the river bed, which is interpreted to indicate groundwater flow in the bedrocks under the dam abutment. It appears that the weathering in the welded tuff is limited to the joint planes, but that in the other soft rocks penetrates into the rock body. The weathering is, however, not intensive in general.

3.3 Site Geology, Turasha Dam Scheme

3.3.1 Topography

The Turasha dam scheme is situated in a zone of the similar topographic characteristics to the Malewa scheme, that is, in a hill zone of low relief developing in the Rift Valley of Kenya. At the contemplated dam site, the river bed at El. 2,096 m is approximately 30 m wide, and the Turasha valley has a width of 380 m at El. 2,160 m or at the level 64 m higher than the river bed. There are several portions of low angled inclination, covered with colluvial deposits, on the slopes on both sides of the river valley, reflecting existence of the soft lake sediment layers.

3.3.2 Geology of the Reservoir Area

Stratigraphy of the reservoir area is summarised as follows:

Age	Lithological Unit	Constituent
Quaternary up to Recent	Colluvium	Silt, sand, pebbles, cobbles, boulders. (River deposits included.)
Upper Tertiary up to Pliocene	Massive tuffs and lake sediments (Kinangop Tuffs)	Tuff, lapilli tuff, tuffaceous siltstone, sandstone and conglomerate, with diatomite
	Welded tuff (Kinangop Tuffs)	Welded tuff
	Treachyte (North Kinangop Trachytes)	Normal lava flow and auto-brecciated lava

The terrain of the contemplated reservoir area and the surroundings is composed of thick lake sediments and a series of Upper Tertiary volcanic and pyroclastic rocks comprising trachytes, welded tuffs and massive tuffs, covered with Quaternary colluvial deposits in parts of flat topography and gentle slopes.

The geological map of the reservoir area is shown in Fig. B.3.1 and the geological profile is shown in Fig.B.3.2.

Geological characteristics of the beds are as described below:

(1) Lithological description

(a) Trachyte

The trachyte, identified under the name of North Kinangop Trachytes, develops only in the contemplated dam site and downstream, forming a gorge and cliffs. Both normal lava features and auto-brecciated lava features are seen in a condition of complicated intermixture. The trachyte bed can probably be divided into several sub-units which represent lava flows of different times. Each sub-unit seems to have its own joint system. The rock is dark grey and hard, often forming cliffs, but inflicted with irregularly developed joints and fissures.

(b) Welded tuff

The welded tuff, consisting of several different flows of similar lithological compositions, develops mainly in the vicinity of the dam site. The characteristics are similar to that in the Malewa scheme area.

(c) Massive tuffs and lake sediments

This geological unit is wide-spread in the contemplated Turasha reservoir area, where the lake sediments dominate the massive tuffs. The geological features are similar to those in the Malewa scheme area described before.

(d) Colluvium

The colluvial deposits, composed of particles of various sizes ranging from silt to boulder, are distributed on flat lands and gentle slopes in the reservoir area. The colluvium develops wider in the Trusha river valley which is flatter than the Malewa valley probably because of a thick lake sediments forming the bedrock in the lower parts of the river banks.

(2) Geological structure

Similar to the Malewa zone, bedding of the bedrocks is sub-horizontal with the general dipping of less than 10 degrees to west-northwest with some variations due to undulation. Two major faults have been found, of which one is inferred to pass through the dam site, though it could not be confirmed for the lack of outcrops. More detailed description of this fault will be presented in the sub-clause of "Geology of the dam site". All the faults show a trend of north-northwest to south-southeast corresponding the regional geomorphological trend of the Great Rift Valley.

3.3.3 Geology of the Dam Site

Stratigraphy of the contemplated dam site is summarised as follows:

Age	Lithological unit	Constituent
Quaternary up to Recent	Riverbed deposit	Clay, silt, sand to boulder.
	Colluvium	Silt, sand, pebble to boulder.
Upper Tertiary up to Pliocene	Welded tuff (Kinangop Tuffs)	Welded tuff
	Massive tuffs (Kinangop Tuffs)	Tuff, lapilli tuff, stratified tuffs
	Lake sediments (Kinangop Tuffs)	Tuffaceous siltstone, sandstone, conglomerate, diatomite
	North Kinangop Trachyte	Massive tuffs (Tuf).
		Trachyte, of normal and auto-brecciated lavas.

The contemplated Turasha dam site is situated among the same geological setting as its reservoir area, with the sub-horizontally bedding volcanic and pyroclastic bedrocks of the Upper Tertiary North Kinangop Trachytes and Kinangop Tuffs, which comprise the trachytes, the massive tuffs and the welded tuffs interbedding with the lake sediments, and the Quaternary overburden of the colluvial deposits and the river alluvial deposits.

The geological map at the Turasha damsite is shown in Fig. B.3.10. The geological profile along the Turasha dam axis is shown in Fig. B.3.11.

Geological descriptions are presented below:

(1) Lithological description

(a) Trachyte

The trachyte, the main member of the North Kinangop Trachytes, is situated at the lowest horizon of the stratigraphy in this area and encountered only in the vicinity of the dam site and downstream. Its geological features are as described in the sub-clause for the reservoir geology.

(b) Massive tuffs (Tuf) of the North Kinangop Trachytes Formation

Occurrence of this massive tuffs, intercalated in the Trachyte lavas, is rather limited. Mainly consisting of green to greenish grey pumiceous and scoria tuffs, the rock is generally porous and friable. A lapilli tuff with white lithic fragments is a minor member of this unit.

(c) Lake sediments

A layer of the lake sediments has been identified on the left bank of the dam site, and two on the right bank. The lake sediment layers on both banks seem to be not continuous, intercepted by a fault passing near the river bed. The lithological characteristics are similar to those in the Malewa site as described before.

(d) Massive tuffs of the kinangop tuffs formation

A layer of the massive tuffs has been identified on the left bank and two on the right bank. The lithological characteristics are similar to those in the Malewa site as described before.

(e) Welded tuff

The welded tuff layers have been identified at three horizons on the left bank and two horizons on the right bank, also intercepted by the said fault through the river bed. The lithological features are similar to the welded tuffs Wtf1 and Wtf2 at the Malewa dam site, except for a layer on the right bank, named Wtf2, which is pale yellow coloured and compact, including smaller pumice fragments, lacking scoria, and smaller and fewer lithic fragments than the other layers, and appears more acidic.

(f) Colluvium

Soil particle composition and locations of the colluvial deposits are as described for the reservoir geology. Boulders contained are often one to two metres in diameter. The thickness observed in the borehole TB-1 on the left bank of the dam site was 8.70 m.

(g) Riverbed deposits

Distribution of this unit is limited only in the bottom of river valleys. Its thickness is estimated to be not more than one metre.

(2) Geological structure

Bedding of the bedrocks is sub-horizontal with west-northwesterly dip of very low angle, as is common in this area, dipping from the left bank to the right bank downstream at the dam site. Two major faults have been found and one inferred in the vicinity of the dam site.

Fault I: Observed on an outcrop on the right bank downstream of the dam site, this trends north-northwest to south-southeast with downthrow on the west side. Width of the sheared zone is approximately 2 m.

Fault II: Identified in the borehole TB-3 and on an outcrop, this fault trends north-northwest to south-southeast, running from a saddle on the left bank to the right bank across the Turasha river. The east side downthrow with width of the sheared zone at one metre.

Fault III: Inferred from geological conditions in the boreholes TB-1 and TB-2 in the dam site, this is deemed to run parallel with Fault II on its east side, with downthrow on the east side. Width of the sheared zone is unknown.

The north-northwesterly trend that all the faults show is concordant with the regional trend of the Great Rift Valley. A sort of horst is formed in a part between Fault I and Fault II, immediately downstream of the dam site, where the gorge and cliffs of the trachyte develop. Fault II and Fault III are supposed to make a set of step faults.

(3) Weathering

The borehole TB-1 revealed that the left bank is moderately to slightly weathered to a depth around 30 m from the ground surface and the groundwater table is at the nearly same level as the river bed. In the other hand, weathering in the right bank is deeper and more intensive and the groundwater table in this bank lies lower than the river bed level, as observed in the boreholes TB-2 and TB-3. These different conditions are deemed to be divided at the Fault II running along the river bed at the dam site, and the highly previous condition with deep penetration of weathering on the right bank probably prevails in the cracky trachyte downstream of the dam site. This trachyte is bounded by Fault II and Fault III, as mentioned above, and a considerable descent of the river bed amounting approximately 40 m in height is formed across this trachyte belt, unfavourably for the watertightness required for the Turasha dam foundation. Grade of the weathering is generally not very high, but for superficial zones and fault vicinities.

IV. ENGINEERING GEOLOGY

4.1 Malewa Dam Scheme

Of all the young volcanic and pyroclastic bedrocks in this area, the Pliocene lake sediments are the weakest from foundation engineering point of view. This sediments are deemed empirically, however, still stable enough for foundation of fill-type dams of some 60 m in height if it is not weathered to more than moderate grade.

The overburden and the highly weathered rock zone are thin, except at the foot of the slopes on both banks. Competent bedrock for the dam foundation can be reached at the depth of several metres from the present ground surface in the dam abutments, while approximately eight metre deep excavation will be required for foundation of impervious earth core of dam in the river bed section in order to remove colluvial overburden and loose zone of the lake sediments. Necessary depth of excavation for dam shell zone foundation would be about five metres in the river bed and two metres in the abutments.

It is possible that the lake sediments, slightly or moderately weathered, may be a tolerable foundation for a low concrete gravity weir structure of the spillway, though confirmation with in-situ rock test will be necessary for a detailed design in future. With no substantial difference in geological conditions of both banks, layout of the spillway is to be determined on the basis other than geology.

The field permeability test in the boreholes show that the permeability in fresh rocks and slightly to moderately weathered rocks is usually 5 Lugeon or less in this site, with a few exceptions. Higher Lugeon values over 10 are only occasionally observed near boundaries of the lake sediments. Ordinary treatment with curtain grouting will be sufficient for underseepage cut-off. Considering the unusually low groundwater table on both banks, it is recommended to extend the grout curtain deep into both abutments with rim grouting.

No sign of significant land sliding, existing or potential, has been found in the reservoir area. The slopes are, however, subject to considerable erosion, particularly below cultivated lands and barren lands. Minor collapses of the slopes are seen being incurred by this sort of surface erosion. It is difficult to eliminate the possibility of minor local landsliding to occur in the colluvial deposits on the slopes around the level of the reservoir water level, but such sliding, if occurs, will be of too small scale to result in any practical damage. Any potential passage for substantial water leakage from the reservoir has not been found.

4.2 Turasha Dam Scheme

This site is characterized by the development of trachyte and the existence of the faults of substantial sizes.

Overburden is as thick as 8.7 m on the left bank, while it is thin on the river bed and the right bank. In the meantime, highly weathered zone of the bedrock is eight metres thick on the right bank but thin on the river bed and the left bank. The bedrock competent enough for foundation of the 60-metre high fill-type dam will be reached at the depth of nearly 10 m from the present ground surface in the abutments. The depth to the dam core foundation under the river bed could be less, e.g. around 6 m. Depth of excavation necessary for the shell zone foundation will averagely be 6 to 7 m in the left bank and 1 or 2 metres on the river bed and the right bank.

The left bank will be preferable for location of the spillway weir, from geological point of view, because of the massive tuff foundation there which is more stable than the lake sediments at the spillway level on the right bank. Foundation excavation to the depth similar to that for the dam core zone will be required for the spillway weir.

Permeability of the bedrock, in particular in the cracky trachyte cut by the faults, is extraordinarily high. Special seepage cut-off structures as a sub-surface wall may be necessitated, other than intensive grouting for curtain and rim.

No evidence of potential landsliding in a substantial scale has been observed in the reservoir area, though possibility of minor, rather harmless slidings remain as in the case of the Malewa scheme.

4.3 Geological Comparison of the Malewa and Turasha Dam Schemes

Contrast of geological conditions for the Malewa scheme and the Turasha scheme is summarised in the following list, which indicates the foundation engineering preference of the Malewa dam scheme.

Item	Malewa Dam	Turasha Dam
Valley section	River bed at El. 2,082 m. Width 190 m at El. 2,145 m.	River bed at El. 2,096 m. Width 380 m at El. 2,160 m.
Bedrock, structure and fault	Upper Tertiary (Pliocene) welded tuffs, massive tuffs, lake sediments, interbedding each other, each layer not thicker than 20 m.	Upper Tertiary (Pliocene) trachytes, welded tuffs, massive tuffs, lake sediments, interbedding each other.
	Dipping 10 degrees or less from the left bank toward the right bank downstream.	Dipping 10 degrees or less from the left bank toward the right bank downstream.
	No major fault.	A major fault identified on the right bank and an inferred fault through the left river bank.
Overburden	Negligibly thin.	Thick colluvial deposit (8.7 m thick) on the left bank.
Weathering	Moderate to slight weathering to depths around 30 m. Fresh in the river bed.	Weathered deeper to under the river bed, intensive on faults
Groundwater and permeability	Groundwater levels on both banks are as low as the river bed level.	Groundwater levels on both banks are as low as the river bed level.
	Permeability of the bedrock under 5 Lugeon.	Permeability of the bedrock more than 100 Lugeon.
Reservoir	No potentiality for serious water loss and hazardous landsliding.	No potentiality for serious landsliding. Intensive treatment will be required to stop probable major water loss downstream from the dam site.

V. FOUNDATION ENGINEERING OF MALEWA DAM

5.1 General

According to the logs of the test drillings, there is no substantial new finding in geological conditions to be added to the results of the Phase 1 Study, except some local variations in thickness of the lithological units.

Some differences in permeability of the bedrocks, however, has been observed. The results of permeability tests in the Phase 2 Study show generally higher values than that obtained through the field investigation of the Phase 1 Study. Especially, around the boreholes, MB-8 and MB-9 on the left bank, several stages up to 60 m in depth show 20 to 50 Lugeon and more than 100 occasionally. In other boreholes the Lugeon values were less than 15 with few exceptions. It is anticipated that ordinary treatment with curtain grouting will be sufficient for underseepage cut-off in dam foundation. Considering the usually low groundwater table on the both banks, it is recommended to extend rim grout curtains far into both abutments.

5.2 Main Dam

5.2.1 Foundation Excavation

Geological map and geological profiles are shown in Figs. B.3.3 to B.3.4. Lugeon maps are shown in Figs. B.5.1 to B.5.3.

Removal of the overburden and the highly weathered rock zone will be sufficient for preparing foundation of dam shell zone, while removal of a zone of 20 Lugeon or more (Zone 1 in the Lugeon map) and other loose zones will be required for foundation of impervious earth core of the dam.

From the above point of view, necessary depth of excavation for dam shell zone foundation would be about 5 m in the river bed and 2 m in the abutments. For foundation of impervious earth core of dam, it would be about 8 m (up to the lower boundary of LSd2) in the left bank, 16 m on the left slope, and 8 m in the river bed, as indicated by boreholes MB9, MB4 and MB2, and 3 to 5 m in the right abutment.

5.2.2 Curtain and Rim Grouting Program

The Lugeon maps show-higher Lugeon values on the left bank, while no substantial problem is seen in permeability of the bedrocks in the area from the river bed to the right bank. In the boreholes MB-8 and MB-9, for instance, several stages up to 60 m of depth show 20 to 50 lugeon and more than 100 occasionally.

Extent and depth of the curtain and rim grouting have been planned as shown in Fig. B.5.1 to B.5.3, with all the following conditions in view.

- Target Lugeon value after grouting (5 lugeon)
- Geology
- Lugeon value before grouting
- Groundwater level and high water level in the reservoir
- Creep length

It is proposed that the curtain and rim grouting shall cover the extent from the borehole, MB-7 on the left bank to the borehole MB-10 on the right bank, and the depth of 30 m to 60 m on the both banks and 30 m in the river bed. A recommendable arrangement of grout holes is two metres intervals on three parallel lanes spaced at one metre.

5.3 Spillway

Geological profile along the spillway is shown in Fig. B.3.8.

It is possible that the lake sediments slightly or moderately weathered, which are the weakest bedrock in this area, still provide a tolerable foundation for a low concrete gravity weir structure of the spillway. Excavation of the surface zone of 20 Lugeon or more (Zone 1 in the lugeon maps) will be required for foundation of the spillway for underseepage cut-off.

From the above point of view, necessary depth of excavation for spillway foundation would be 8 m for the overflow weir and 5 to 8 m for the chuteway.

Long and high cut slope will be formed by excavation of spillway. Slope protection works, e.g., shotcrete or sodding, will be required, especially for the lake sediments, in order to protect it from weathering and failure.

5.4 Diversion Tunnel

Geological profile along the diversion tunnel route is shown in Fig. B.3.7.

The greater part of the bedrock along the diversion tunnel is of soft rocks of the lake sediments and tuffs including non-welded tuff layer. Hard welded tuff is encountered only in a 50 memtre section from the tunnel outlet, i.e., only in a 15 per cent portion of the tunnel length.

Weathered or loose zones near the tunnel portals will require supporting measures. There is no problem of groundwater discharge except for welded tuff area within about 50 m from the outlet.

5.5 Trans-basin Diversion Tunnel

Geological profile along the trans-basin tunnel route is shown in Fig. B.3.2 (E-E' profile).

Geology around the intake structures of the trans-basin tunnel is composed of soft rocks of the lake sediments and tuffs as shown in the drilling logs of the borehole MB-11.

Small collapses and slaking may occur on the surface of excavated rock, exposed to atmosphere. Seepage water inflow to the tunnel can be minor because of the low permeability of the lake sediments and tuffs.

The tunnel will pass through the soft rocks of the lake sediments and tuffs in its initial 1.9 km section from the intake portal, and then, through the hard trachyte in the subsequent 0.7 kilometres to the outlet. Fault I (refer to the sub-section 3.2) may be encountered in the vicinity of the point 1.7 km from the intake and Fault II may be met near the outlet.

Exfoliation or partial cave-in may occur near the tunnel portals and on fractured zones, unless due supporting measures with steel ribs or shotcrete and rock bolts are applied. Groundwater discharge from fissured trachyte and sheared zones should be taken into account.

5.6 Sliding or Subsidence of Lake Sediments

The softness of the lake sediment has raised a question on possibility of sliding and subsedence on reservoir impounding. Subsidence due to consolidation, however, is unlikely for even a soft bedrock which had once been under heavy overburden thicker than that in the present time. Minor deformation, that may take place due to change in mechanical characteristics of the lake sediment under saturation, will be of magnitude practically not serious.

Sliding is possible where a slide surface (sliding plane) is likely to develop. Small slidings or slips as a part of erosion may occur in the lake sediment bed, while sliding of large scale, involving many other bedrocks, does not seem likely to occur because any long slide surface is difficult to develop through harder rock beds in sub-horizontal alternation.

Protective measures, however, are recommended for stability of the slopes located near important structures, by means of slope trimming, covering with filter and rock material, counterweight embankment or others which fit to site conditions.

TABLES

Table B2.1 QUANTITY OF PRELIMINARY GEOLOGICAL INVESTIGATION

1. FIELD GEOLOGICAL RECONNAISSANCE AND MAPPING 24.5 km^2

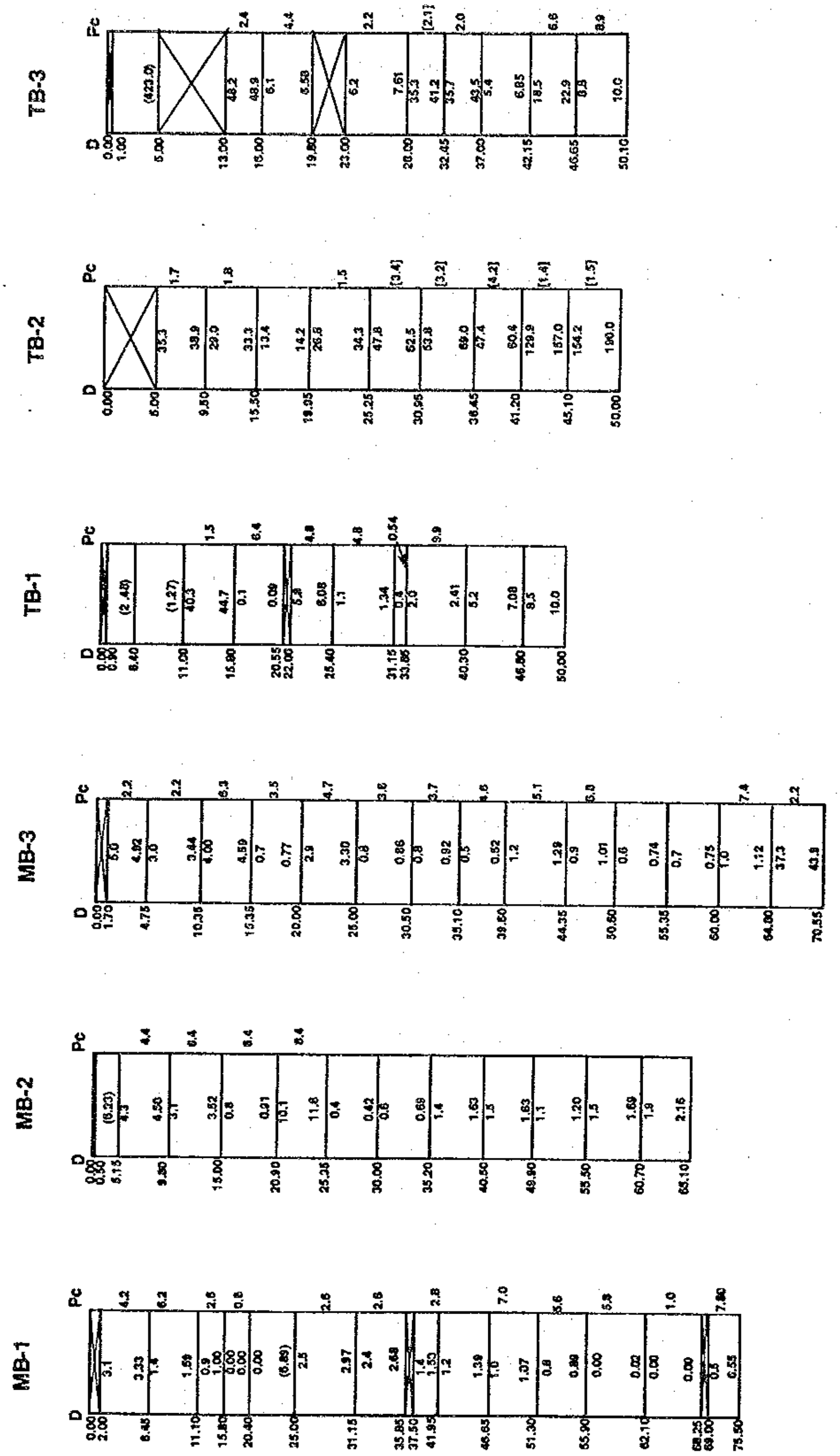
LOCATION	QUANTITY
Reservoir areas (Scale 1/5,000)	
Malewa river	11.5 km^2
Turasha river	11.0 km^2
Dam sites (Scale 1/500)	
Malewa river	1.0 km^2
Turasha river	1.0 km^2

2. EXPLORATORY CORE DRILLING 360.0 m (permeability test 71 stages)

Dam Site	Hole No.	Location	Elevation (m)	Depth (m)	Borehole TEST	Permeability (stage)
Malewa	MB-1	Left bank	2151.42	75.0	14	(1)
	MB-2	River bed	2087.83	65.0	13	(1)
	MB-3	Right bank	2153.33	70.0	14	
			Sub-total	210.0	41	(2)
Turasha	TB-1	Left bank	2128.61	50.0	10	(2)
	TB-2	River bed	2098.18	50.0	10	(1)
	TB-3	Right bank	2132.43	50.0	10	(2)
			Sub-total	150.0	30	(5)

Note: Parentheses ( ) show the number of Constant Head Test.

Table B.2.2



Note : (1) D means depth in m

(2) Upper value means Lugeon unit, Lower value means cofficient of permeability in 10^{-5} cm / sec
( ) means obtained by constant head method.

(3) Pc means critical pressure in kg / sq . cm
[ ] means available maximum pressure.

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Table B.2.3 Quantity of Detailed Geological Investigation

Exploratory Core Drilling 560.0 m (Permeability test 112 staged)

Boreholes		Location	Elevation (El. m)	Depth (m)	Permeability Test (nos.)
Phase 1	MB-1	Left bank	2,151.42	75	14 (1)
	MB-2	River bed	2,087.83	65	13 (1)
	MB-3	Right bank	2,153.33	70	14
			Sub total	210	41 (2)
Phase 2	MB-4	Left bank	2,129.77	70	14 (1)
	MB-5	Right bank	2,131.97	70	14 (1)
	MB-6	River	2,088.44	70	14 (1)
	MB-7	Left bank	2,159.60	70	14
	MB-8	Left bank	2,157.03	70	14
	MB-9	Left bank	2,157.25	70	14 (1)
	MB-10	Right bank	2,160.22	70	14 (1)
	MB-11	Intake	2,115.20	70	14 (1)
			Sub total	560	112 (6)
			Total	770	153 (8)

Note ; The Figures in perentheses show the number of tests by a constant head method.

Table B.2.4

MB-4

D (from – to)	Upper value	Lower value	Pc
0 – 5.00	(41.5)		
5.00 – 10.00	14.2	15.9	0.9
10.00 – 15.00	36.1	40.4	0.7
15.00 – 20.00	0.0	0.0	0.4
20.00 – 25.00	0.8	0.859	2.6
25.00 – 30.00	1.0	1.09	2.5
30.00 – 35.00	2.2	2.55	4.5
35.00 – 40.00	1.5	1.77	6.6
40.00 – 45.00	7.0	8.09	5.6
45.00 – 50.00	9.9	11.4	3.2
50.00 – 55.00	13.5	15.5	6.0
55.00 – 60.00	5.2	5.93	9.0
60.00 – 65.00	1.4	1.60	5.3
65.00 – 70.00	0.41	0.467	4.9

MB-5

D (from – to)	Upper value	Lower value	Pc
0 – 5.00	(214)		
5.00 – 10.00	8.5	9.77	3.5
10.00 – 15.00	9.3	10.7	4.5
15.00 – 20.00	8.1	9.28	4.2
20.00 – 25.00	7.8	9.00	4.5
25.00 – 30.00	9.5	10.9	1.2
30.00 – 35.00	6.7	7.70	1.2
35.00 – 40.00	27.6	31.8	4.7
40.00 – 45.00	7.3	8.41	5.2
45.00 – 50.00	20.1	23.1	6.5
50.00 – 55.00	12.6	14.5	6.3
55.00 – 60.00	13.3	15.2	3.3
60.00 – 65.00	1.1	1.21	9.4
65.00 – 70.00	0.7	0.822	9.2

MB-6

D (from – to)	Upper value	Lower value	Pc
0 – 5.00	(4,160)		
5.00 – 10.00	10.6	12.2	
10.00 – 15.00	9.8	11.2	8.5
15.00 – 20.00	9.7	11.1	
20.00 – 25.00	12.6	14.5	8.5
25.00 – 30.00	12.0	13.8	8.5
30.00 – 35.00	3.2	3.65	
35.00 – 40.00	1.8	2.10	
40.00 – 45.00	1.7	1.98	
45.00 – 50.00	5.2	6.03	8.5
50.00 – 55.00	4.7	5.46	8.6
55.00 – 60.00	2.1	2.44	
60.00 – 65.00	1.0	1.10	
65.00 – 70.00	1.1	1.23	

MB-7

D (from – to)	Upper value	Lower value	Pc
0 – 2.00			
2.00 – 6.55	5.8	6.34	2.5
6.55 – 10.00	10.5	11.8	2.7
10.00 – 15.00	0.9	0.992	0.6
15.00 – 20.00	0.0	0.0	1.6
20.00 – 25.00	5.4	6.07	3.2
25.00 – 30.00	7.1	7.90	0.8
30.00 – 35.00	13.5	15.5	7.4
35.00 – 40.00	1.5	1.71	2.1
40.00 – 45.00	9.0	10.4	3.6
45.00 – 50.00	11.4	13.1	3.2
50.00 – 55.00	13.2	15.1	8.6
55.00 – 60.00	0.1	0.079	4.6
60.00 – 65.00	0.1	0.157	2.3
65.00 – 70.00	0.7	0.877	4.7

MB-8

D (from – to)	Upper value	Lower value	Pc
0 – 1.30			
1.30 – 6.30	20.5	23.0	2.4
6.30 – 10.90	6.2	7.69	8.8
10.90 – 15.00	29.6	33.2	[6.5]
15.00 – 20.00	29.2	32.7	[6.7]
20.00 – 25.00	14.2	15.9	0.7
25.00 – 30.00	55.3	62.0	[3.6]
30.00 – 35.00	11.6	13.6	1.6
35.00 – 40.00	14.2	15.9	1.7
40.00 – 45.00	1.6	1.73	2.0
45.00 – 50.00	24.8	27.8	[6.9]
50.00 – 55.00	13.9	16.0	8.6
55.00 – 60.00	0.1	0.152	3.0
60.00 – 65.00	5.3	6.09	2.8
65.00 – 70.00	7.4	8.46	2.9

MB-9

D (from – to)	Upper value	Lower value	Pc
0 – 6.50	(18.9)		
6.50 – 10.00	56.0	57.5	3.0
10.00 – 15.00	3.4	3.76	3.3
15.00 – 20.00	3.4	3.78	4.4
20.00 – 25.00	10.2	11.7	2.6
25.00 – 30.00	177.6	204	[0.4]
30.00 – 35.00	19.3	22.2	1.2
35.00 – 40.00	0.8	0.863	3.1
40.00 – 45.00	1.7	2.00	3.8
45.00 – 50.00	2.7	3.11	4.1
50.00 – 55.00	12.3	14.1	9.3
55.00 – 60.00	12.0	13.8	9.4
60.00 – 65.00	9.0	10.3	
65.00 – 70.00	0.9	10.6	4.8

MB-10

D (from – to)	Upper value	Lower value	Pc
0 – 5.00	(229)		
5.00 – 10.00	143.2	161	0.7
10.00 – 15.00	99.9	112	0.9
15.00 – 20.00	9.0	10.1	8.7
20.00 – 25.00	2.5	2.81	2.6
25.00 – 30.00	2.4	2.70	8.8
30.00 – 35.00	12.9	14.4	7.8
35.00 – 40.00	1.7	1.96	
40.00 – 45.00	1.8	2.03	
45.00 – 50.00	3.5	3.90	5.3
50.00 – 55.00	3.5	4.00	7.7
55.00 – 60.00	8.6	9.61	9.5
60.00 – 65.00	29.6	34.0	4.1
65.00 – 70.00	3.8	4.40	4.9

MB-11

D (from – to)	Upper value	Lower value	Pc
0 – 5.00	(113)		
5.00 – 10.00	14.2	16.0	4.2
10.00 – 15.00	15.0	16.8	4.6
15.00 – 20.00	5.6	6.28	3.8
20.00 – 25.00	9.4	11.0	0.8
25.00 – 30.00	32.7	37.6	5.5
30.00 – 35.00	15.3	17.6	0.6
35.00 – 40.00	3.3	3.79	
40.00 – 45.00	14.5	16.6	9.3
45.00 – 50.00	1.8	2.06	
50.00 – 55.00	2.0	2.31	
55.00 – 60.00	2.5	2.91	9.4
60.00 – 65.00	1.6	1.82	9.1
65.00 – 70.00	0.2	0.197	

Note : (1) D means depth in m

(2) Upper value means Lugeon unit, Lower value means cofficient of permeability in 10^{-5} cm / sec
( ) means obtained by constant head method.

(3) Pc means critical pressure in kg / sq . cm
[ ] means available maximum pressure.

THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	*THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM* *GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION* JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Results of Borehole Permeability Test (Pase 2)

Table B3.1 Regional Geological Stratigraphy

QUATERNARY	RECENT		SUPERFICIAL DEPOSITS ; SOILS, ALLUVIUM, ETC. HOT SPRING DEPOSITS ; TRAVERTINE VOLCANIC ROCKS UPPER MENAGAI VOLCANICS ELEMENTAITA BASALTS SEDIMENTS : LOBOI SILTS MAKALIA SEDIMENTS LOGOMUKUM SEDIMENT -------- .Weak unconformity - - - - ?Gamblian sediments of Nderit and Makalia Sections
	PLEISTOCENE	UPPER	MINOR FAULTING Lamudia Sediment; Solai Tuff; Tuffs and fluviatic Sediments of MUGRIN and NDOLAITA Pumice Showers from Menengai; Fluviatile Sediments of Lower Arabet Valley MINOR FAULTING
		MIDDLE	UPPER MIDDLE: Elementaita Basalts (Older) (Elementaita Cones) (Honeymoon Hill Cones) Kariandas Lake Beds "Kangeran" Acheulian Arfifacts THIRD MAJOR FAULTING OF RIFT VALLEY LOWER MIDDLE: Gilgil Trachyte; Ronda Sediments; Ronda Phonolite and Trachyte Enigina Cove sediments; West Cliff sediments Mbarak Basalt Willan's Farm Trachyte; Nakuru Lake Sysndicate Phonolite (Late Pumice Tuff, Welded Tuff Ignimbrite) and sediments forming uncomformable outliers an the Kinangop and Bahati Tuffs)
c. 1 x 10^6 years		Lower	
UPPER TERTIARY	PLIOCENE ↓ ? ↑		SECOND MAJOR FAULTING OF RIFT VALLEY MAU TUFFS; 6. BAHATI TUFF; 5. KINANGOP TUFFS; LOWER MENENGAI VOLCANIC SERIES and SIRROCON VALCONIC SERIES 5. Kisinana Sediments; 4. Fragmental Trachyte of Kariandus 4. Dispei - Lake Hannington; 3. North Kinangop Trachyte 3. (Chemeron Sediments); 2. Turasha Lake Beds 2. Kwaibus Basalt; 1. Turasha Basalt, Olivin Basalt Flows 1. Gotumet Basalt (Total thickness of Pliocene succession may be locally over 10,ooo feet.) FIRST MAJOR FAULTING OF RIFT VALLEY THOMSON FALLS PHONOLITES OLORONYI BASALT OL DONYO OLEIP BASALT RUMULTI FOREST BASALT; SATTIMA LAVAS RUMURUTI PHONOLITES WRAPPING OF FAULTING (? and Erosion) .........UNCOMFORMITY (may be localized) SAMBURU VALCONIC SERIES; SIMBARA VOLCANIC SERIES Sub - valconic Sediments at Kirimun and Palagalagi FIRST MINOR WARPING OF RIFT VALLEY FORMING BASINS IN AHICH SUB - VALCONIC SEDIMENTS WEE DEPOSITED.
c. 20 x 10^6 years	MIOCENE		
EARLY TERTIARY MESOZOIC PALEOZOIC			INTERVAL OF SEVRAL HUNDRED MILLION YEARS IN WHICH SUCCESSIVE EROSION CYCLES AND EPEIROGENIC MOVEMENTS AFFECTED THE CONTINENTAL SURFACE.
PRECAMBRIAN			BASEMENT SYTEM : (PRECAMBRIAN ORGENIC MOVEMENTS TO SOME EXTENT CONTROL TERTIARY - QUATERNARY STRUCTURES)

FIGURES

Fig. B.2.1

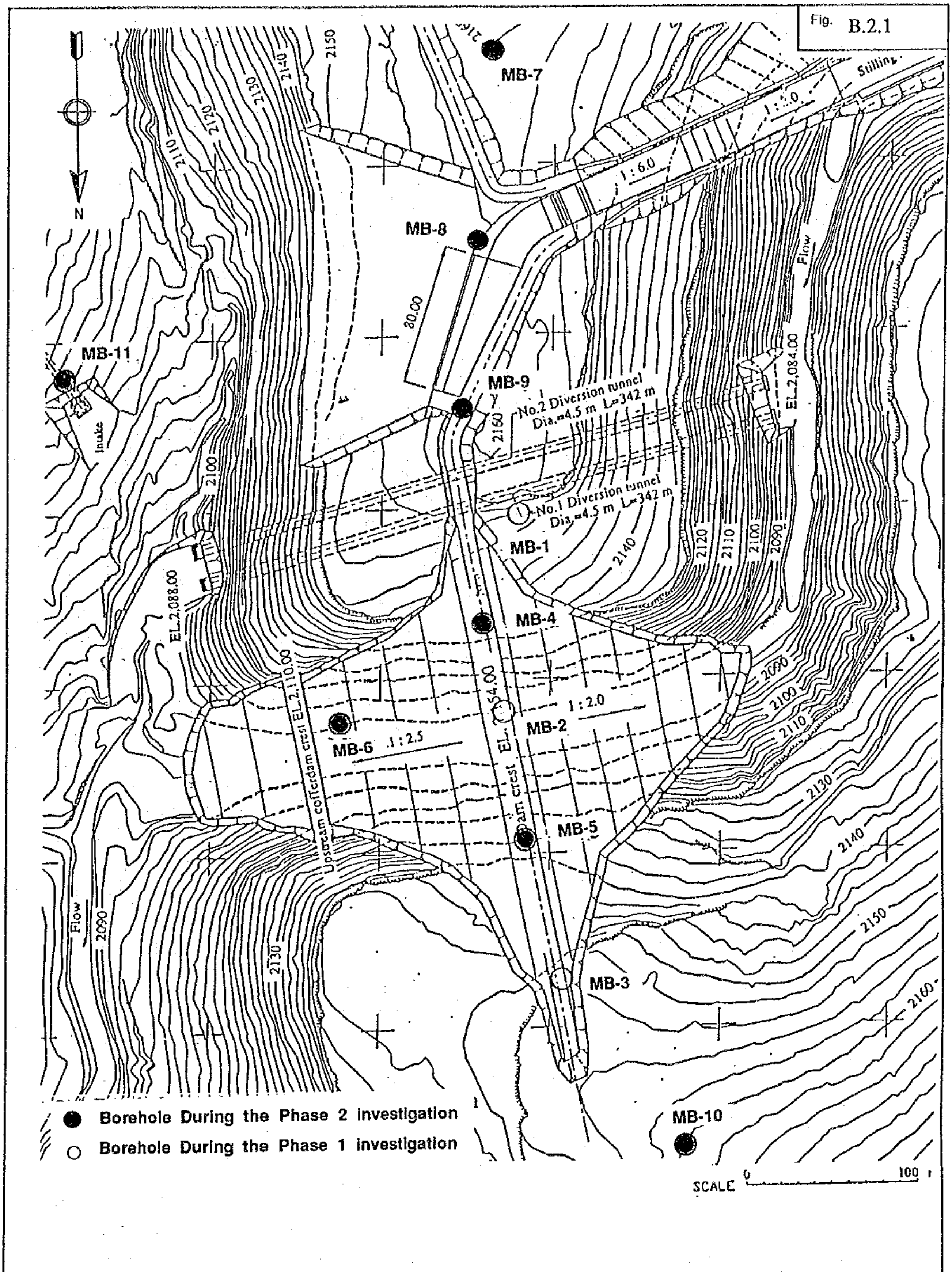

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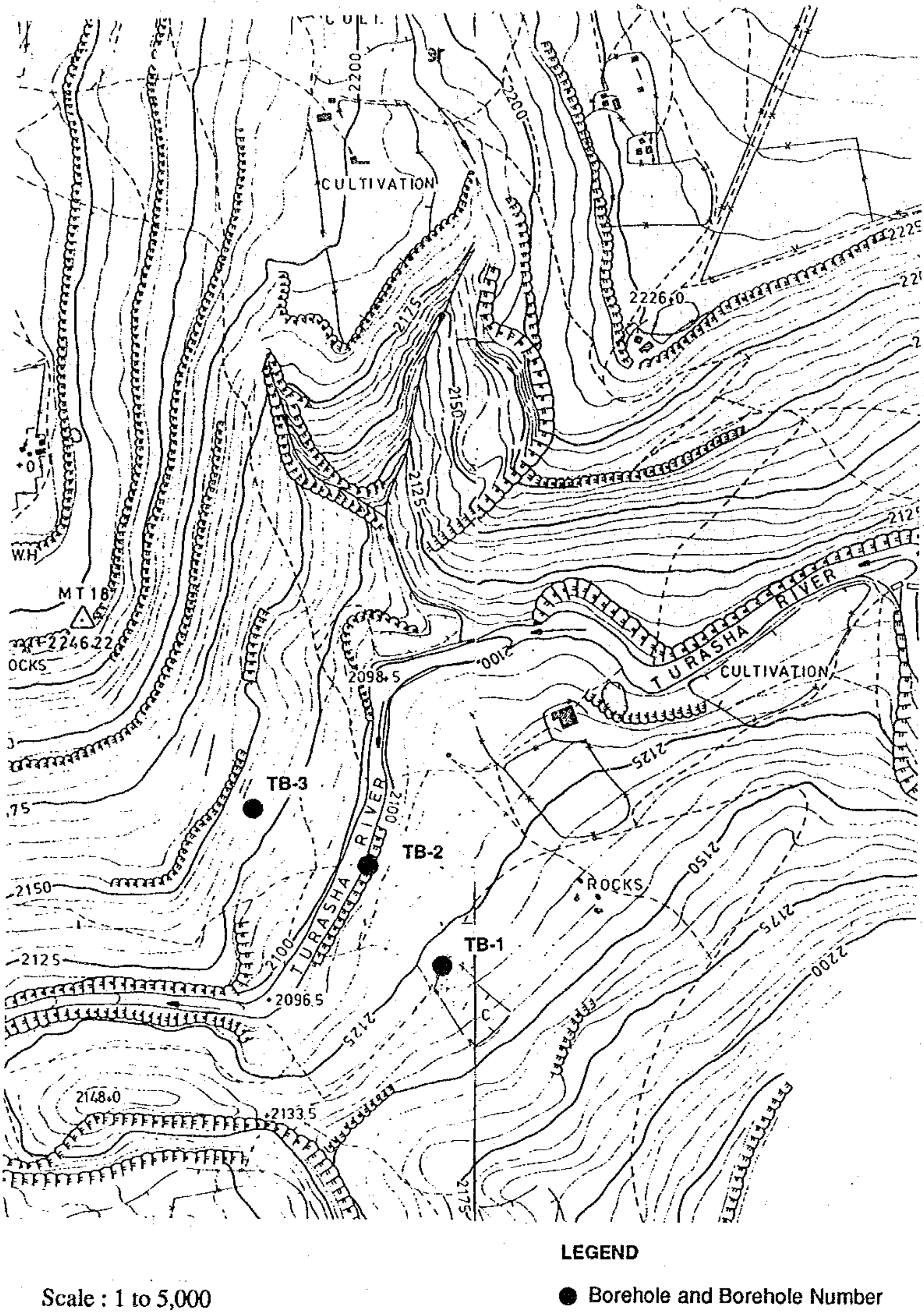
Fig. B.2.2



Scale : 1 to 5,000

LEGEND

● Borehole and Borehole Number

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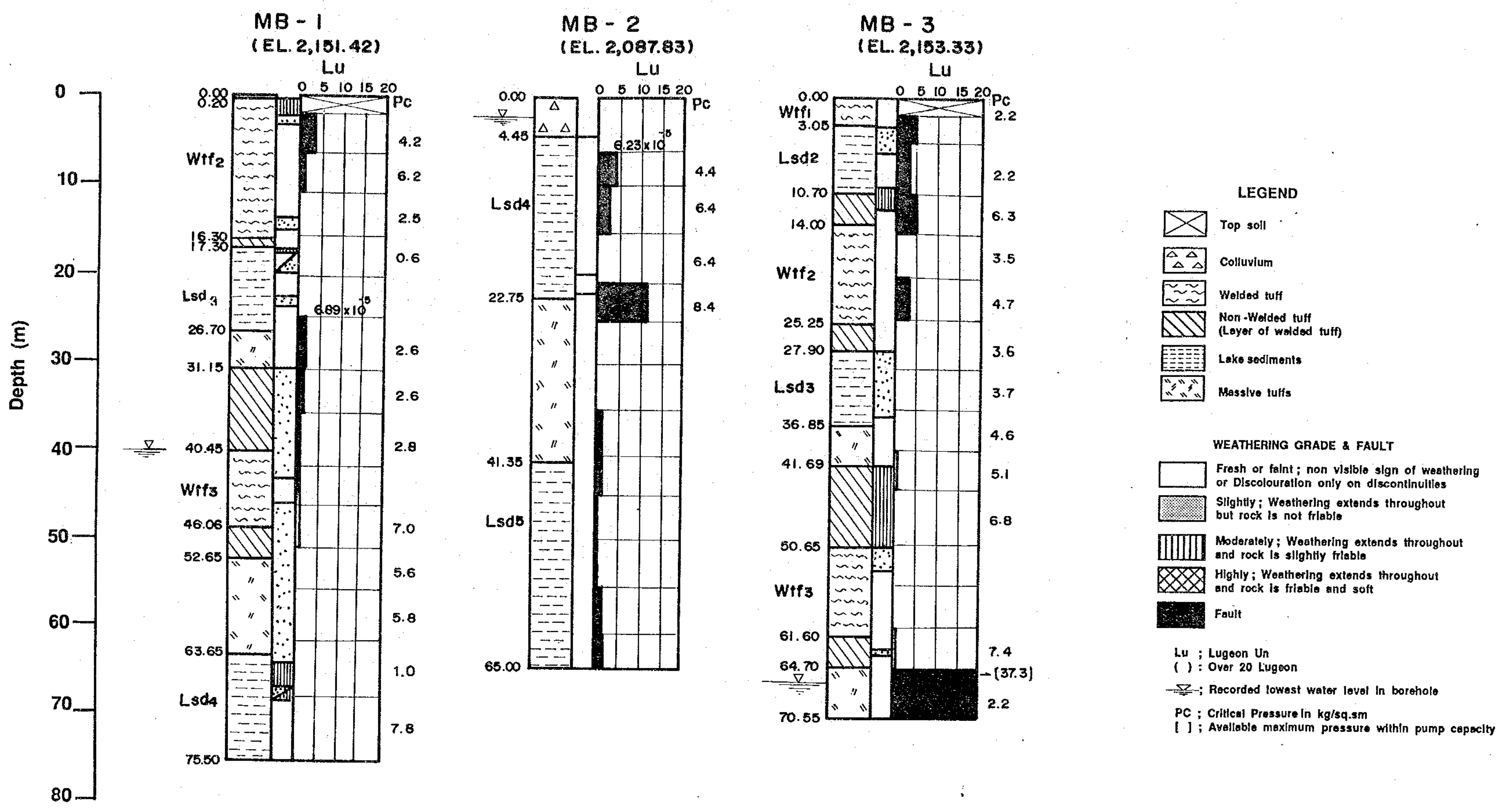
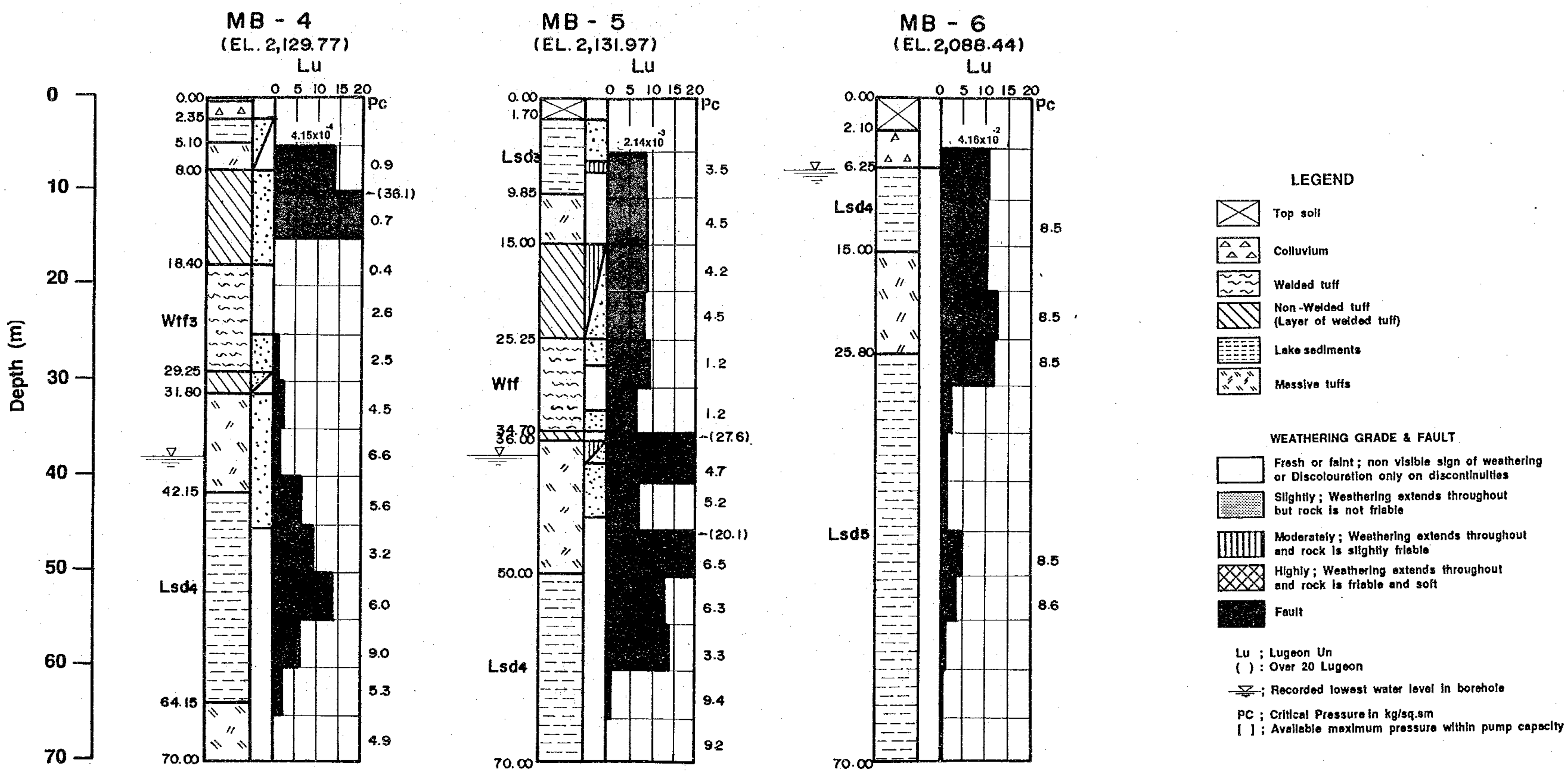


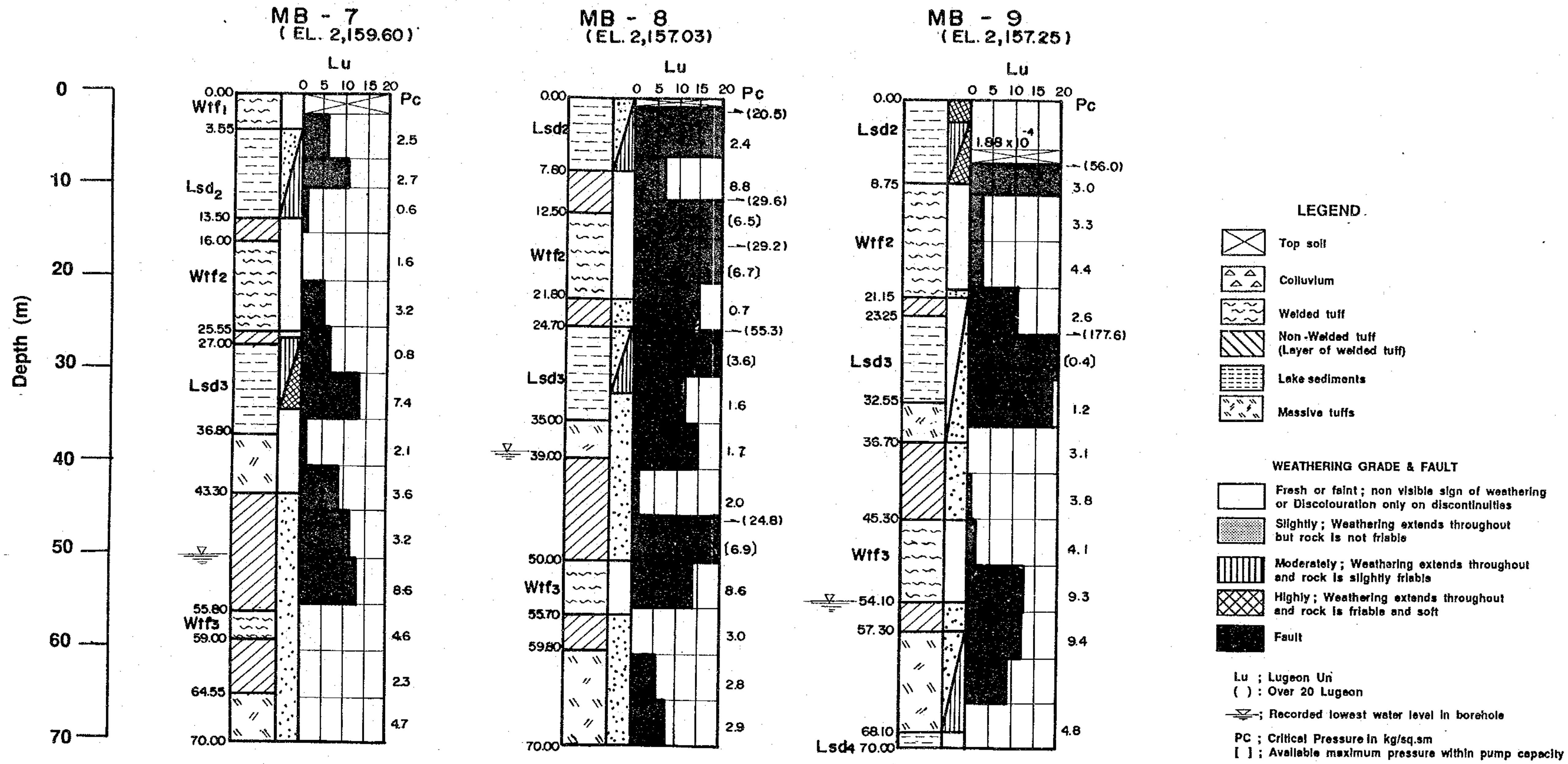
THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Drilling Logs at Malewa Damsite

Fig. B.2.3



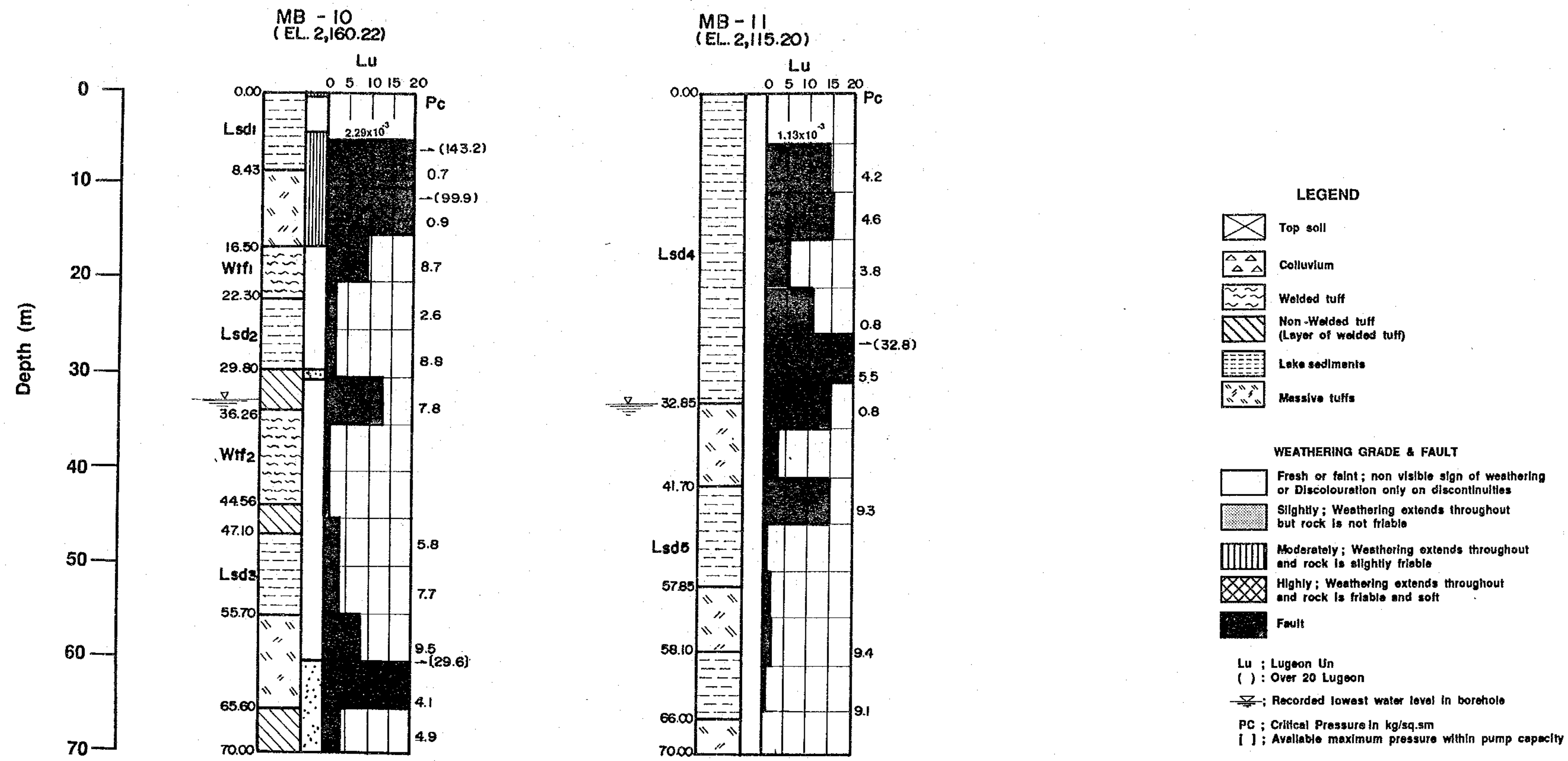
THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Drilling Logs at Malewa Damsite

Fig. B.2.3

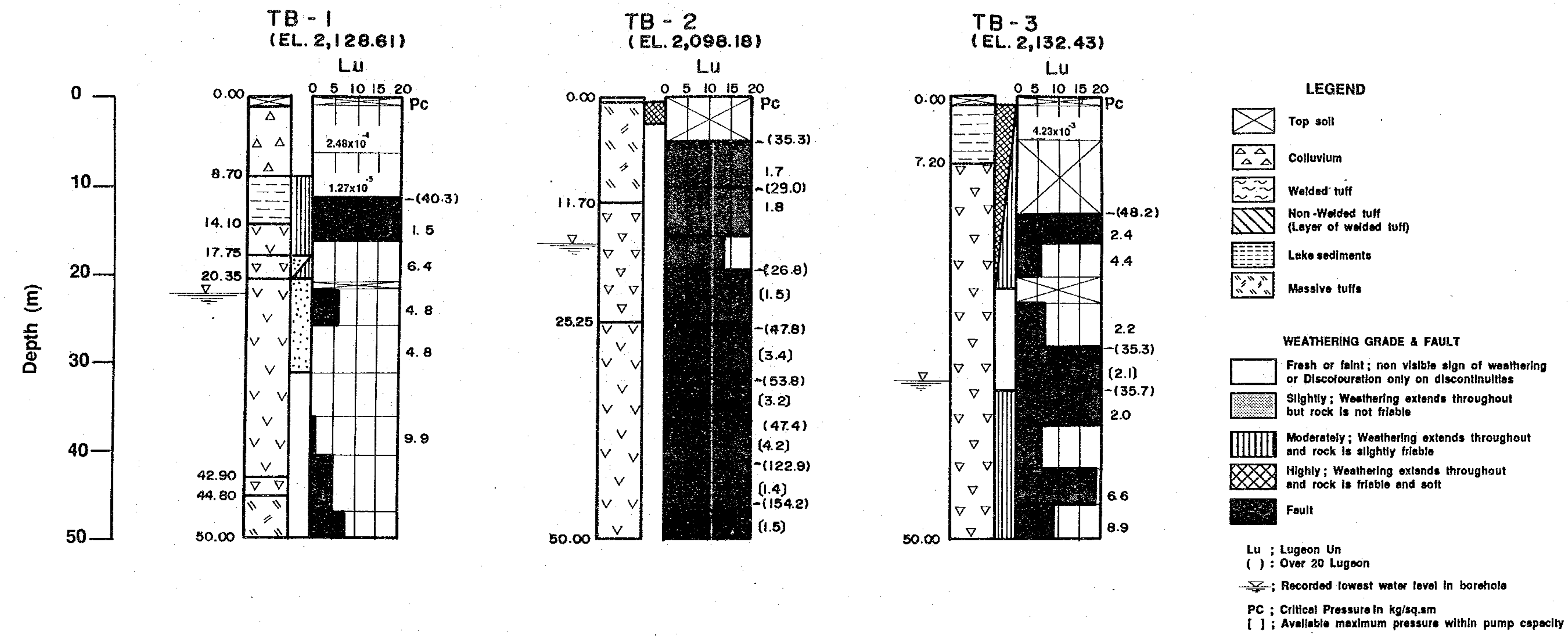


THE REPUBLIC OF KENYA	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION	TITLE
MINISTRY OF WATER DEVELOPMENT		Drilling Logs at Malewa Damsite
NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	JAPAN INTERNATIONAL COOPERATION AGENCY	

Fig. B.2.3

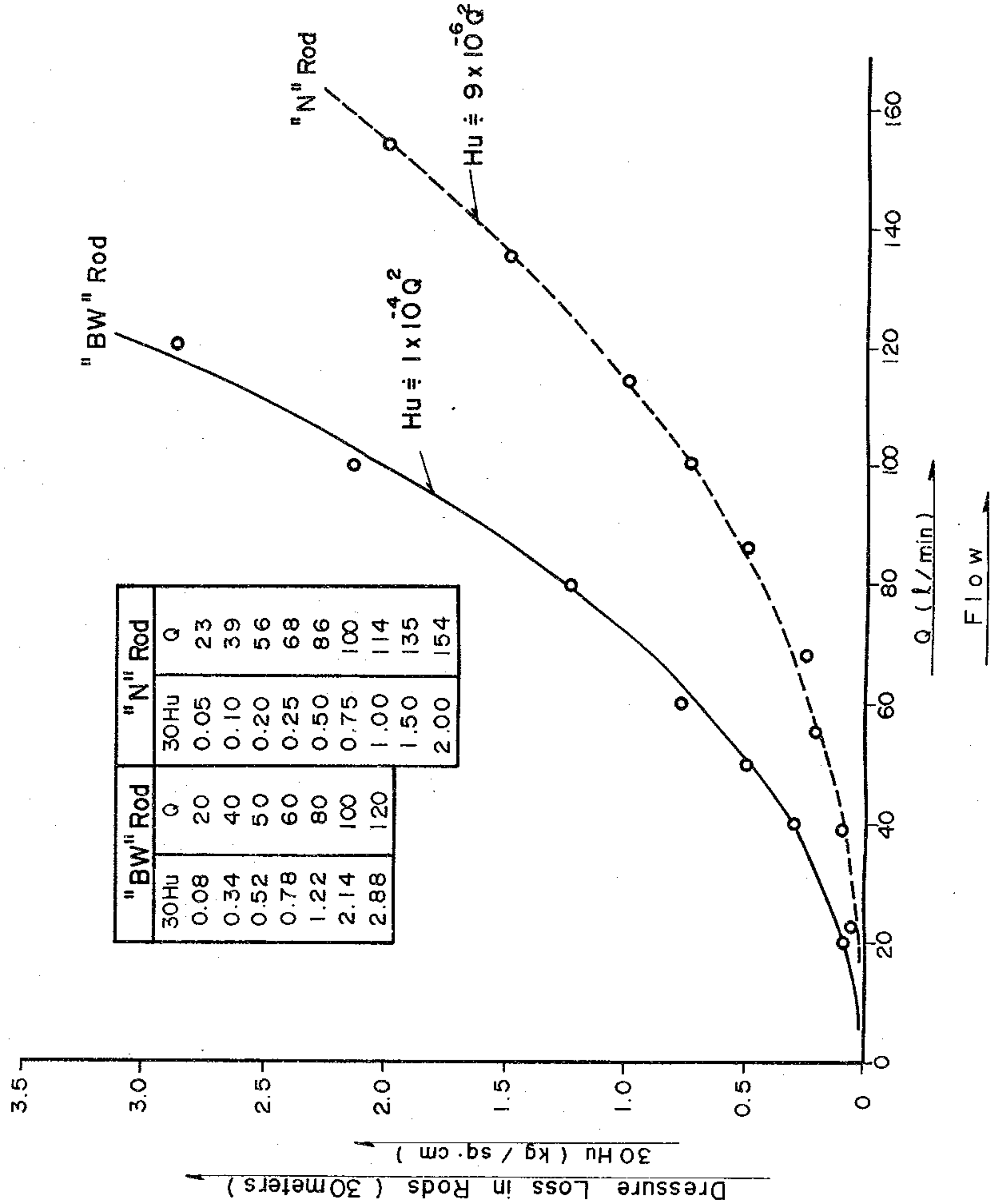


THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Drilling Logs at Malewa Damsite



THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Drilling Logs at Turasha Damsite

Fig. B.2.5



"BW" Rod 30Hu	"BW" Rod Q	"N" Rod 30Hu	"N" Rod Q
0.08	20	0.05	23
0.34	40	0.10	39
0.52	50	0.20	56
0.78	60	0.25	68
1.22	80	0.50	86
2.14	100	0.75	100
2.88	120	1.00	114
		1.50	135
		2.00	154

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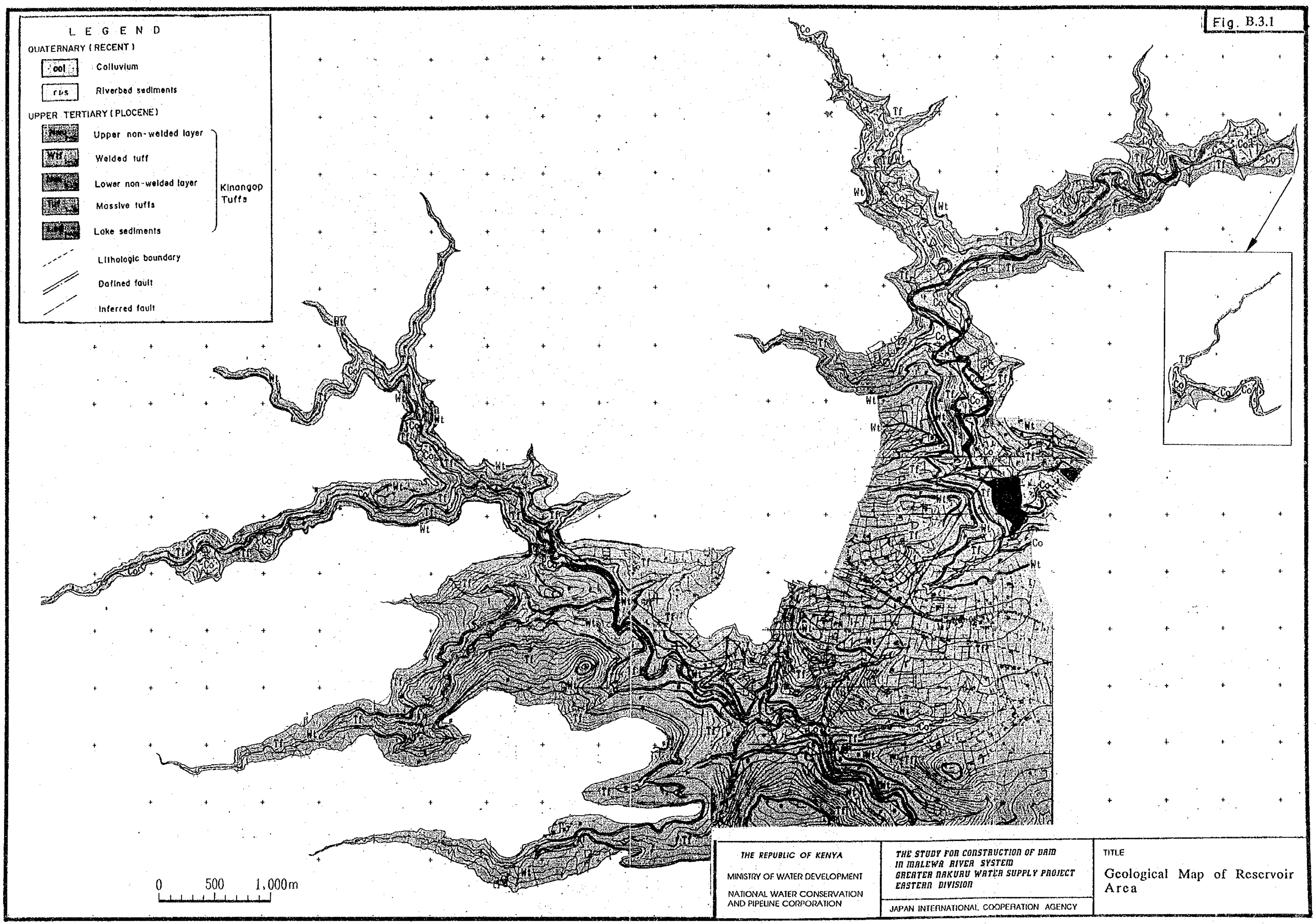
Fig. B.3.1
LEGEND
QUATERNARY (RECENT)
col Colluvium
rbs Riverbed sediments
UPPER TERTIARY (PLOCENE)
Upper non-welded layer
Wtf Welded tuff
Lower non-welded layer
Tff Massive tuffs
Lake sediments
Kinangop Tuffs
Lithologic boundary
Defined fault
Inferred fault
0 500 1,000m
THE REPUBLIC OF KENYA
MINISTRY OF WATER DEVELOPMENT
NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION
THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM
GREATER NAKURU WATER SUPPLY PROJECT
EASTERN DIVISION
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE
Geological Map of Reservoir Area

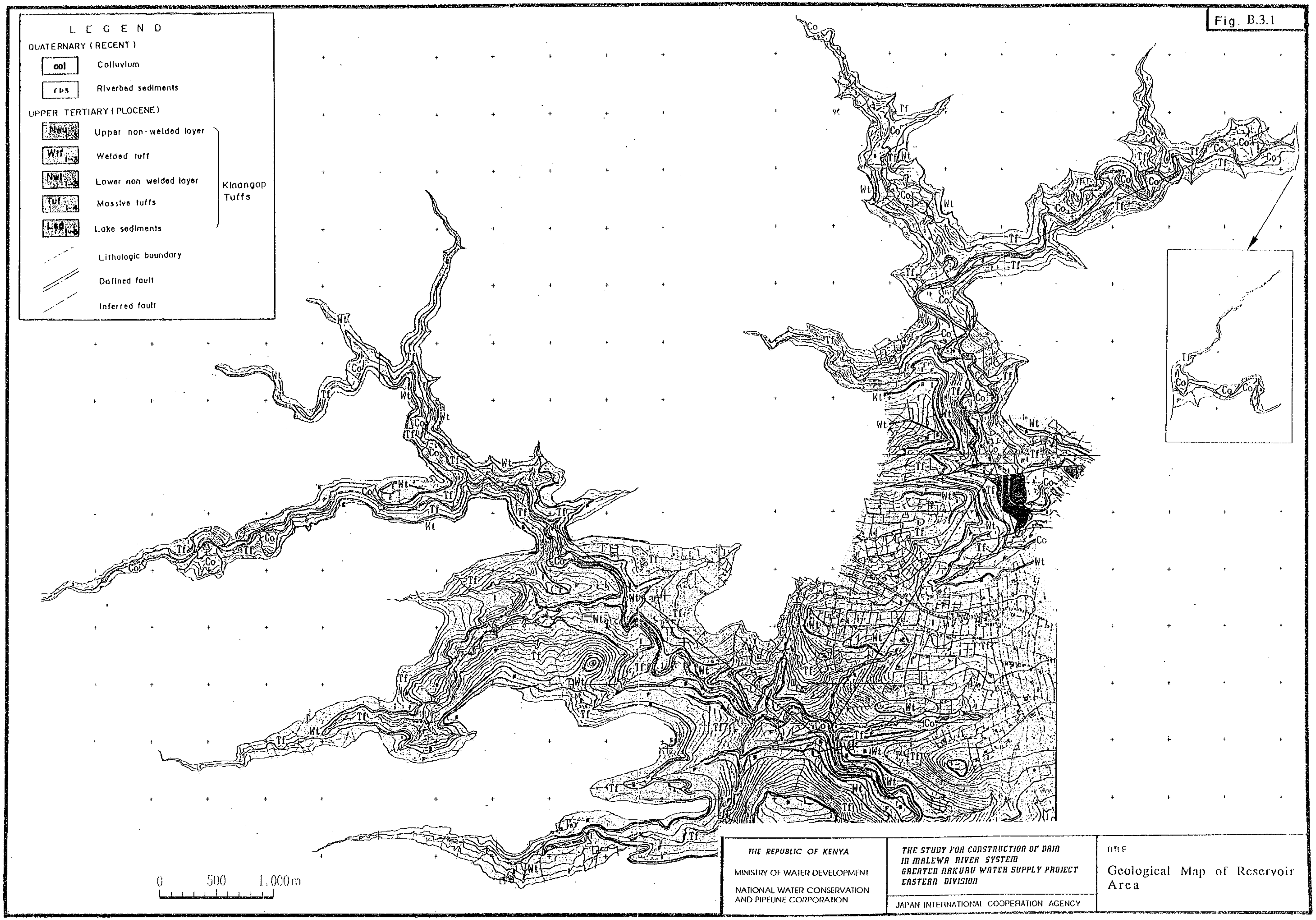
Fig. B.3.1
LEGEND
QUATERNARY (RECENT)
col Colluvium
rbs Riverbed sediments
UPPER TERTIARY (PLOCENE)
Nwu Upper non-welded layer
Wtf Welded tuff
Nwl Lower non-welded layer
Tuf Massive tuffs
Lsd Lake sediments
Kinangop Tuffs
Lithologic boundary
Defined fault
Inferred fault
0 500 1,000m
THE REPUBLIC OF KENYA
MINISTRY OF WATER DEVELOPMENT
NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION
THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE
Geological Map of Reservoir Area

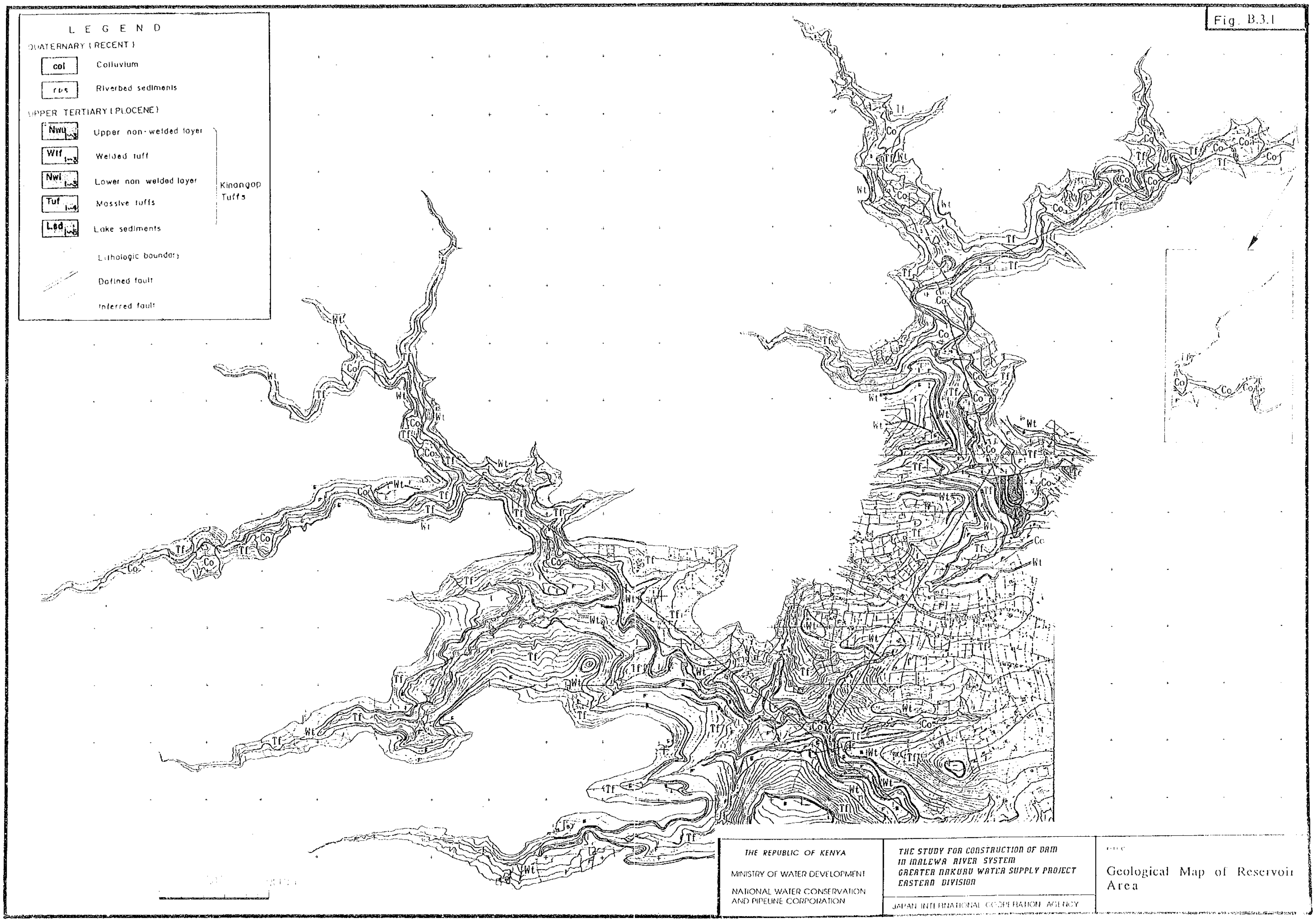
Fig. B.3.1
LEGEND
QUATERNARY (RECENT)
col Colluvium
rbs Riverbed sediments
UPPER TERTIARY (PLOCENE)
Nwu Upper non-welded layer
Wtf Welded tuff
Nwl Lower non welded layer
Tuf Massive tuffs
Lsd Lake sediments
Kinangop Tuffs
Lithologic boundary
Defined fault
Inferred fault
THE REPUBLIC OF KENYA
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THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION
JAPAN INTERNATIONAL COOPERATION AGENCY
Geological Map of Reservoir Area

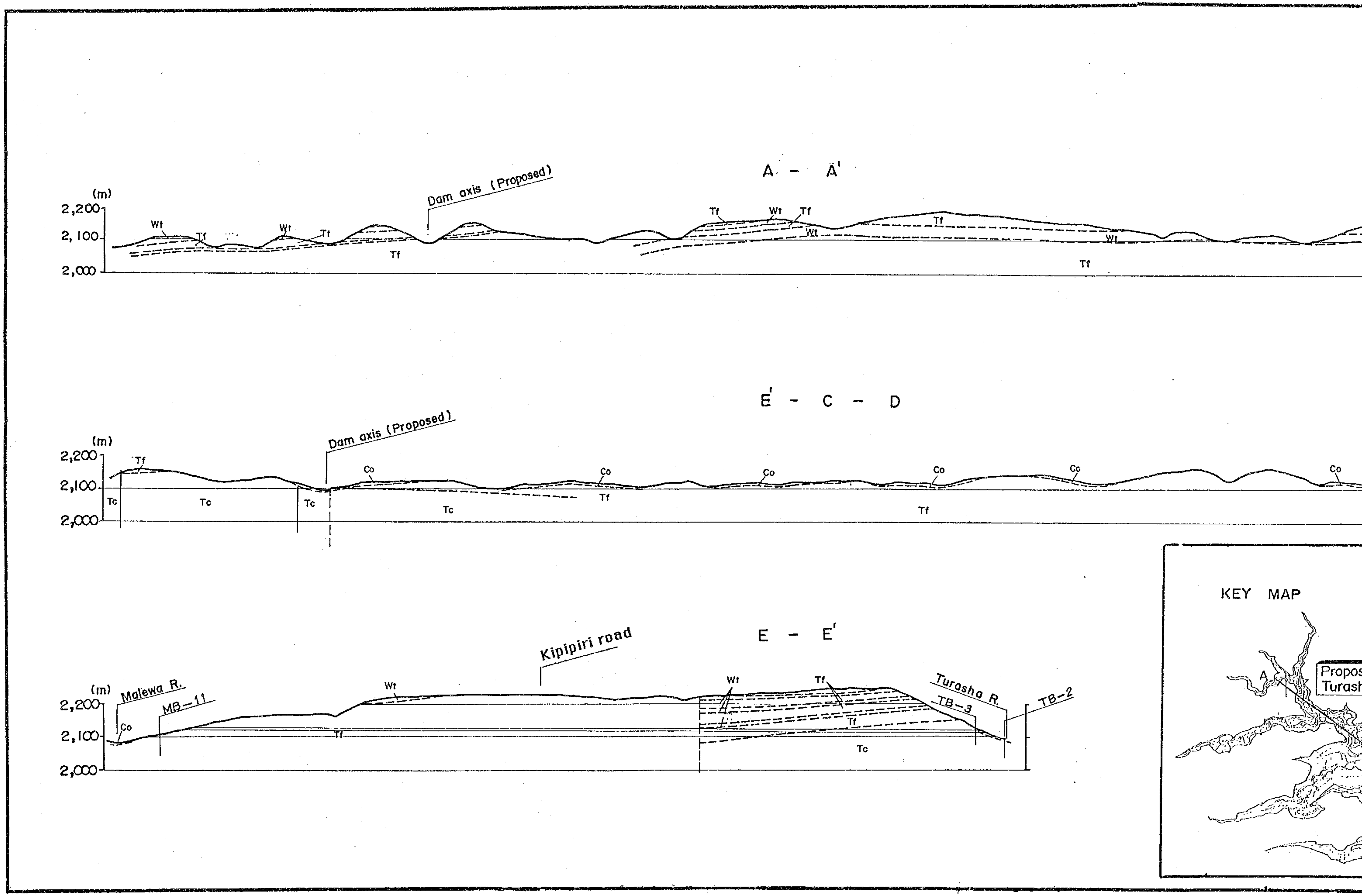
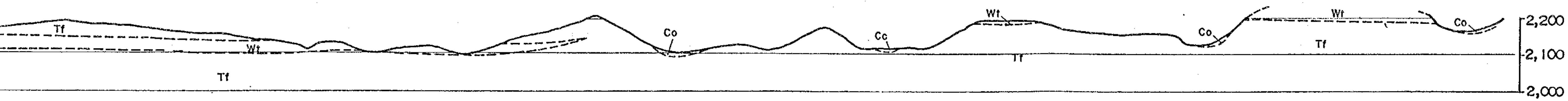
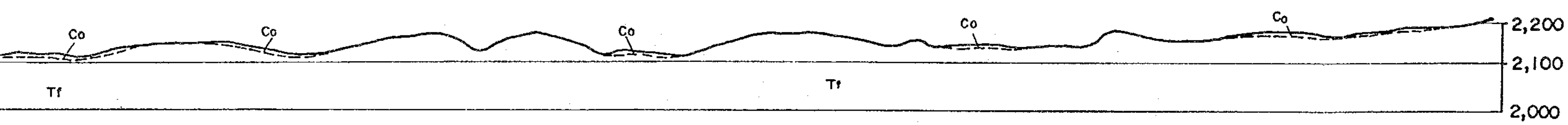
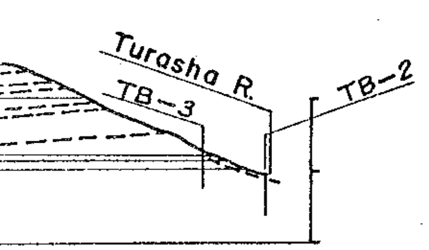

A - A'
(m)
2,200
2,100
2,000
Dam axis (Proposed)
Wt
Tf
E' - C - D
Co
Tc
E - E'
Kipipiri road
Malewa R.
MB-11
Turasha R.
TB-3
TB-2
KEY MAP

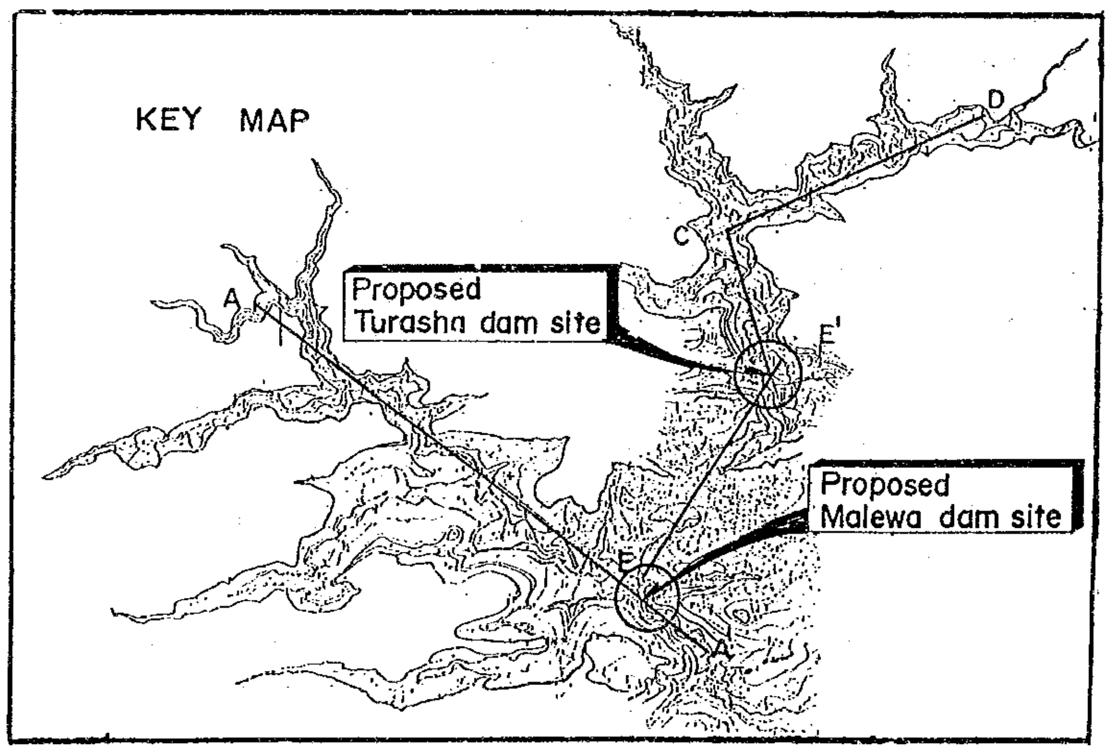
Fig. B.3.2



D







L E G E N D

QUATERNARY (RECENT)

Co — Colluvium
Partially includes riberbed sediments

UPPER TERTIARY (PLOCENE)

Tf — Massive tuffs & Lake sediments } Kinangop Tuffs
Wt — Welded tuff } Kinangop Tuffs
Tc — Trachyte) North Kinangop Trachytes

Lithologic boundary

Defined fault
(Chain line means covered part)

Inferred fault

THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Geological Profile of Reservoir Area