THE REPUBLIC OF TANZANIA

Ministry of Water, Energy,
Construction, Lands and
Environment, Zanzibar

THE REPUBLIC OF FINLAND

Ministry for Foreign
Affairs
FINNIDA

ZANZIBAR URBAN WATER SUPPLY PROJECT

REPORT ON HYDROGEOLOGY

APRIL 1992

Plancenter Ltd

REPORT ON HYDROGEOLOGY

LIST OF CONTENTS

ZANZIBAR URBAN WATER SUPPLY PROJECT

REPORT ON HYDROGEOLOGY, APRIL 1992

1. WORK PLAN

This report is based on the following Work Plan of Hydrogeology, April 1992

1. To assess the hydrogeology of the Bububu spring and the Mtoni Spring. To contribute to the protection of spring areas by defining the protection zones in the field and contributing to the report which is going to be given to the President with regard of this issue. To work with the Hydrogeologist who is member of the survey committee for the catchment areas. To discuss on the communication to the local residents who have to move away from the spring catchment areas.

2. To initiate the pumping tests in the recently completed Kijito Upele Borehole. To interpret the pumping test results.

3. To revise the hydrogeological monitoring programme, to review the designing of boreholes

4. To prepare the drilling programme for 1992

5. To assess the need of geo - electrical sounding programme for defining hydrogeological conditions. If needed to organize the programme with the University of Dar es Salaam. To arrange use of the services of the University for analyzing of selected drilling samples.

6. To discuss on the training and education of hydrogeology team

7. To prepare reports of this consultancy

2. REVIEW OF THE HYDROGEOLOGY OF MTONI AND BUBUBU SPRINGS

2.1 Background

Overall assessment of the hydrogeology of the spring areas was given in the Water Resources Report of the planning phase. The Master Plan, Environmental Assessment and the Water Resources Repot brings out the concern on the environmental issues very strongly as dense human settlements have begun to develop in the spring catchment areas. During the first months of the First implementation Phase of the Zanzibar Urban Water Supply Project the issues of the Geology of the spring areas has been under frequent discussions. Based on the available background information this report aims at clarifying the geological and hydrogeological conditions of the springs and to make a more detailed proposal on tapping larger quantities of ground water from the spring areas.

Since 1920´s several studies have been prepared on the geology of the Mtoni and Bububu springs. G. M. Stockley, Director of Geological Survey, Tanganyika Territory, Gives an assessment on the possibility to increase water withdrawal from the spring areas in his report of 1951. The recommendations of G. M. Stockley are much similar to those of the Master Plan of 1991. While the Water Resources Study recommends geophysical surveys and test drilling to the water saturated formation at a safe distance from the springs, Stockley recommends at first to try to utilize the Dunduki and Welezo springs, and then to locate best possible drilling sites by geo - electrical sounding from the water saturated formation. (Unfortunately it has not been possible to locate the report of Messrs. Howard Humphreys & Sons, Consulting Engineers to the Crown agents of late 40´s or early 50's regarding the possibilities of augmenting the town supply by increasing withdrawal of water from the spring areas.)

2.2 Water Balance

The average run off from the Bububu and Mtoni springs is estimated to be 4000 m3/day and 4400 m3/day respectively. The total average water flow at the moment from the two springs and the small rivers is estimated to be about 20,000 m3/day. These figures are in accordance with those of Mr. Stockley. The catchment areas of the two springs are approximately same size, 4 km2 each. The average daily recipitation to the two catchment areas is over 70,000 m3/day. According to the water resources study it could be possible to develop further 3000 - 8000 m3/day from the catchment areas. This would mean a minimum increase of 1500 m3/d from each of the catchments. The study advises that these figures are to be verified by further tests.

2.3 Geology and hydrogeology of the catchment areas

The springs are located in the same geological horizon of Miocene limestones clays and sands. The chemical composition of water in both the springs show that considerable amount of lime is dissolved in the water from the geological horizon. Stockley calls the horizon of Mtoni and Bububu Springs as Chlamys Werthi Beds. He mentions that old boring records prove that there is a clay bed underlying the aquifer limestone horizon. Mr. Jonson mentions that the Miocene limestones of Mazingini Ridge may be karstic, but so far there is no clear evidence of that. A cave formation can be observed at the Mtoni spring. At a higher elevation there is another aquifer horizon along the Welezo - Dunduki line.

2.4 Environmental consideration

An instruction for environmental protection on the catchment areas, including the Mtoni and Bububu spring catchments, was drafted during this consultancy and it is in accordance with the environmental report of 1992. It is presented in Annex 1.

2.5 Recommendation

The instructions for catchment areas should be applied in the spring catchment areas with immediate effect. The boundaries of the catchment areas are given in the Annex 2.

During the water resources study the Dunduki and Welezo spring areas were registered as shallow well areas, although Stockley had proposed that it will be possible to tap some artesian water from Dunduki and supply it to the existing Bububu and Mtoni pipeline. There is no information if these possibilities were tested in 50´s. Stockley planned to clear the swampy spring areas and develop up to 1300 m3/day from the upper aquifer zone. The swampy areas in Welezo are nowadays developed to rice fields. There are several very small spring outlets in the surroundings of the rice fields. It would be very difficult to tap water in a hygienic way for urban supply. On the other hand the quantity of water remains rather low. The Dunduki spring area is somewhat on similar nature as Welezo except the swamp area has no agricultural inputs. It is not recommended to develop these sources for the urban water supply at this stage.

The simplest way to try to increase the discharge from the springs would be the lowering of the discharge water level. This could be done either by pumping with a high capacity pump from the spring eye or by opening the discharge channel at a lower altitude. Deepening of the existing discharge channel would be the safest and easiest operation to be done. The technical solutions for this need to be carefully thought out prior to starting the construction works. The actual increase in the water quantity will be found out only by monitoring the output of the springs after the modification operations.

It can be assumed that some natural aquifers have developed in the Chlamys Werthi beds in the spring catchment areas. The Water Resources Study recommends drilling of test boreholes in this formation at a safe distance from the springs. The same recommendation is repeated here, if the lowering of the discharge water level will not lead to satisfactory results. The borehole drilling should be stopped when hitting the underlying clay formation or after penetrating an aquifer with good yield.

The drilling sites should first be located by geo - electrical sounding. The sounding should be done by Slumberger Method along the lines that are presented in the Annex 3. The

distance of the drilling sites from the springs should be decided after interpreting the geophysical survey results.

3. GEO - ELECTRICAL SOUNDING

The Sounding programme for Kijito Upele, Mwembe Chomeke and Mtoni in Unguja Island is presented in the Annex 4. The Sounding programme for Mkoani, Chake Chake and Wete in Pemba island is presented in Annex 5. The field measurements will be subcontracted to the University of Dar es Salaam.

The survey of the most urgent sites, Kijito Upele, Mwembe Chomeke and Mtoni was done on 23rd - 26th April 1992. The University team completed 10 sounding points. The calculated results are presented in Annex 6 and 7. The sounding survey should be completed in July 1992.

The Miocene clay is at the approximate depth of 30 m in kijito upele. The aquifer seems to be a little better on the southern side of the existing borehole. The clay is over 50 m deep in Miembe Chomeke and high yielding boreholes can be drilled on the South Eastern side of the existing borehole.

4. DRILLING PROGRAMME

The Work Plan of 1992 includes drilling of two boreholes. The first drilling has been completed by the end of April 1992 in Kijito Upele. It is thought that at least two more production boreholes and three observation holes can be completed by the end of the year. The sites for these boreholes are given in the annex 8. The location of the test boreholes nos 2,3 and 4 were determined according to the sounding results. They are located in the sounding points Kijito3, Mtoni9 and Miembe6. The sites of the survey points are marked with yellow paint in the field. The observation hole no 5 (no production drilling in these area) will be drilled in Fuoni area approximately to the area which is marked in the annex 8. Depending on the test drilling results, production holes will be drilled about 25 m from the test holes.

Seventeen other potential Drilling sites in Unguja and Pemba are given in the map of Annex 8. The accurate location of these boreholes will be determined after the completion of the geo - electrical sounding Programme.

5. HYDROGEOLOGICAL MONITORING

During the Master Plan preparation, 112 and 53 local wells were identified for monitoring in the catchment areas of the planned water intakes in Unguja and Pemba respectively. Intensive monitoring has continued more than one year. The water table monitoring results of eighteen months are presented in the Annex 9. The maximum water table fluctuation is presented in Annex 10. Conductivity monitoring results are shown in Annex 11. The areas of lowest fluctuation and lowest conductivity correlate. These areas are those with the

highest aquifer storativity and will be further studied by geo - electrical sounding for identification of the ideal sites of high yielding boreholes and borehole fields.

The monitoring programme was revised and 20 local wells were selected for further monitoring. These wells are located both in the Quaternary and in the Miocene formations. The revised monthly monitoring programme is presented in the map of Annex 9 and 10. From these wells it should be possible to observe if any major changes will take place in the groundwater conditions after the pumping to the urban areas will be increased.

6. PUMPING TESTS

A pumping test in the Kijito Upele failed due to generator break down. The results of air flushing and bailer tests show that the new borehole is yielding less than the old one. It becomes evident that the storativity of the Kijito Upele area is less than 10%. The assumption of the Master Plan that a maximum of 230 m3/h can be drawn from this area can be verified after the completion of the second test hole in this area.

The new production boreholes will be drilled with observation/test holes and aquifer tests of about three days bumping + recovery tests will be performed.

7. BOREHOLE DESIGNS

The high yielding boreholes should be screened with stainless steel screens. The plain casings should be of PVC. The lower yielding boreholes (50m3/h or less) should be made with PVC screens and plain casings. The slot size of the PVC screens should be 1 mm or more. The slot size of the stainless screens should be 0.75 mm or more. The length of the screens to be determined according to the geological formation and water flow velocity in the screen.

Kijito Upele and possibly some other old boreholes can be rehabilitated by installing a plastic casing with stainless steel screen together with filter sand in the borehole.

Observation and test holes should be furnished with 4 in plastic casing.

8. TRAINING

The following training needs were identified

- Training in technical issues related to Drilling and Hydrogeology
- Material procurements and supply procedures, store keeping
- Planning of daily, weekly, monthly, yearly works
- Administrative, personnel and training issues

- Management and running of the programme

The on the job training with discussion meetings will continue. As and when suitable training courses will be identified relevant people may participate.

Each team member will complete four seminar works during 1992. The works will be planned based on individual training needs of each staff member. At suitable times seminar meetings will be arranged for discussion and presenting of the completed works.

Mr. Hamad Bakar will discuss with the staff and further clarify the training needs and he will accordingly plan and identify the individual seminar works.

The expatriate advisor will discuss and advise and arrange relevatn training material as and when required

9. WORK PROGRAMME FOR THE HYDROGEOLOGY TEAM, May - Dec 1992

1. To prepare a schedule for this work plan

2. To communicate the contents of this work plan to the Pemba team

3. To analyse the monitoring results of Pemba

4. To complete the following four (or more) seminar works as a part of training programme. Planning and follow up responsibility with Hamad Bakar.

   - Preparation of job descriptions to all staff
   - Management of work plan implementation, including definition of staff needs, training needs, organising of works in the field.
   - Material supplies to the field units, including procurements, local and overseas.

   - Technical seminar work

     - Borehole design
     - Technical solutions in problematic situations at the drilling site
     - Safe working habits
     - Correct way of handling hand tools

5. Geo-electrical soundings as per the Annexes 3 - 5.

6. Drilling of test and production holes, in the following order. The order may be changed if necessary.

   1. Kijito Upele, 2. Mtoni, 3. Bububu (after the interpretation of sounding results) Mwembe Chomeke (Two B-Holes) 4. Mkoani (Uweleni, Changaweni, Mgombeni)

   - Analyzing the soil samples in Dar es Salaam University, Geology Department
   - Preparation of geological logs of the BH:s and borehole reports

7. Pumping tests of the new production holes

   - Registering the results
   - Drawing of drawdown/time - curves
   - Calculation of aquifer parameters

8. Monitoring of local wells as per long term programme of Annex 9.

   - Water table monitoring
   - Conductivity monitoring

9. Water quality and environmental monitoring as per the environmental work programme

10. LITERATURE

1. Zanzibar Urban Water Supply Development Plan, 1991 -2015, September 1991

2. Zanzibar Urban Water Supply Development Plan, Water Resources Study, April 1991

3. A Review of the Hydrogeology of Zanzibar Island, J. Johnson, 1982

4. Report on the Geohydrological conditions governing the Zanzibar Town Water Supplies, G. M. Stockley, 1951

LIST OF ANNEXES

8. Potential drilling sites

9. Local well monitoring results

10. Water table fluctuation map, Unguja

11. Pumping test results, Kijito Upele

ANNEX 1

Instruction for environmental protection

PROTECTED AREA PLAN AROUND WATER INTAKES

A - ZONE

RESTRICTED AREA

No human activities allowed

The immediate vicinity of the springs and boreholes should be protected by fence. The oval shaped fenced area should reach about 100 m upstream from the Mtoni and Bububu springs and 50m downstream from the spring. With the boreholes and other springs the size of the fenced area will be depending on local conditions

In the fenced area admittance should be prohibited. Only water supply related operations should be allowed.

B - ZONE

PROTECTED AREA

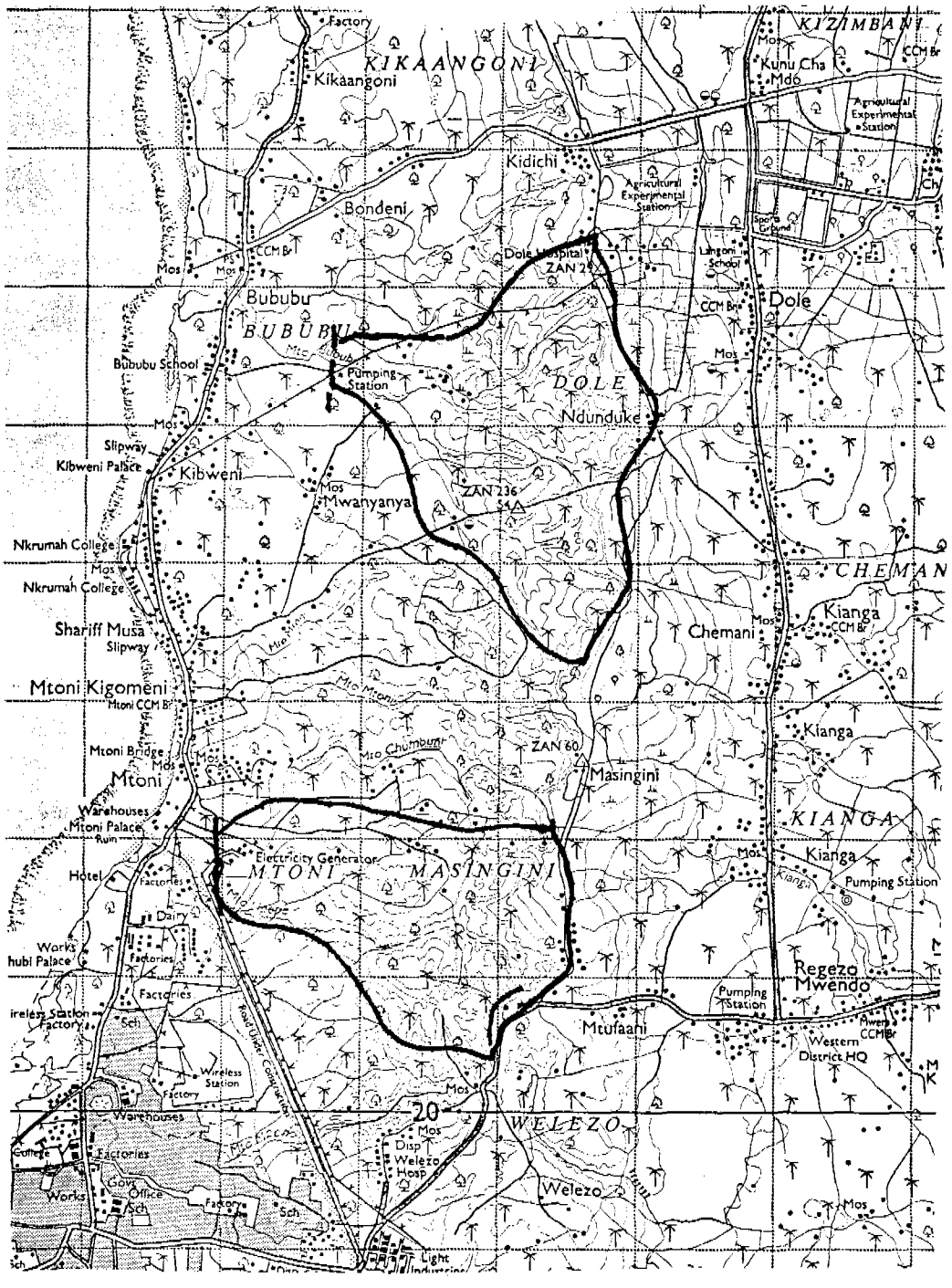
Only limited and controlled human activities allowed
Construction and waste management to be planned according to instructions and approval of the Water Authority

The whole catchment area should be protected as follows:

- existing settlements without reliable sewerage should be gradually removed and no new houses should be allowed
- factories, industrial establishments, livestock buildings, fodder storage, silos etc. should not be allowed
- improper removal of soil, trees and vegetation as well as digging of holes should not be allowed
- transport or storage of dangerous chemicals, dumping of wastes, agriculture, improper use of fertilizers and pesticides, cemetery should not be allowed
- The catchment area nearby the existing settlements should be surrounded by clear instruction sign boards, mounted in cement.

ANNEX 2

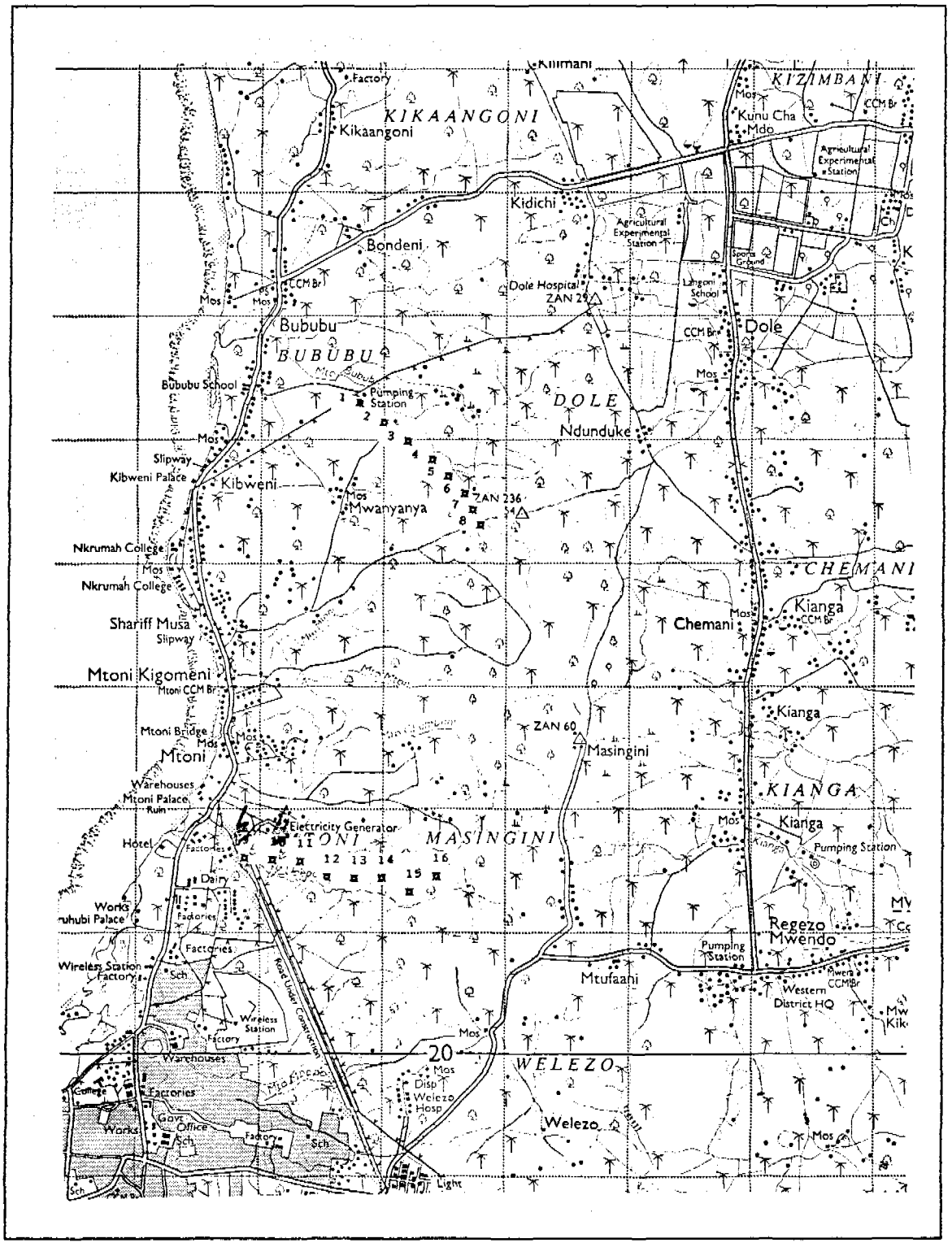
Boundaries of the catchment areas, Mtoni and Bububu springs



BOUNDARIES OF THE CATCHMENT AREAS, MTONI AND BUBUBU SPRINGS

ANNEX 3

Geo-electrical survey programme for the Mtoni and Bububu spring catchment areas

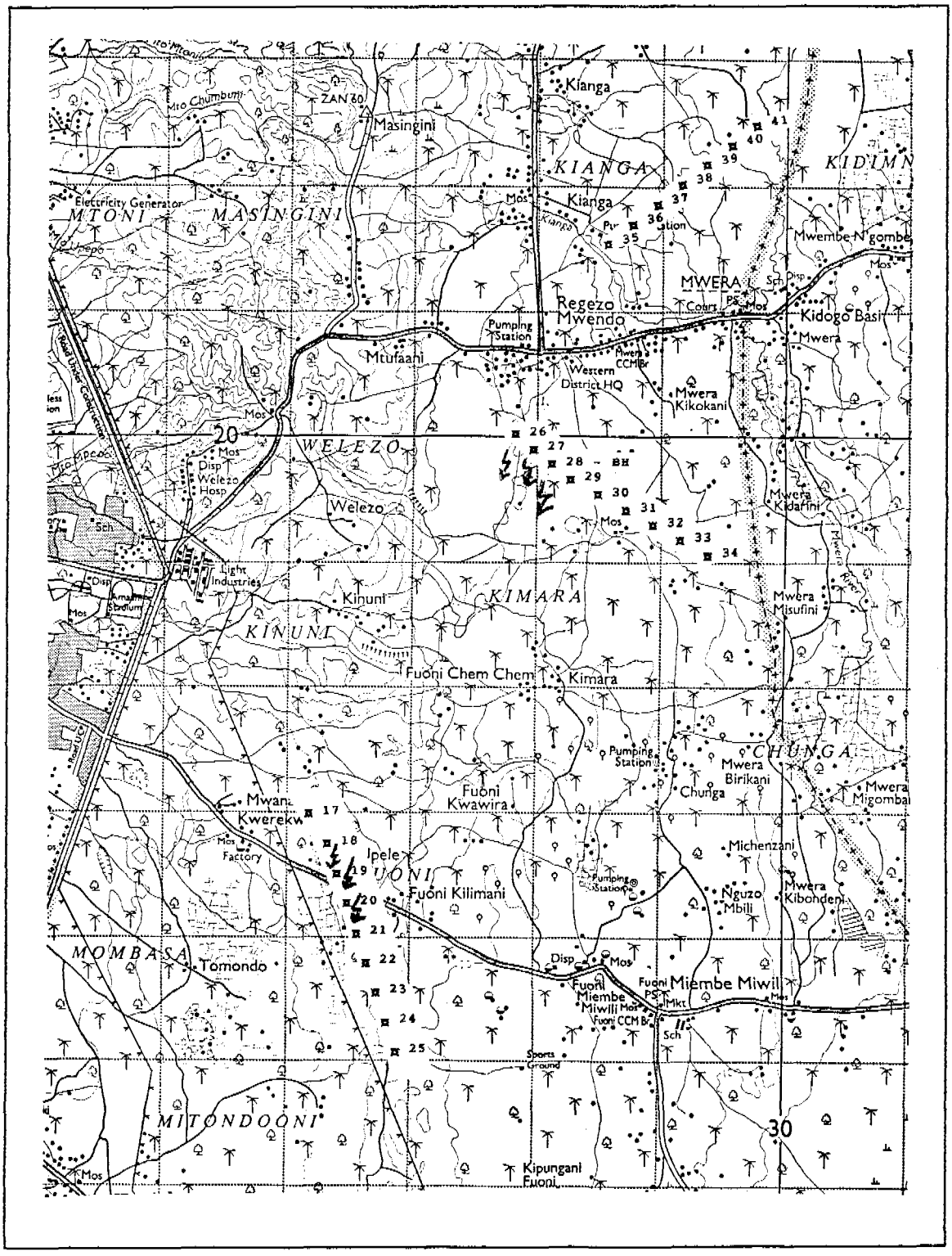


GEO - ELECTRICAL SURVEY PROGRAMME FOR THE MTONI AND BUBUBU SPRING CATCHMENT AREAS

↯ completed

ANNEX 4

Geo-electrical survey programme on Unguja Island

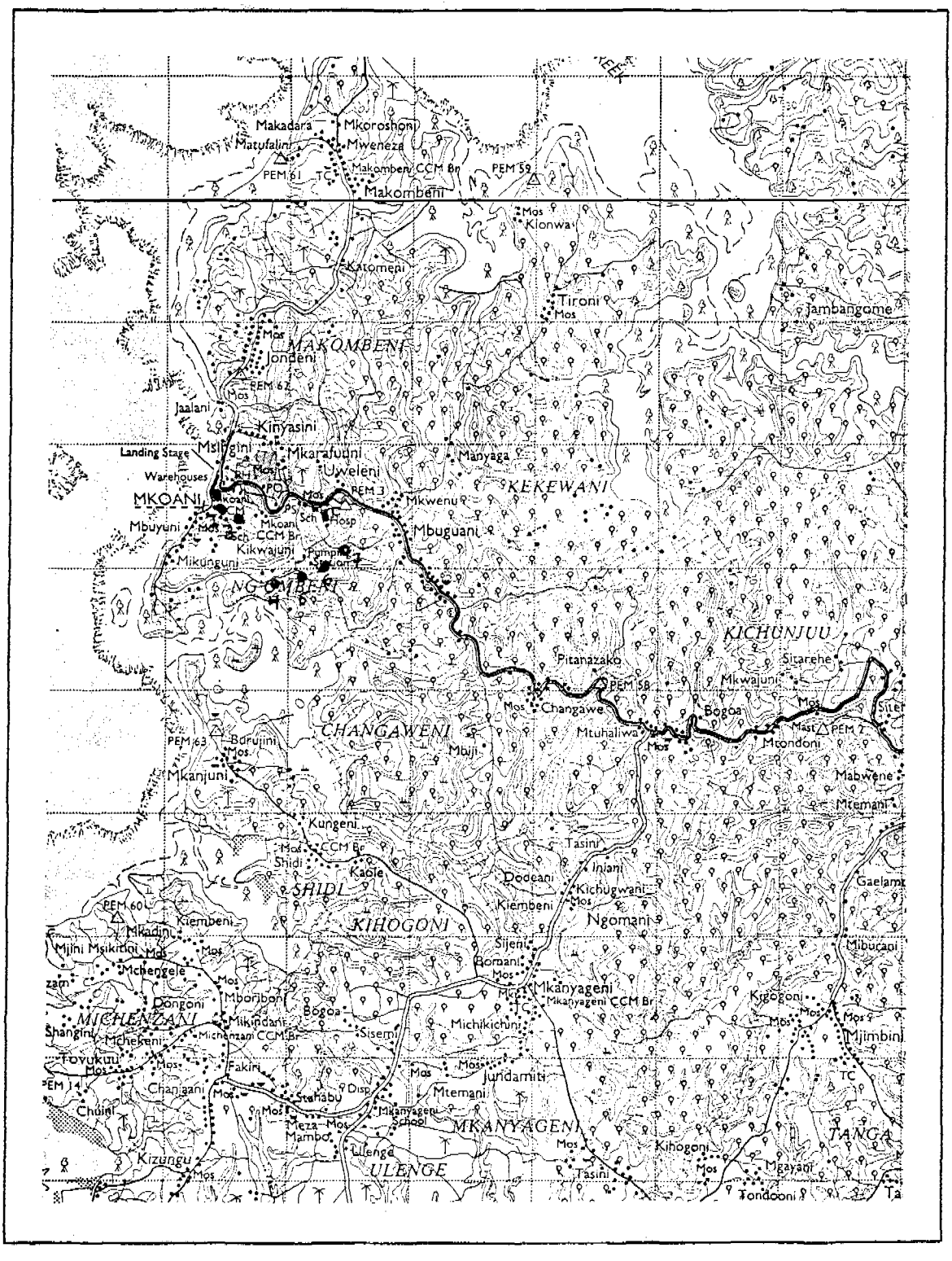


GEO - ELECTRICAL SURVEY PROGRAMME ON UNGUJA ISLAND, DRILLING AREAS

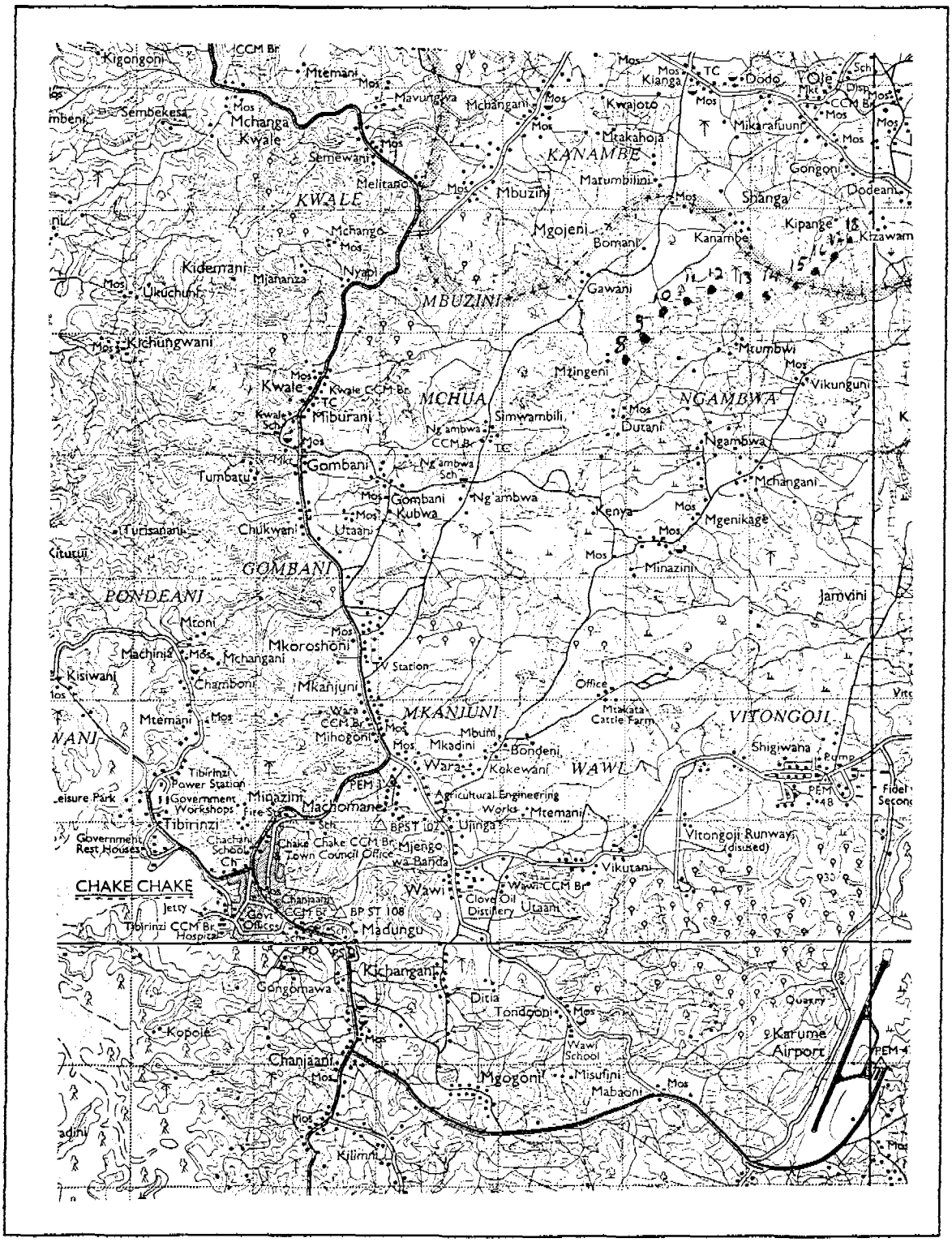
ϟ completed

ANNEX 5

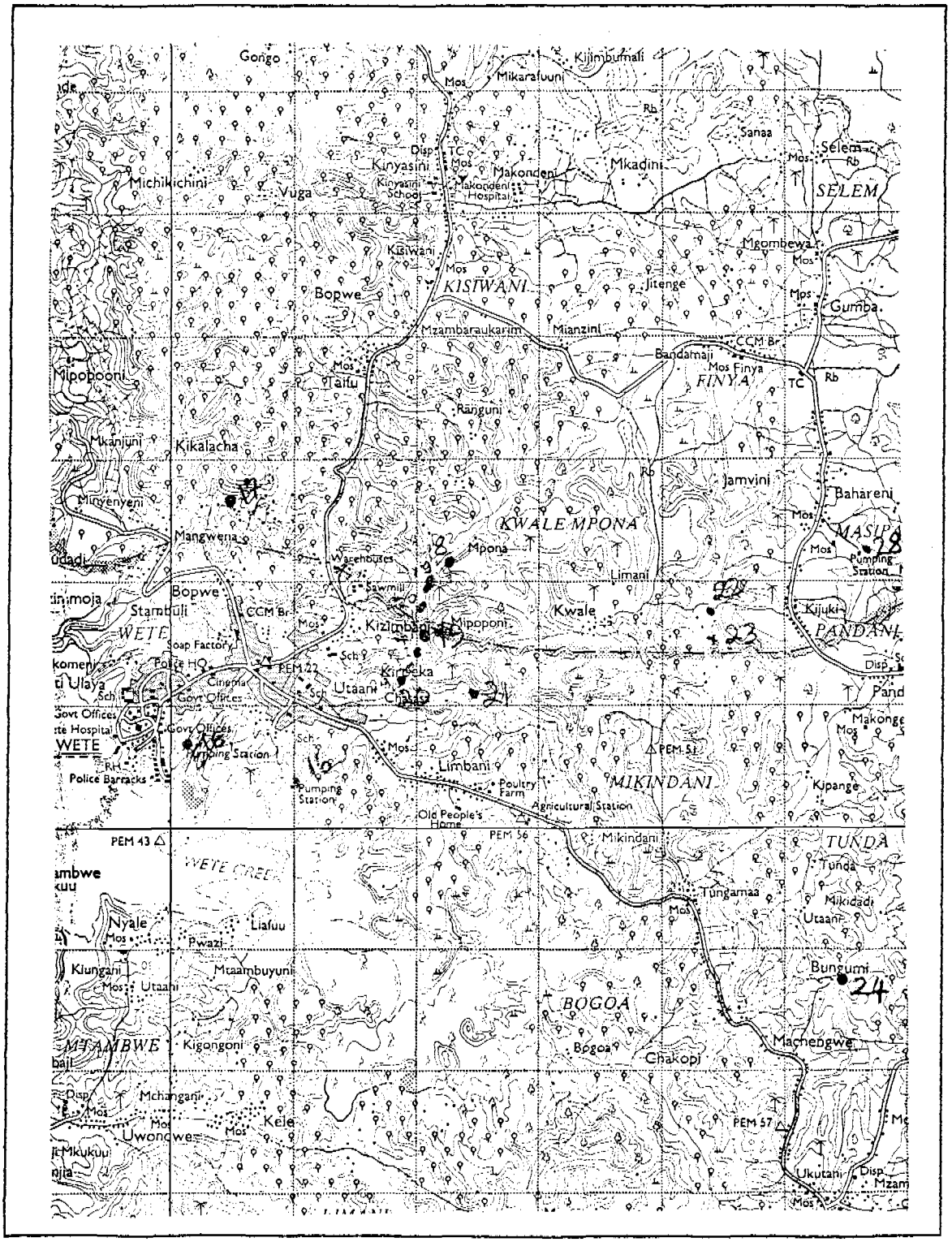
Geo-electrical survey programme on Pemba Island



GEO - ELECTRICAL SURVEY PROGRAMME ON PEMBA ISLAND, MKOANI



GEO - ELECTRICAL SURVEY PROGRAMME ON PEMBA ISLAND, CHAKE CHAKE



GEO - ELECTRICAL SURVEY PROGRAMME ON PEMBA ISLAND, WETE

ANNEX 6

Geo-electrical survey results

Kijito Upele 1

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	66.600
2	1.50	67.000
3	2.00	69.500
4	3.00	56.400
5	5.00	20.000
6	7.00	16.000
7	10.00	9.000
8	30.00	18.200
9	50.00	21.700
10	70.00	23.600
11	100.00	35.600
12	120.00	24.120
13	150.00	21.200
14	200.00	21.000

Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	78.467	1.739	1.739
2	6.180	4.293	6.032
3	12.242	5.627	11.658
4	35.359	4.433	16.091
5	56.813	2.353	18.444
6	49.439	11.350	29.794
7	19.532	-----.---	-----.---

Kijito Upele 2

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	160.000
2	1.50	119.000
3	2.00	46.000
4	3.00	37.000
5	5.00	14.000
6	7.00	11.000
7	10.00	14.000
8	15.00	25.000
9	20.00	17.000
10	30.00	20.000
11	50.00	20.000
12	70.00	17.000
13	120.00	18.000
14	150.00	24.000
15	200.00	19.000

Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	187.706	0.963	0.963
2	9.027	3.138	4.101
3	14.499	5.734	9.836
4	29.945	3.615	13.451
5	49.122	1.805	15.256
6	29.377	8.000	23.256
7	16.458	-----.---	-----.---

Kijito Upele 3

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	66.000
2	1.50	49.000
3	2.00	80.000
4	3.00	32.000
5	5.00	16.000
6	7.00	12.000
7	10.00	13.000
8	15.00	11.000
9	20.00	12.000
10	30.00	9.000
11	50.00	20.000
12	70.00	22.000
13	100.00	23.000
14	120.00	28.000
15	150.00	20.000
16	200.00	30.000

Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	64.204	1.310	1.310
2	10.399	4.764	6.073
3	9.275	8.274	14.348
4	32.064	4.103	18.451
5	55.368	1.992	20.443
6	46.312	10.992	31.435
7	25.533	-----.---	-----.---

Kijito Upele 4

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	123.000
2	1.50	58.000
3	2.00	23.000
4	3.00	43.000
5	5.00	21.000
6	7.00	14.000
7	10.00	13.000
8	15.00	12.000
9	20.00	15.000
10	30.00	20.000
11	50.00	17.000
12	70.00	19.000
13	120.00	25.000
14	150.00	24.000
15	200.00	23.000

Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	91.856	1.449	1.449
2	9.501	4.146	5.595
3	10.936	6.465	12.061
4	28.480	3.933	15.994
5	47.594	2.726	18.720
6	31.779	9.215	27.935
7	22.373	-----.---	-----.---

Kijito Upele 5

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	112.000
2	1.50	103.000
3	2.00	81.000
4	3.00	41.000
5	5.00	12.000
6	7.00	8.000
7	10.00	8.000
8	15.00	8.500
9	20.00	9.000
10	30.00	10.500
11	50.00	12.000
12	70.00	14.000
13	100.00	13.900
14	120.00	15.000
15	150.00	15.000
16	200.00	14.500

Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	130.561	1.187	1.187
2	6.180	5.493	6.680
3	8.233	8.747	15.427
4	27.038	4.697	20.124
5	49.704	1.845	21.969
6	32.158	8.392	30.361
7	12.547	-----.---	-----.---

Mwembe Chomeke 6

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	168.000
2	1.50	134.000
3	2.00	108.000
4	3.00	68.000
5	5.00	25.000
6	7.00	12.000
7	10.00	10.000
8	15.00	13.000
9	20.00	16.000
10	30.00	22.000
11	50.00	29.000
12	70.00	36.000
13	100.00	42.000
14	120.00	45.000
15	150.00	47.000
16	200.00	39.000

Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	163.237	1.435	1.435
2	6.787	6.220	7.656
3	46.609	19.737	27.393
4	114.544	32.221	59.614
5	23.973	-----.---	-----.---

Mwembe Chomeke 7

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	400.000
2	1.50	330.000
3	2.00	286.000
4	3.00	179.000
5	5.00	82.000
6	7.00	50.000
7	10.00	18.000
8	15.00	19.000
9	20.00	19.000
10	30.00	23.000
11	50.00	29.000
12	70.00	28.000
13	100.00	34.000
14	120.00	34.000
15	150.00	44.000
16	200.00	44.000

Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	350.547	1.884	1.884
2	11.280	5.220	7.104
3	26.355	31.830	38.935
4	87.440	33.856	72.790
5	32.910	-----.---	-----.---

Mwembe Chomeke 8

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	146.000
2	1.50	120.000
3	2.00	93.000
4	3.00	54.000
5	5.00	28.000
6	7.00	21.000
7	10.00	16.000
8	15.00	14.000
9	20.00	13.000
10	30.00	11.500
11	50.00	15.000
12	70.00	24.000
13	100.00	22.000
14	120.00	26.000
15	150.00	27.000
16	200.00	25.000

Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	153.064	1.149	1.149
2	19.167	4.998	6.147
3	10.208	23.902	30.049
4	75.459	30.010	60.059
5	23.352	-----.---	-----.---

Mtoni 9

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	11.900
2	1.50	14.000
3	2.00	15.400
4	3.00	19.200
5	5.00	23.300
6	7.00	26.300
7	10.00	31.000
8	15.00	37.000
9	20.00	41.000
10	30.00	44.000
11	50.00	44.300
12	70.00	39.000
13	100.00	32.500
14	130.00	28.400
15	140.00	28.000

Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	13.141	2.015	2.015
2	52.311	9.218	11.233
3	83.869	7.038	18.271
4	26.074	-----.---	-----.---

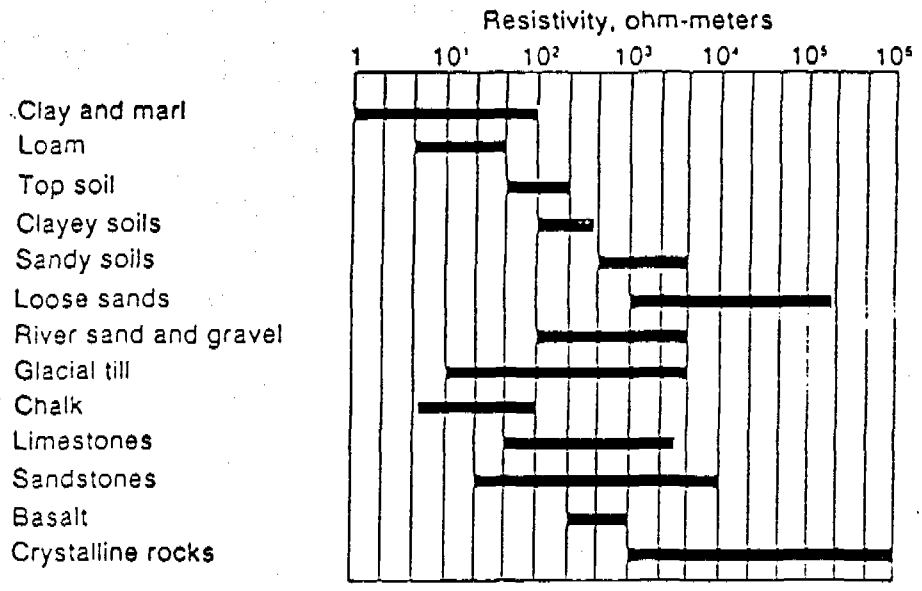
Mtoni 10

Point [No]	AB/2 [m]	Res [ohmm]
1	1.00	236.000
2	1.50	253.000
3	2.00	227.000
4	3.00	175.000
5	5.00	114.000
6	7.00	96.000
7	10.00	39.000
8	15.00	13.500
9	20.00	21.000
10	30.00	18.000
11	50.00	21.000
12	70.00	31.000
13	100.00	33.000
14	120.00	28.000
15	150.00	27.000
16	200.00	28.000

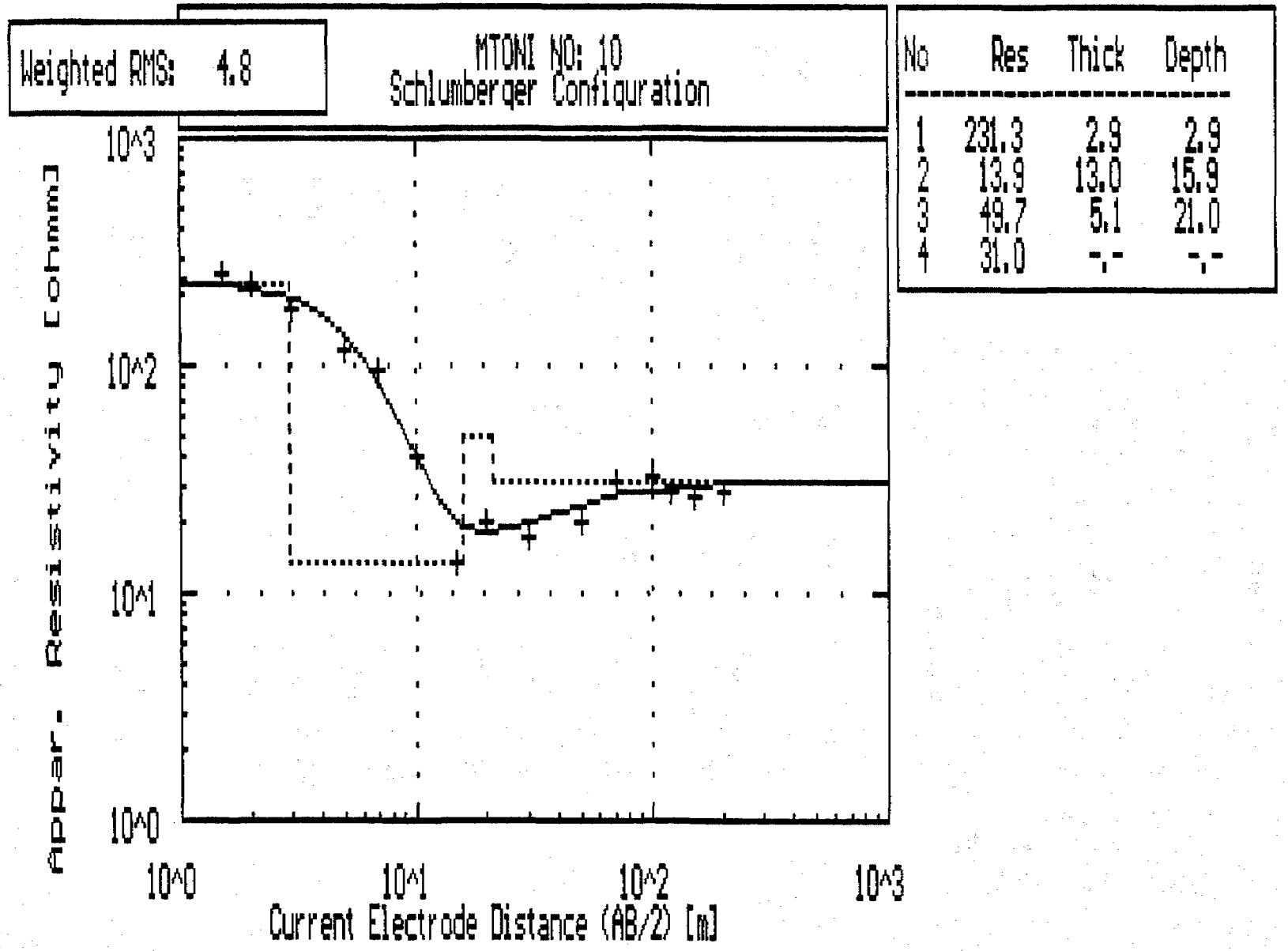
Layer [No]	Res [ohmm]	Thick [m]	Depth [m]
1	231.302	2.923	2.923
2	13.847	12.912	15.835
3	49.712	5.122	20.957
4	31.000	-----.---	-----.---

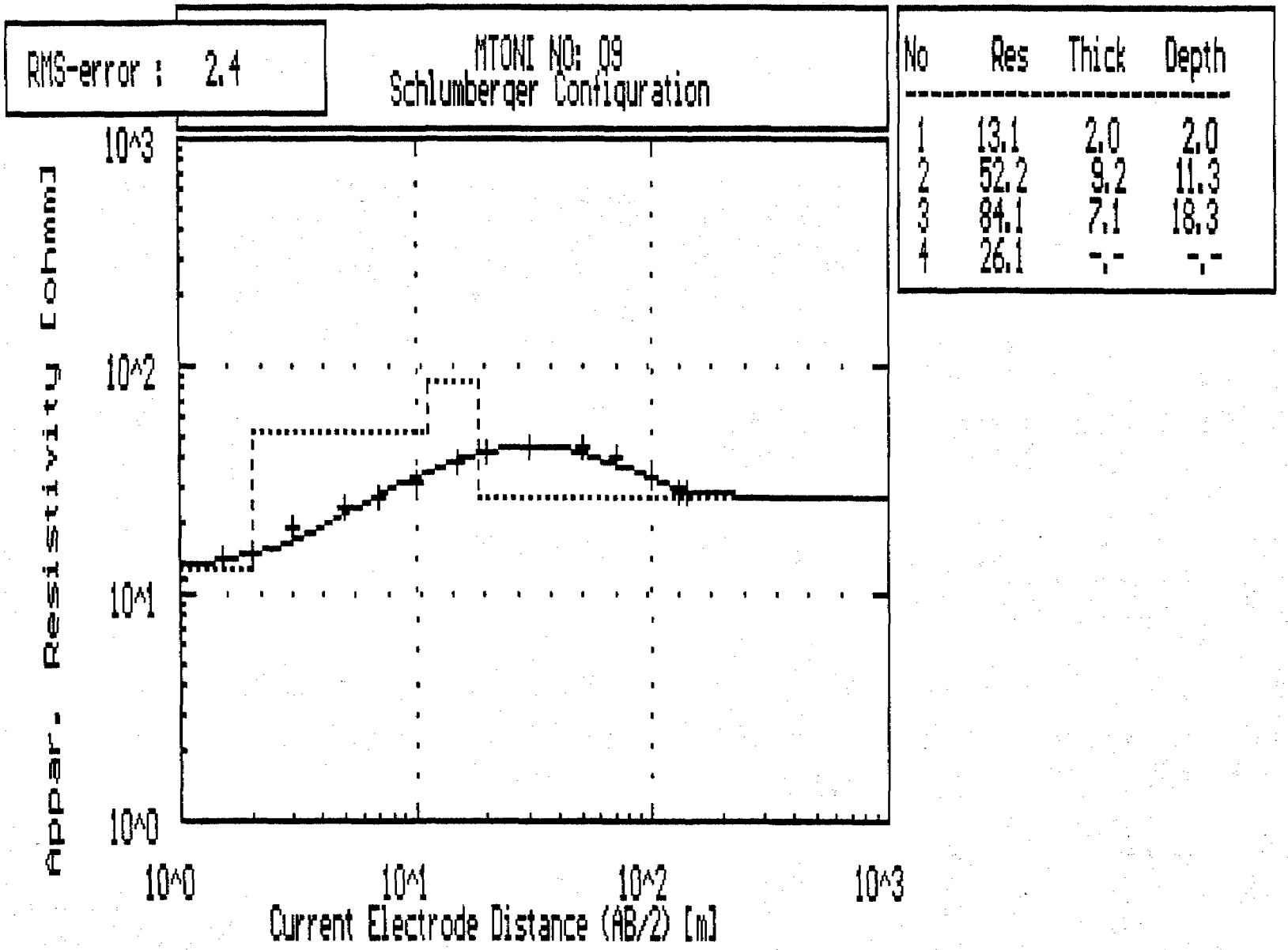
ANNEX 7

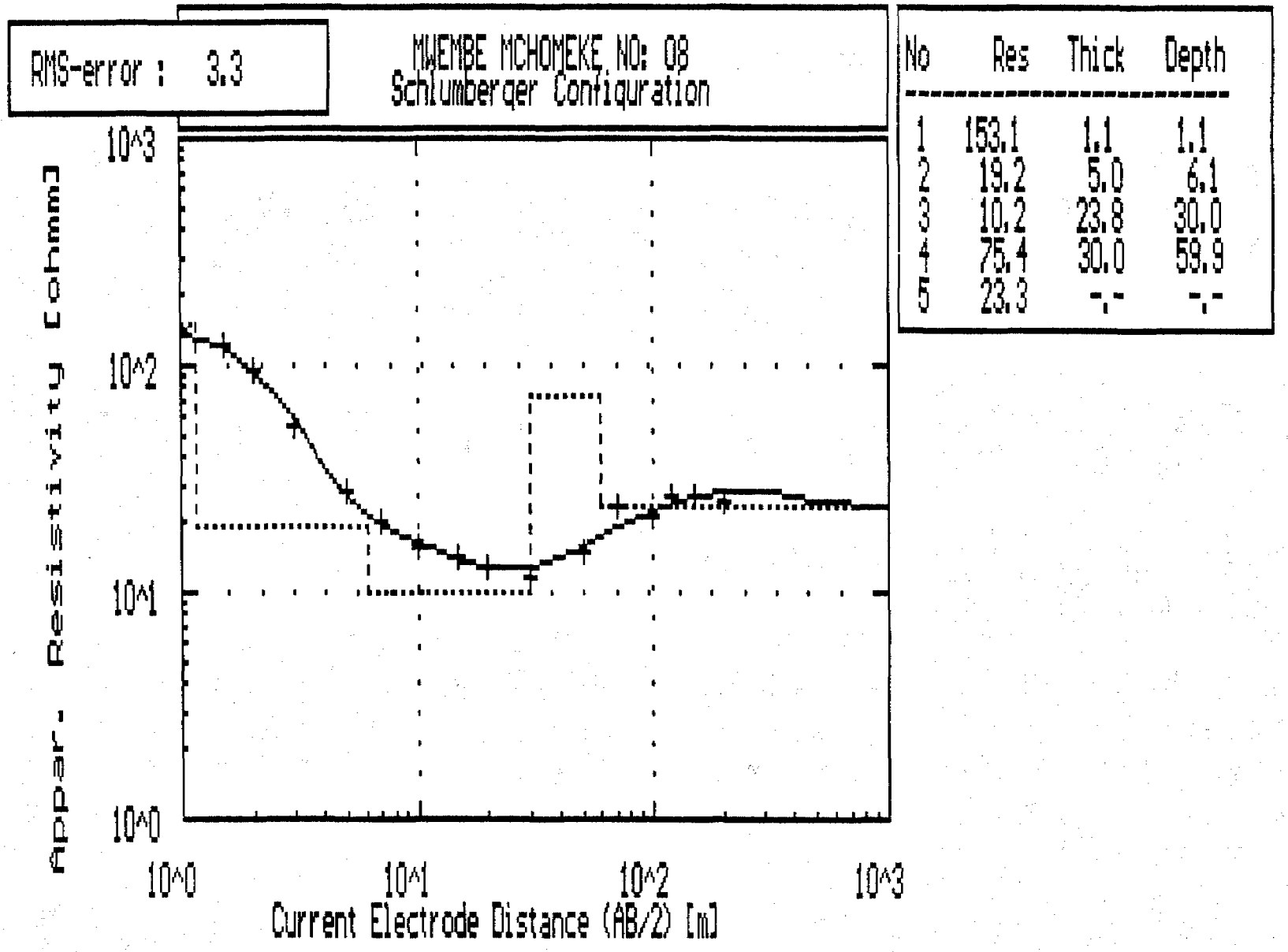
Interpretation of Geo - electrical survey results

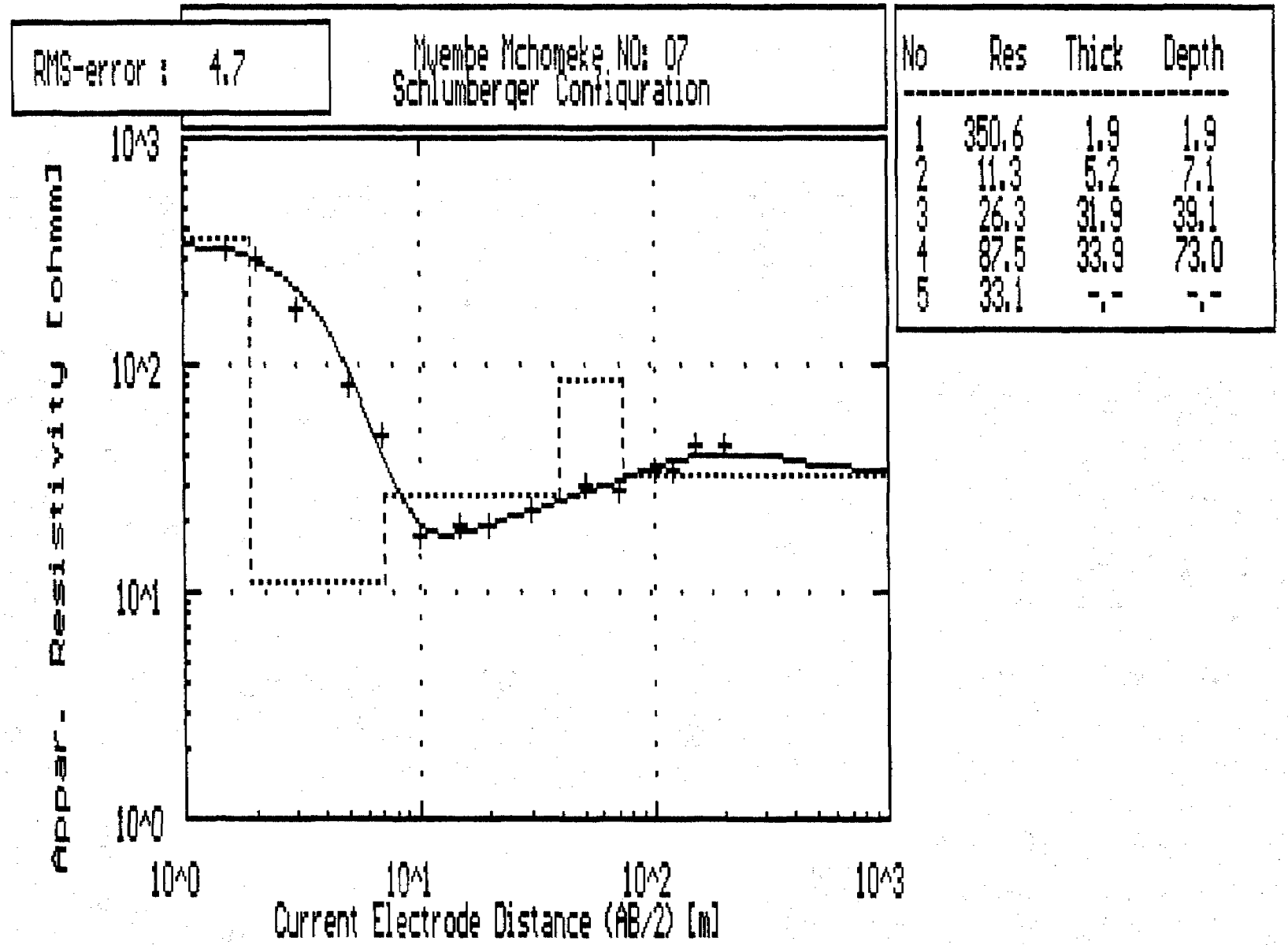


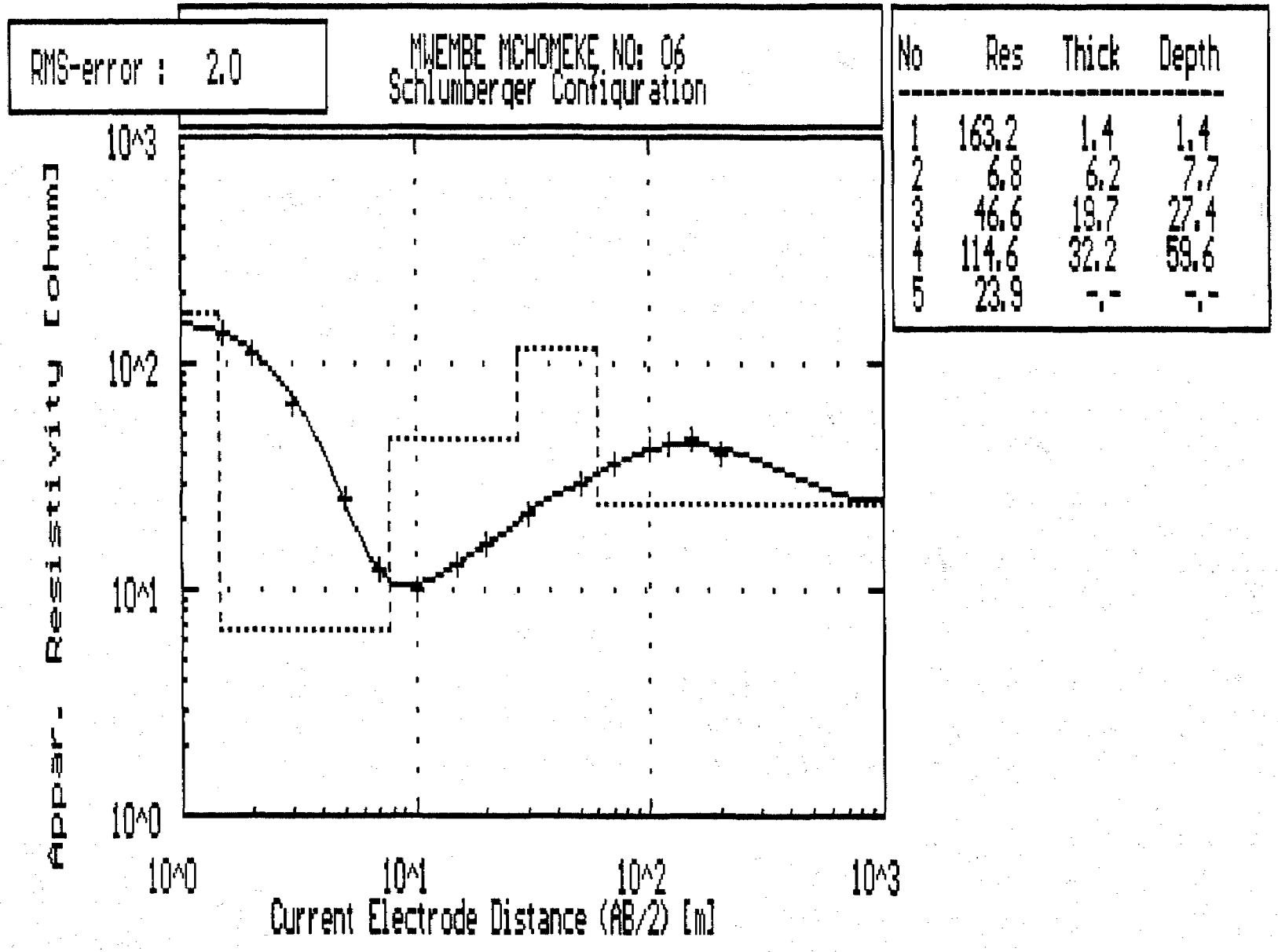
Approximate Correlation with Geological Formation and Apparent Resistivity

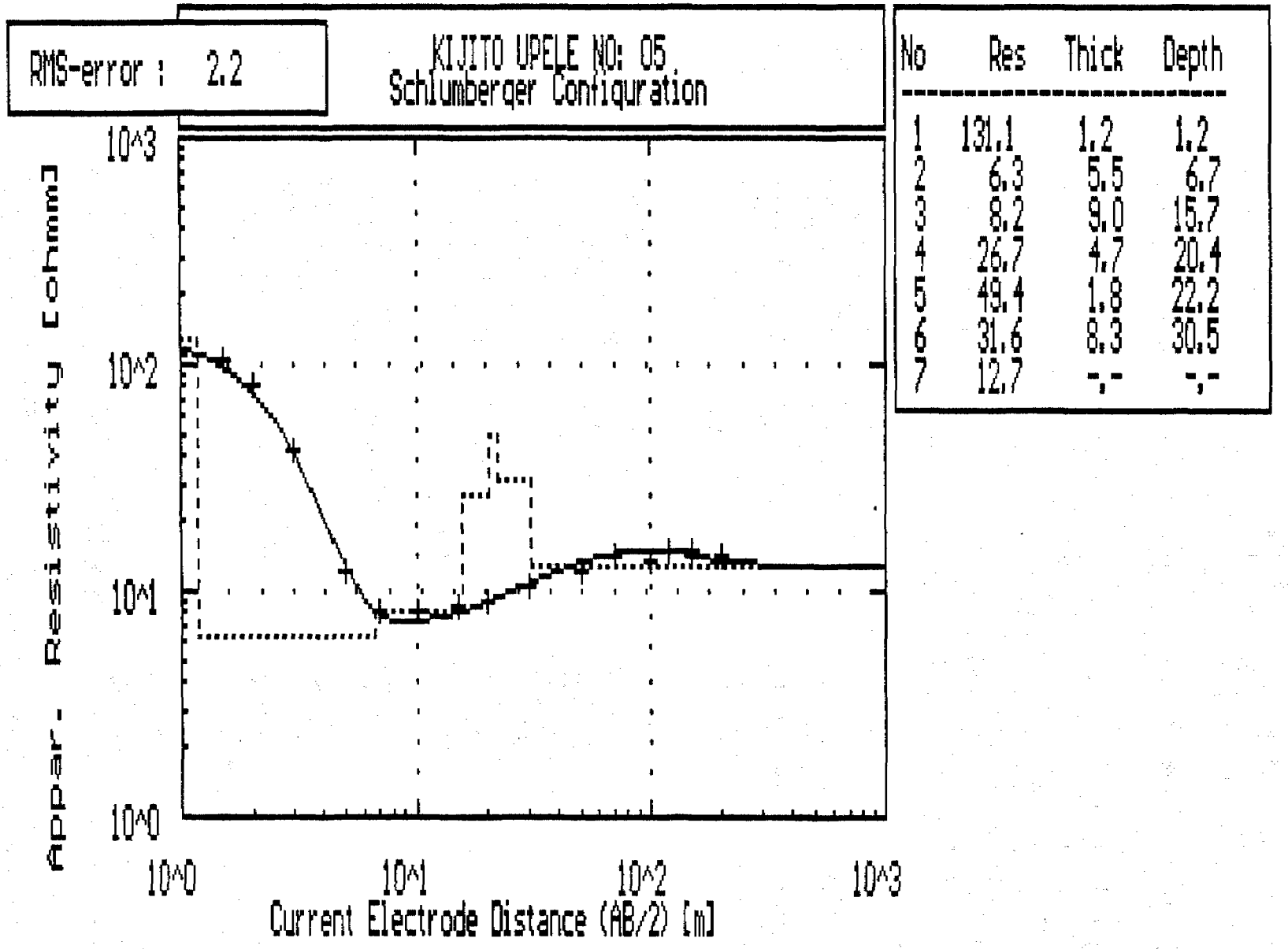

Weighted RMS: 4.8
MTONI NO: 10
Schlumberger Configuration
No Res Thick Depth
1 231.3 2.9 2.9
2 13.9 13.0 15.9
3 49.7 5.1 21.0
4 31.0 -.- -.-
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]

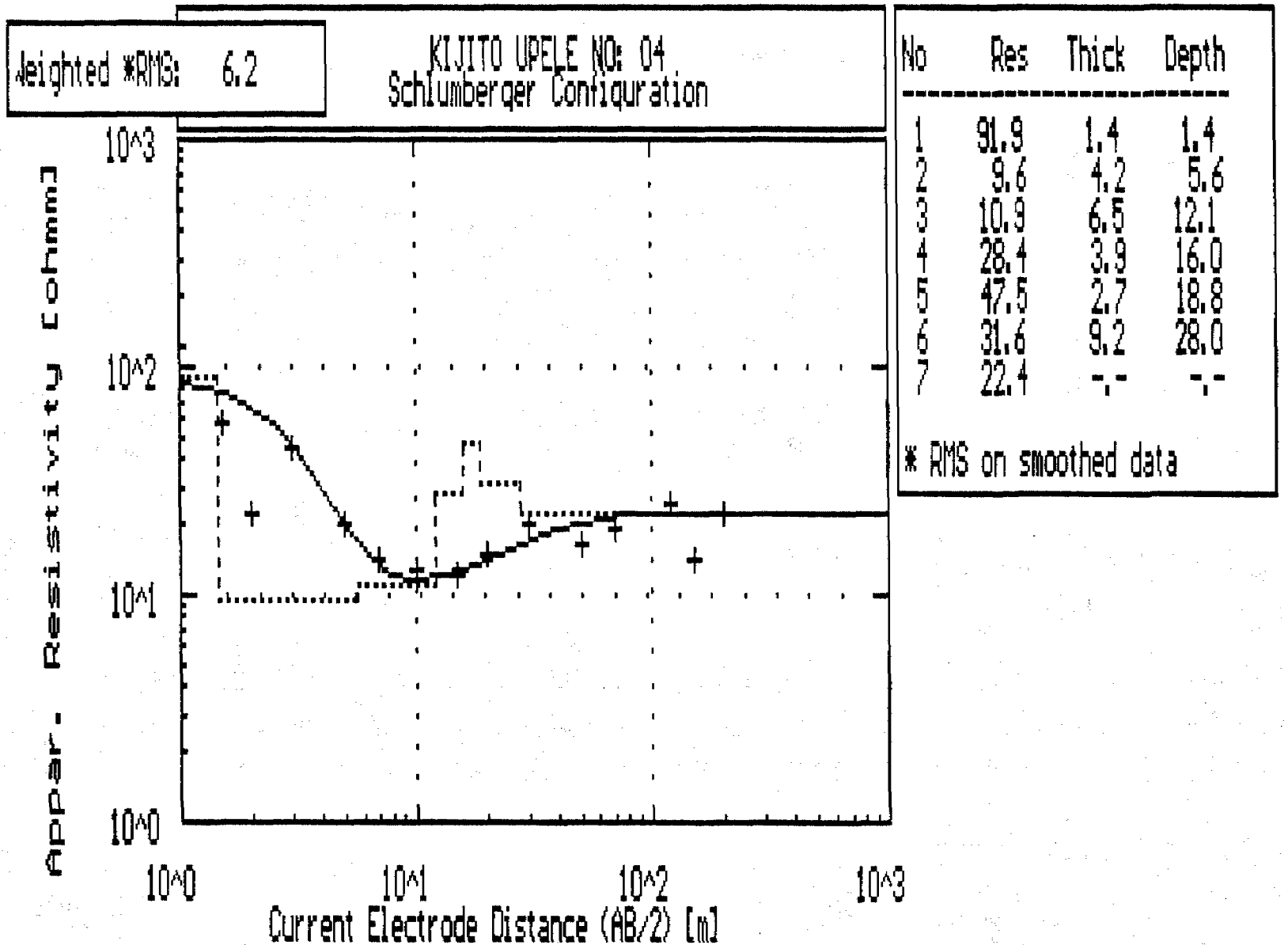

RMS-error : 2.4
MTONI NO: 09
Schlumberger Configuration
No Res Thick Depth
1 13.1 2.0 2.0
2 52.2 9.2 11.3
3 84.1 7.1 18.3
4 26.1 -.- -.-
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]

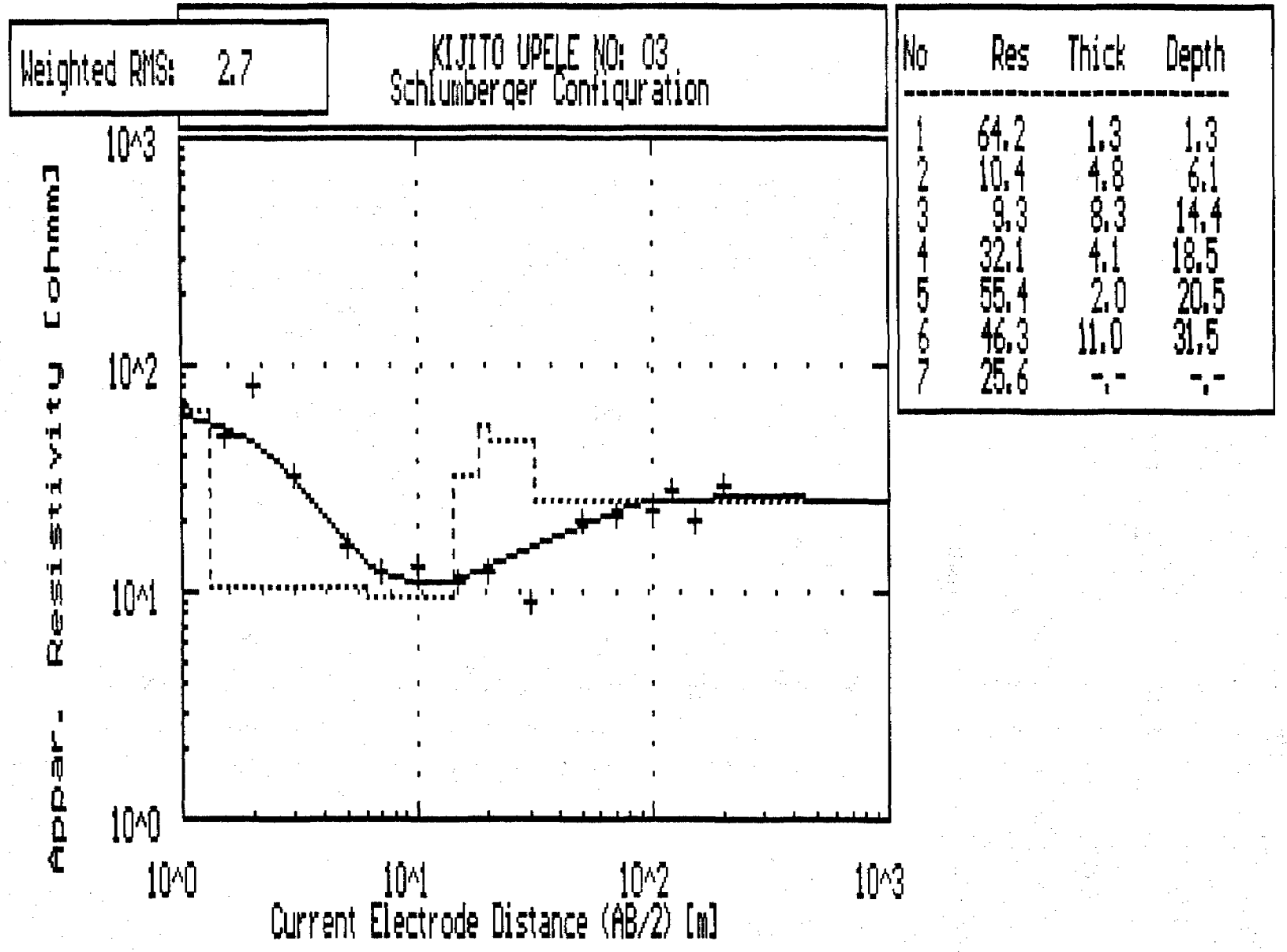

RMS-error : 3.3
MWEMBE MCHOMEKE NO: 08
Schlumberger Configuration
No Res Thick Depth
1 153.1 1.1 1.1
2 19.2 5.0 6.1
3 10.2 23.8 30.0
4 75.4 30.0 59.9
5 23.3 -.- -.-
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]

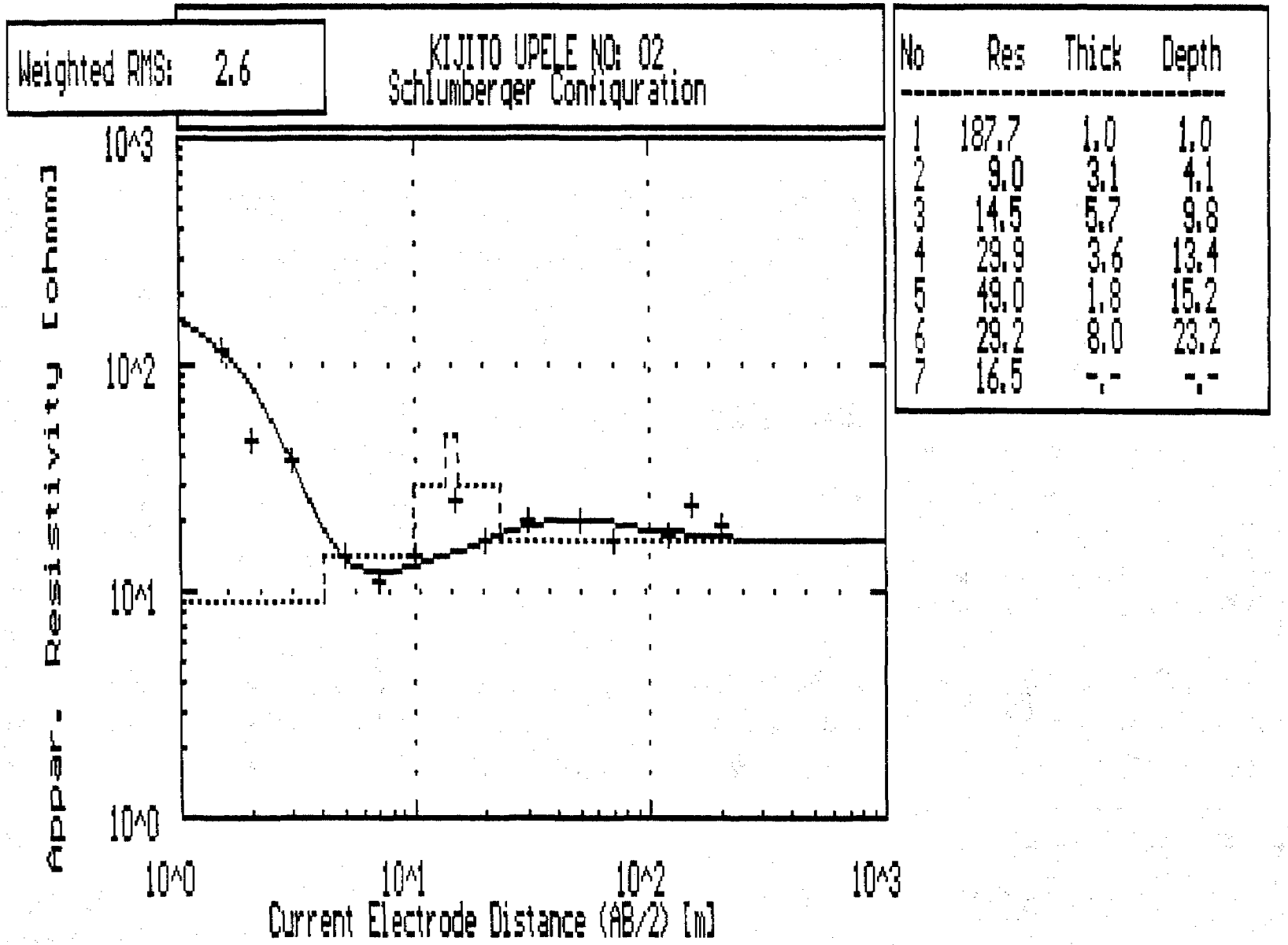

RMS-error : 4.7
Mwembe Mchomeke NO: 07
Schlumberger Configuration
No Res Thick Depth
1 350.6 1.9 1.9
2 11.3 5.2 7.1
3 26.3 31.9 39.1
4 87.5 33.9 73.0
5 33.1 -.- -.-
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]

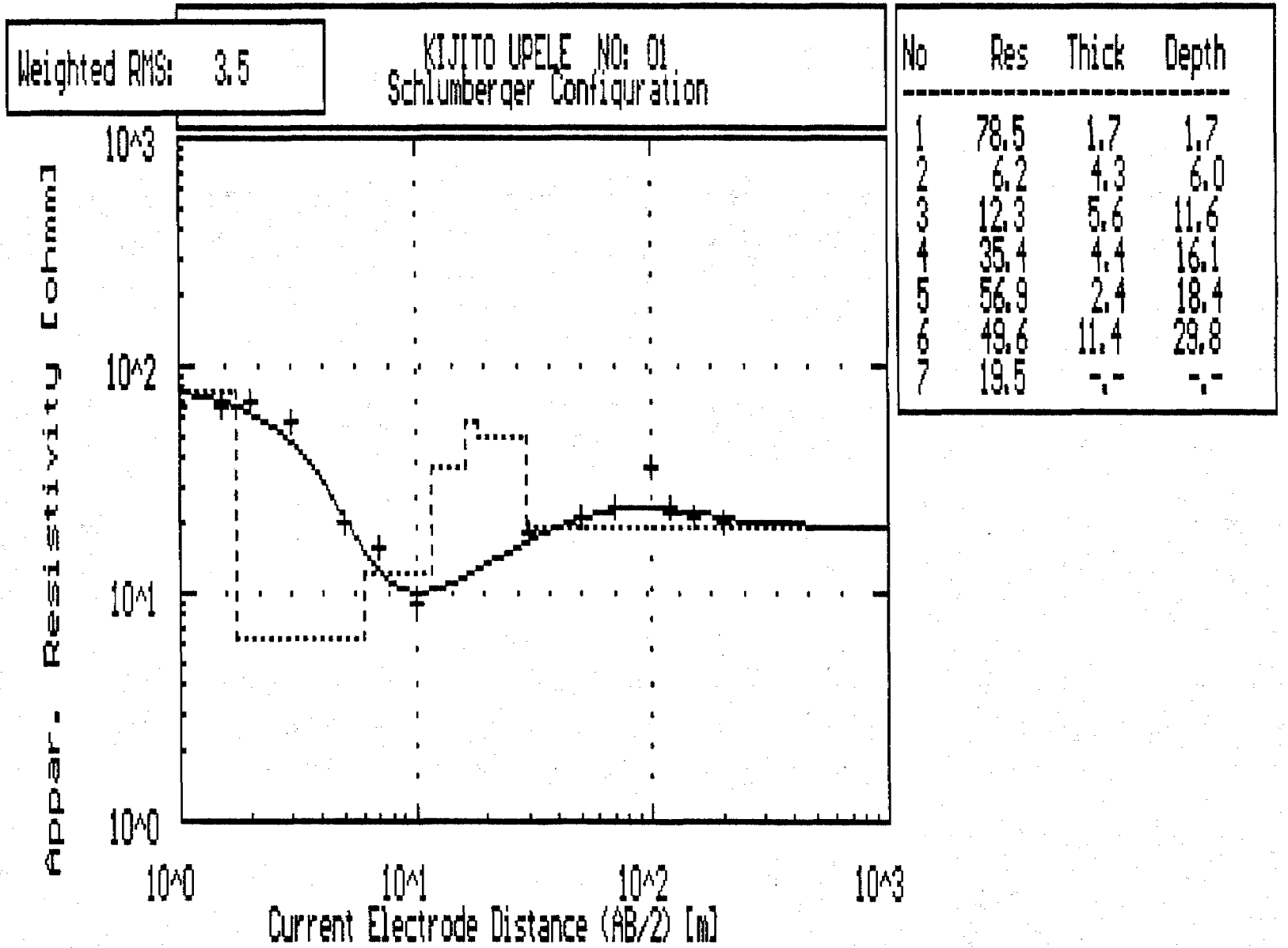

RMS-error : 2.0
MWEMBE MCHOMEKE, NO: 06
Schlumberger Configuration
No Res Thick Depth
1 163.2 1.4 1.4
2 6.8 6.2 7.7
3 46.6 19.7 27.4
4 114.6 32.2 59.6
5 23.9 -.- -.-
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]


RMS-error : 2.2
KIJITO UPELE NO: 05
Schlumberger Configuration
No Res Thick Depth
1 131.1 1.2 1.2
2 6.3 5.5 6.7
3 8.2 9.0 15.7
4 26.7 4.7 20.4
5 49.4 1.8 22.2
6 31.6 8.3 30.5
7 12.7 -.- -.-
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]


Weighted *RMS: 6.2
KIJITO UPELE NO: 04
Schlumberger Configuration
No Res Thick Depth
1 91.9 1.4 1.4
2 9.6 4.2 5.6
3 10.9 6.5 12.1
4 28.4 3.9 16.0
5 47.5 2.7 18.8
6 31.6 9.2 28.0
7 22.4 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]

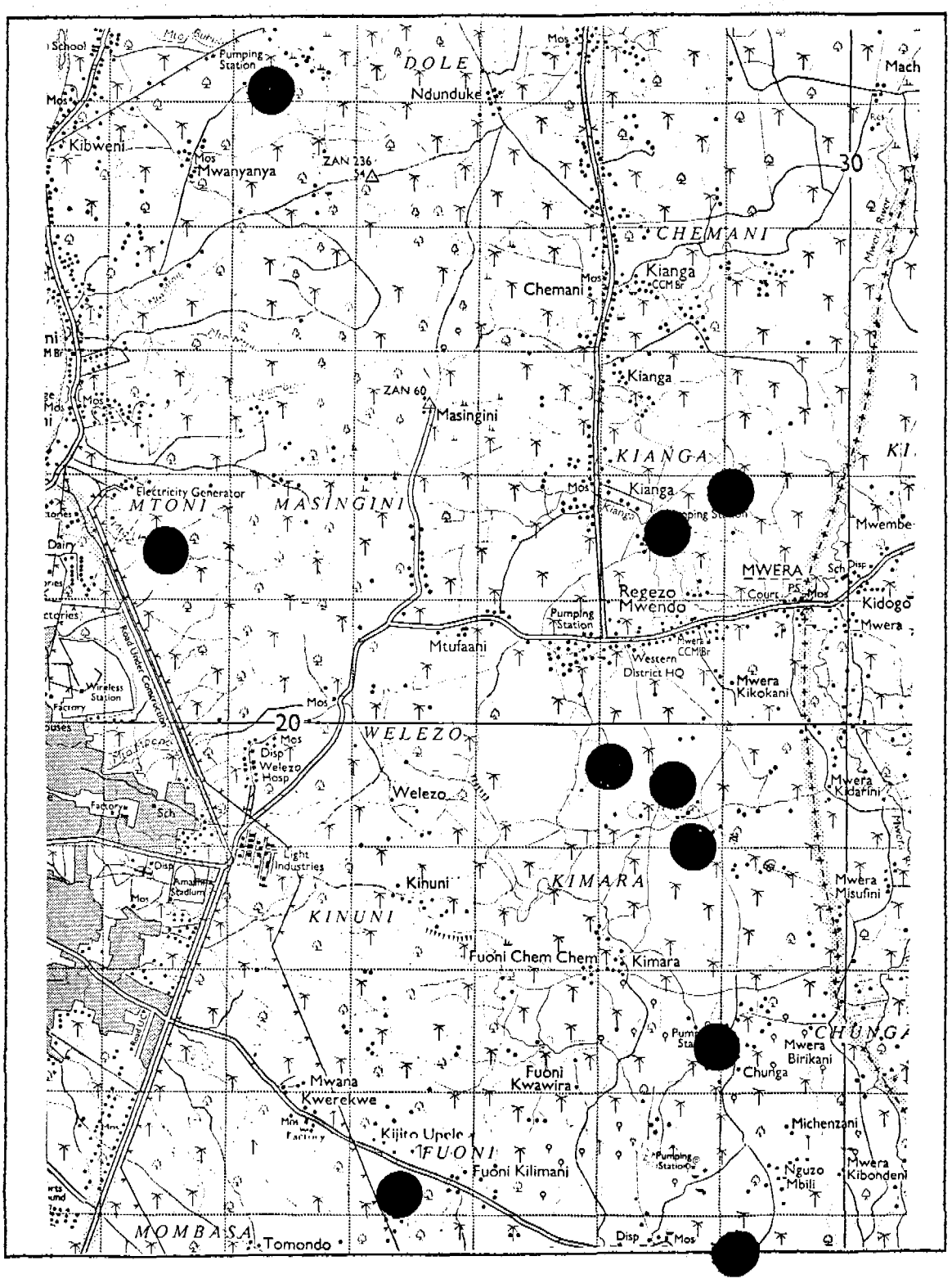

Weighted RMS: 2.7
KIJITO UPELE NO: 03
Schlumberger Configuration
No Res Thick Depth
1 64.2 1.3 1.3
2 10.4 4.8 6.1
3 9.3 8.3 14.4
4 32.1 4.1 18.5
5 55.4 2.0 20.5
6 46.3 11.0 31.5
7 25.6 -.- -.-
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]


Weighted RMS: 2.6
KIJITO UPELE NO: 02
Schlumberger Configuration
No Res Thick Depth
1 187.7 1.0 1.0
2 9.0 3.1 4.1
3 14.5 5.7 9.8
4 29.9 3.6 13.4
5 49.0 1.8 15.2
6 29.2 8.0 23.2
7 16.5 -.- -.-
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]


Weighted RMS: 3.5
KIJITO UPELE NO: 01
Schlumberger Configuration
No Res Thick Depth
1 78.5 1.7 1.7
2 6.2 4.3 6.0
3 12.3 5.6 11.6
4 35.4 4.4 16.1
5 56.9 2.4 18.4
6 49.6 11.4 29.8
7 19.5 -.- -.-
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]

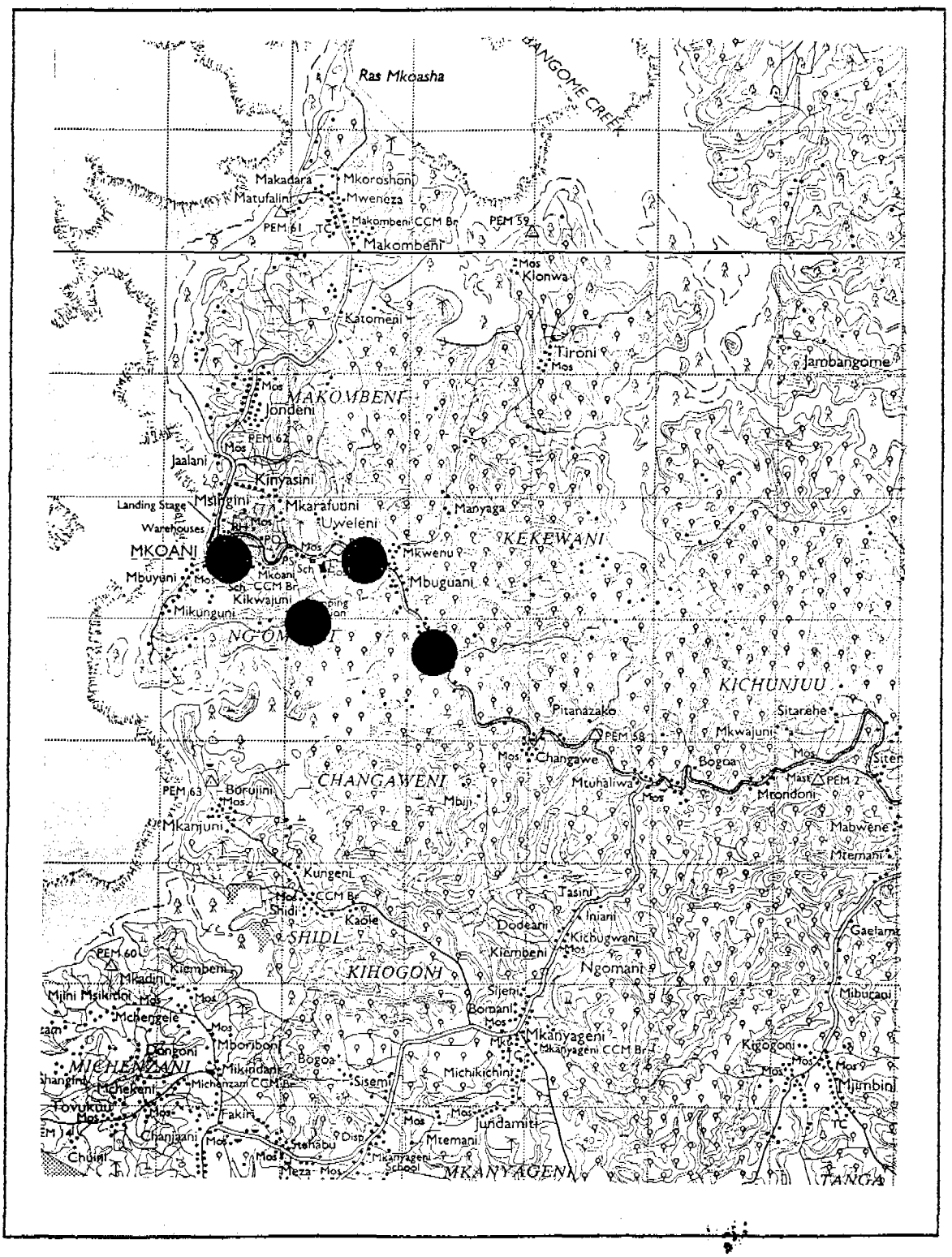
ANNEX 8

Potential drilling sites

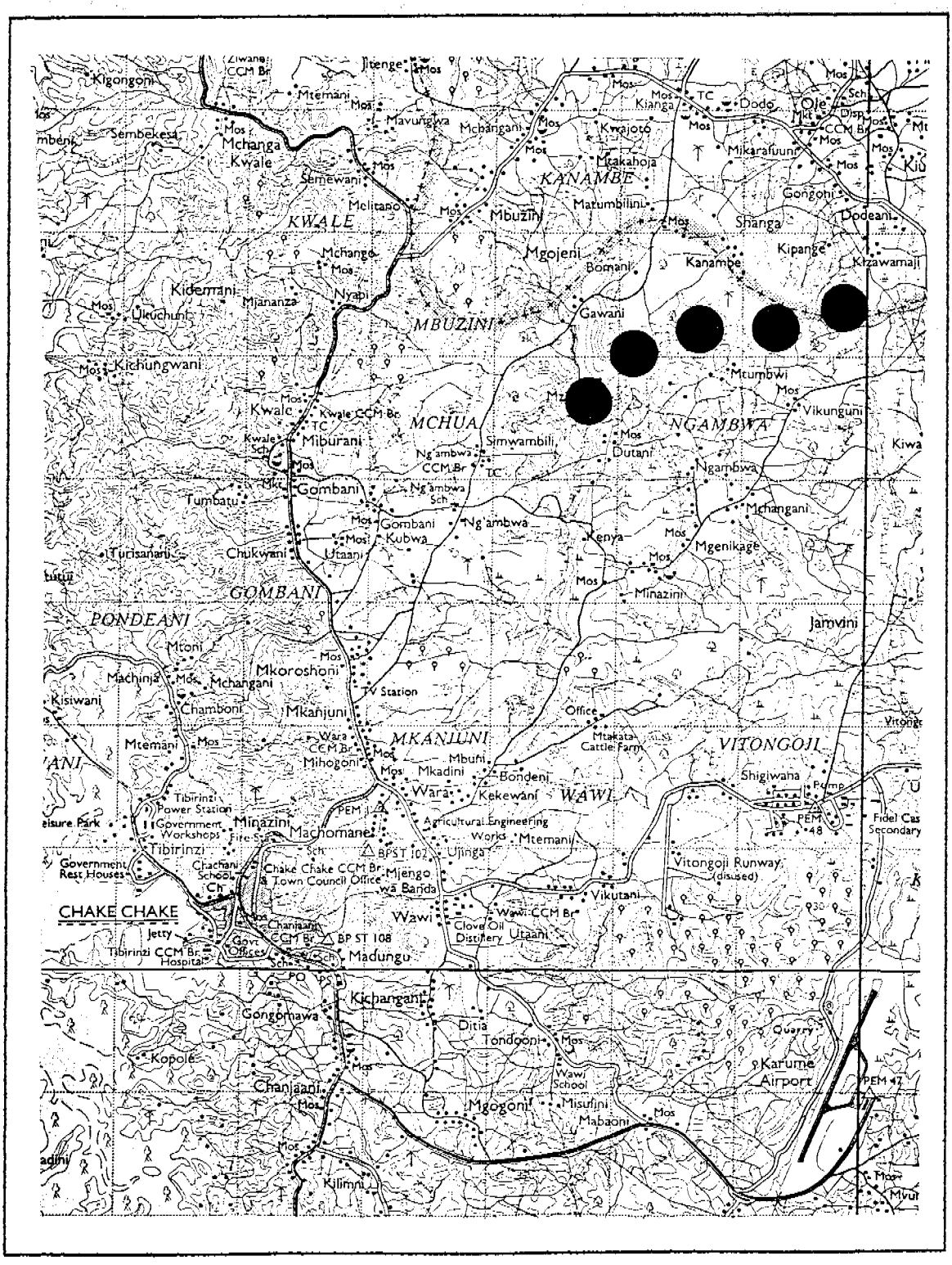


POTENTIAL DRILLING SITES, ZANZIBAR TOWN

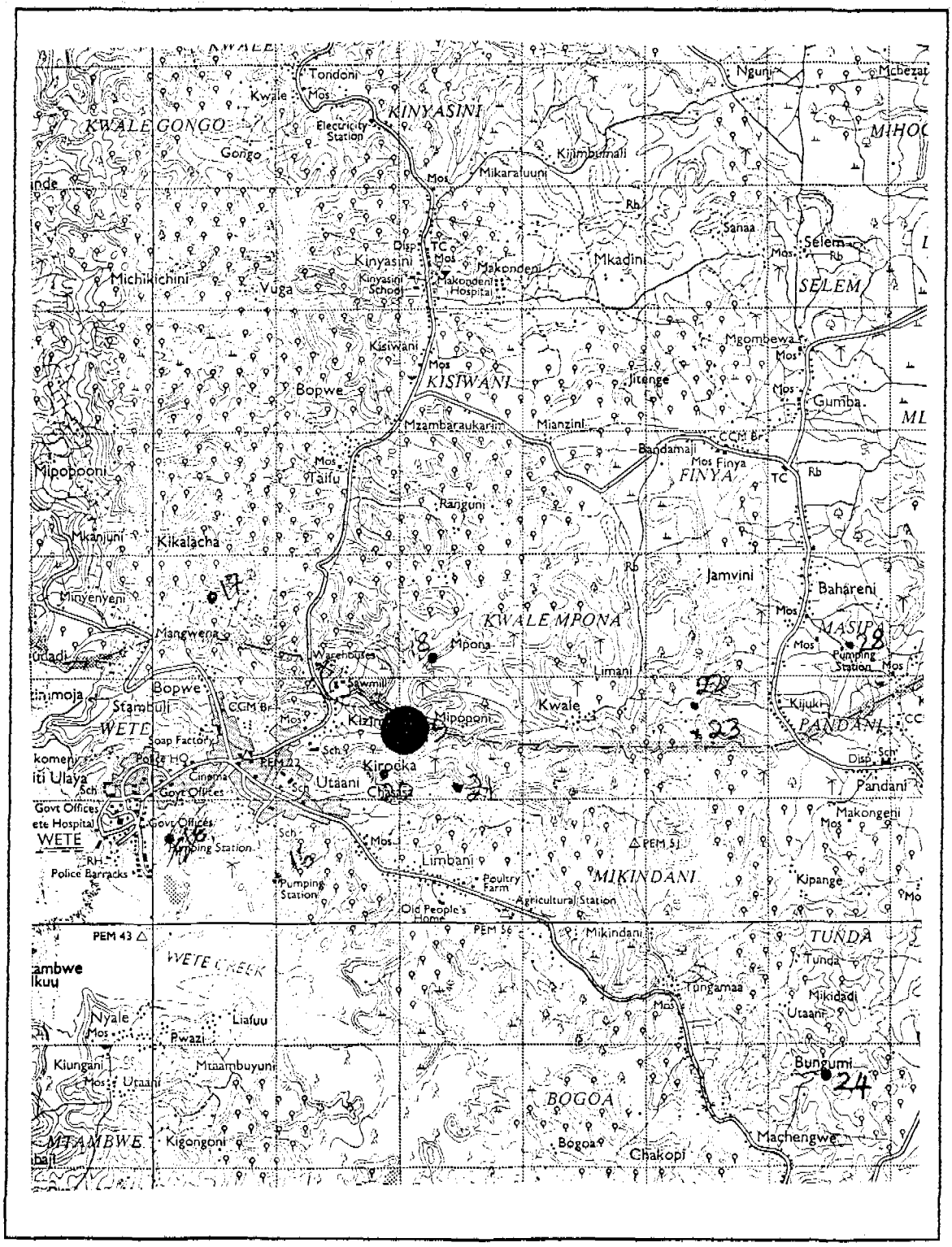
Observation hole



POTENTIAL DRILLING SITES, MKOANI



POTENTIAL DRILLING SITES, CHAKE CHAKE

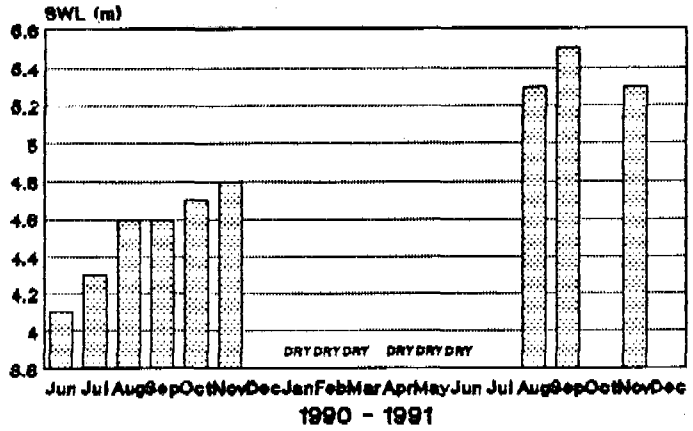


POTENTIAL DRILLING SITES, WETE

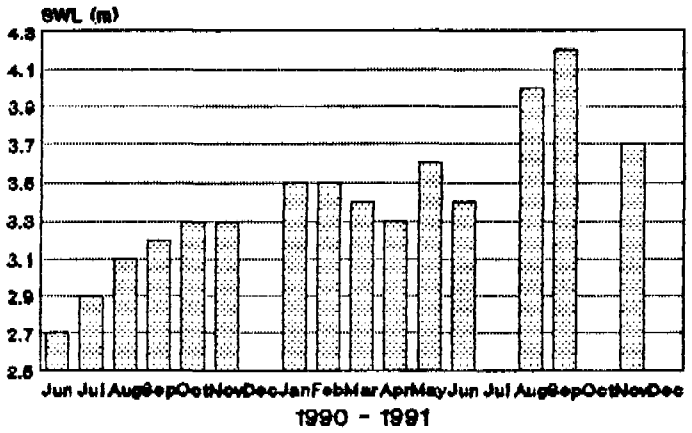
ANNEX 9

Local well monitoring results

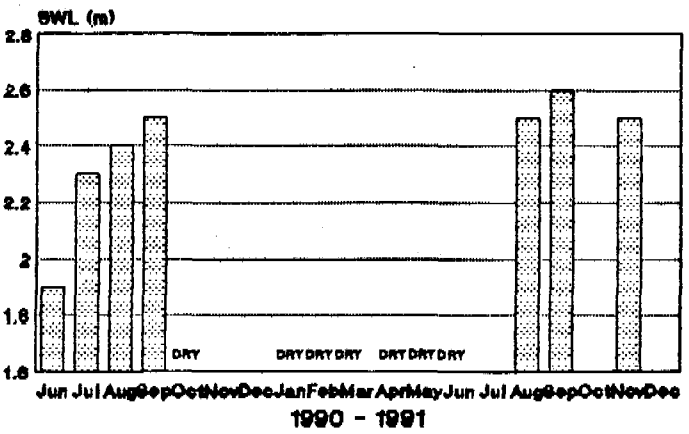
KISAKASAKA - WELL NO. 1



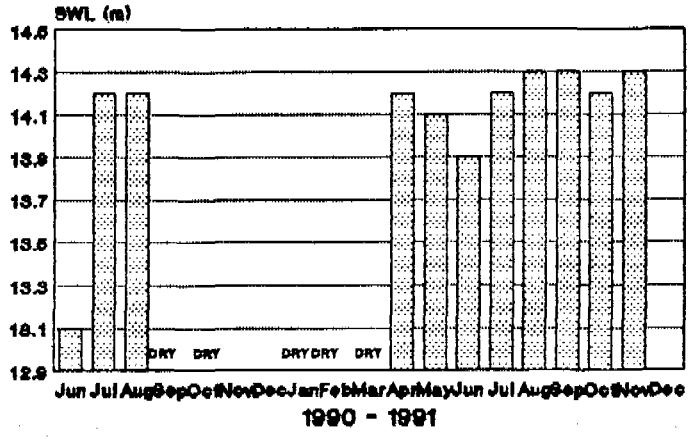
KISAKASAKA - WELL NO. 2



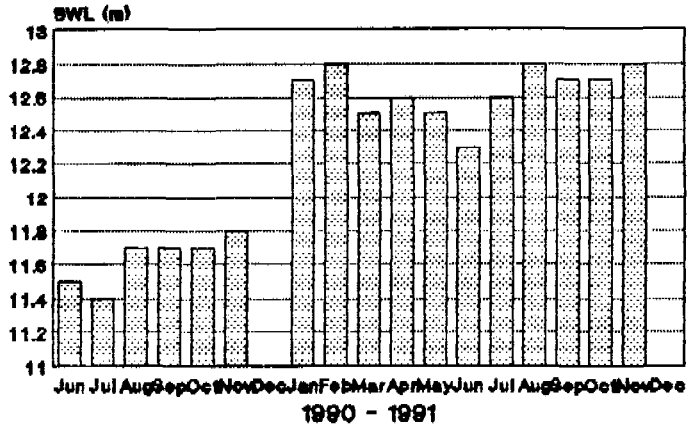
MKUNGA - WELL NO. 3



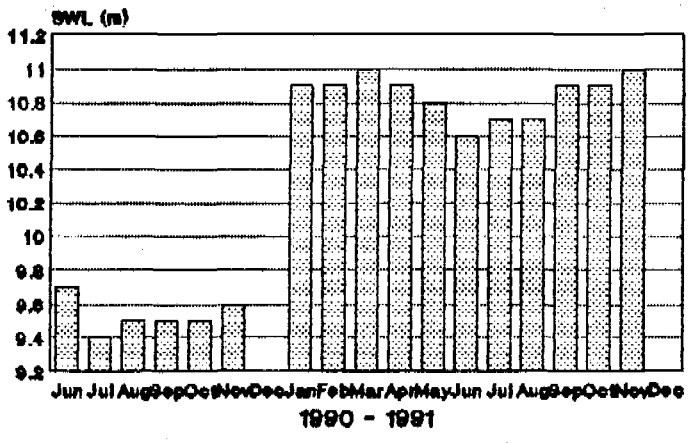
FUONI - WELL NO. 4



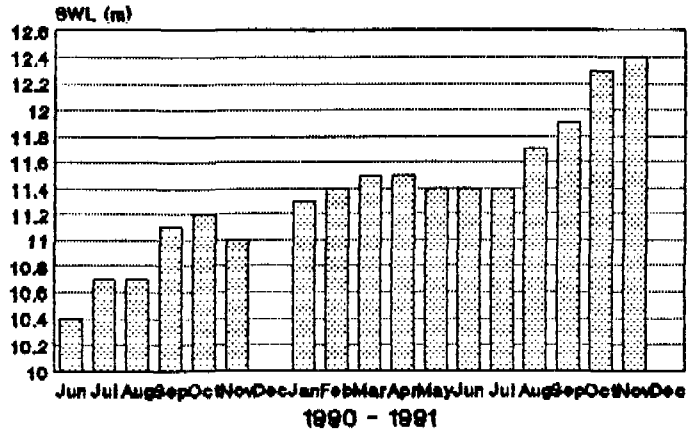
FUONI - WELL NO. 5



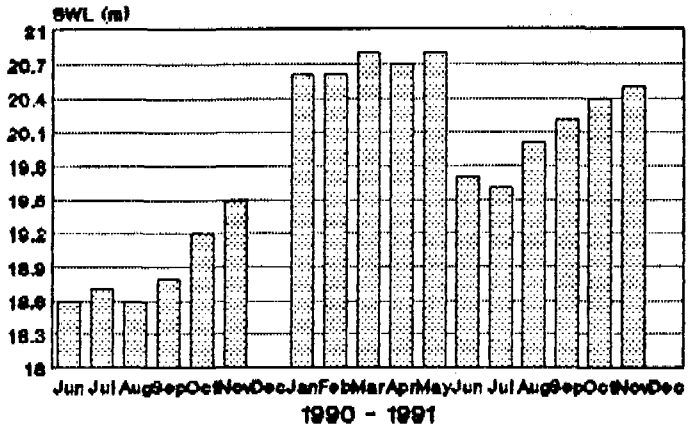
FUONI - WELL NO. 6



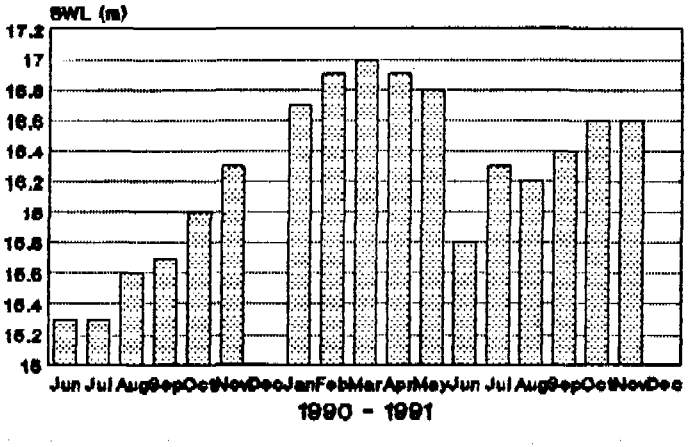
JUMBI - WELL NO. 7



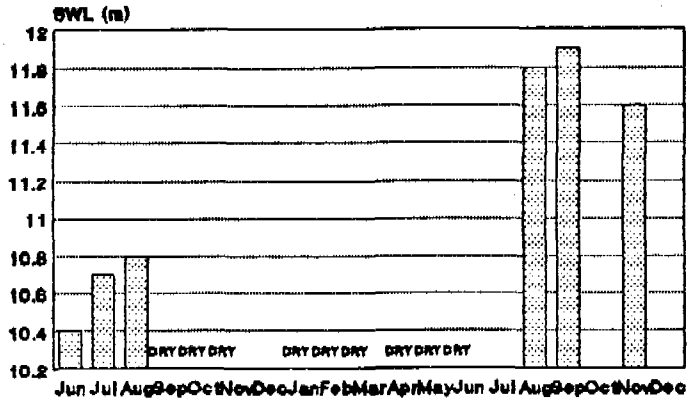
JUMBI - WELL NO. 8



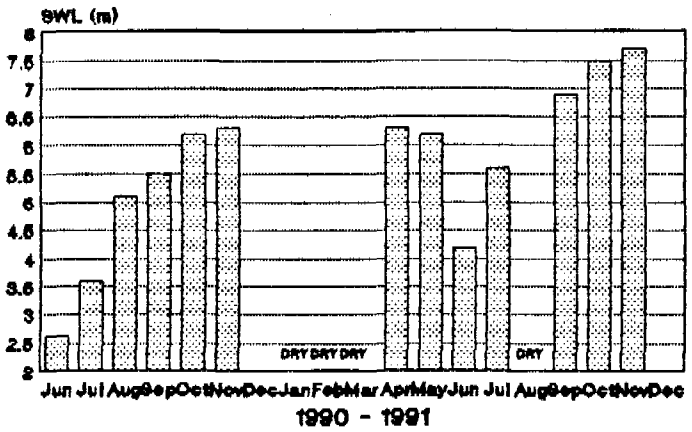
TUNGUU - WELL NO. 10



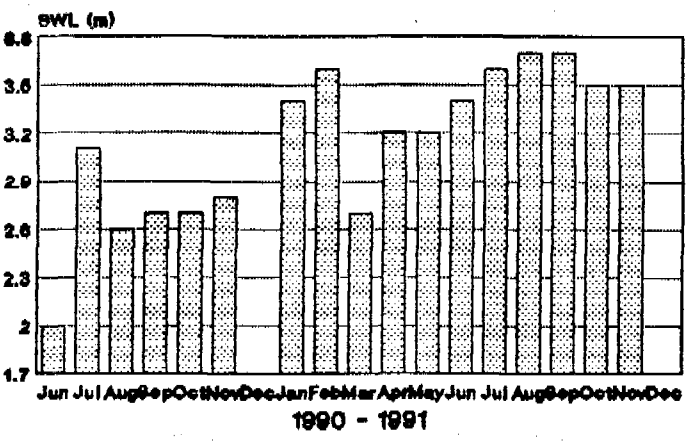
KOMBENI - WELL NO. 11



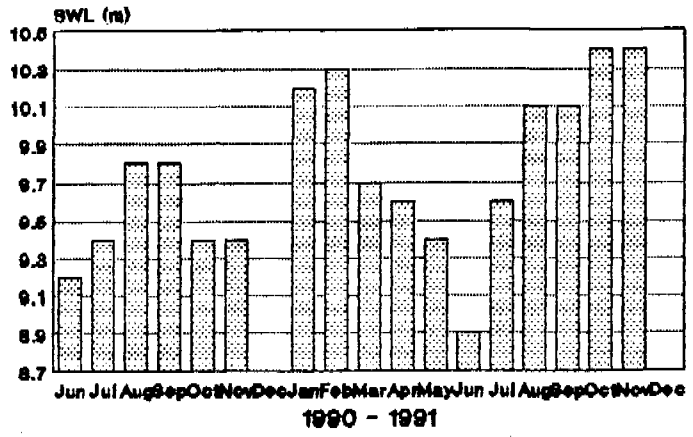
MWERA - WELL NO. 12



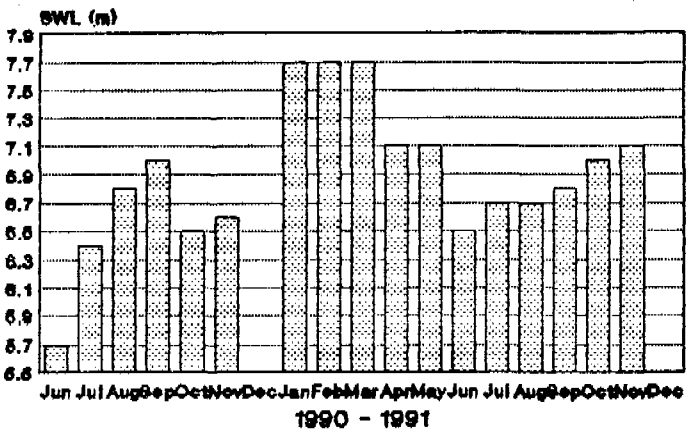
MWERA - WELL NO. 13



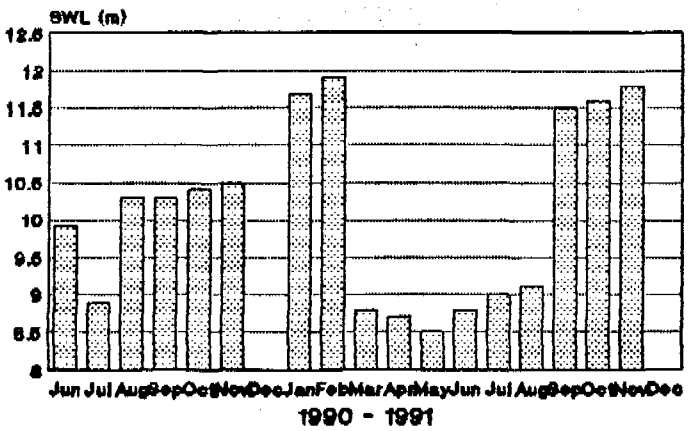
MWERA - WELL NO. 14



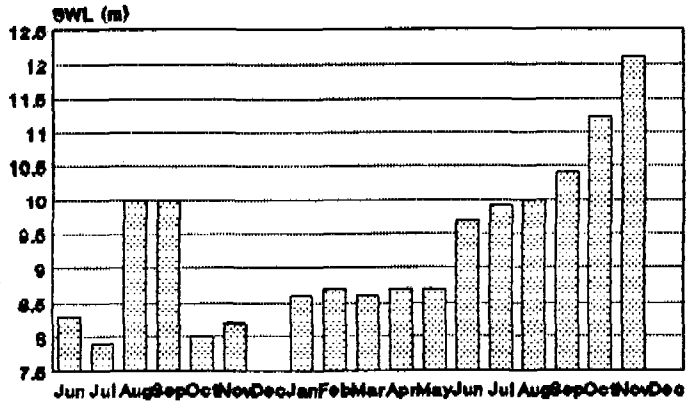
KOANI - WELL NO. 18



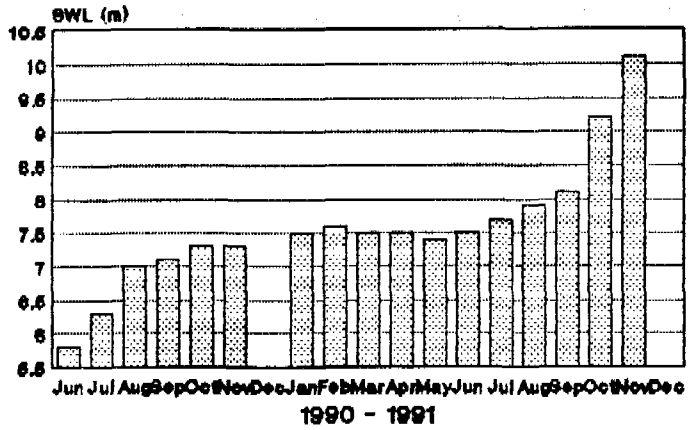
KOANI - WELL NO. 19



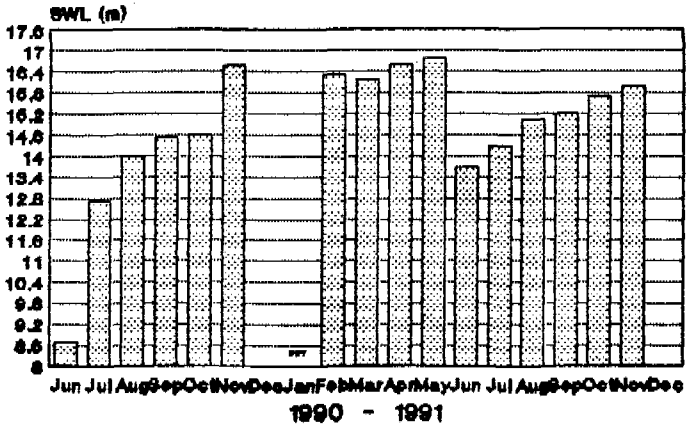
PONGWE - WELL NO. 20



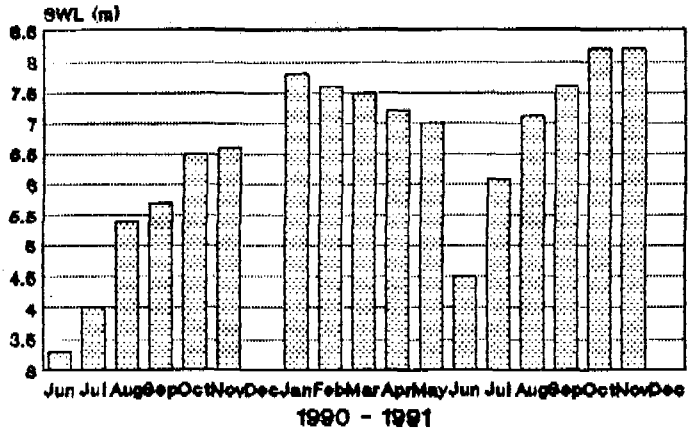
PONGWE - WELL NO. 21



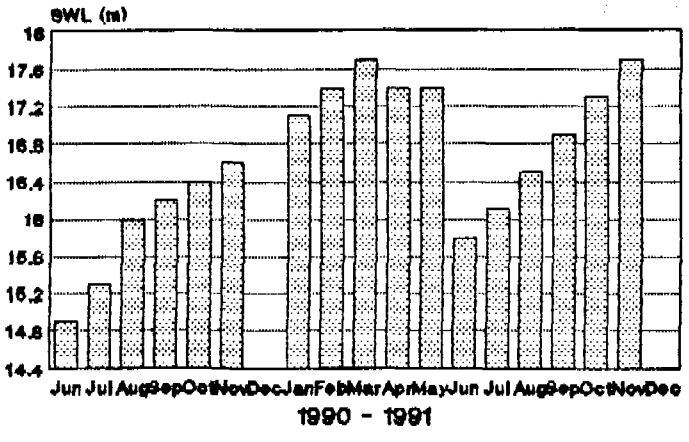
KIANGA - WELL NO. 23



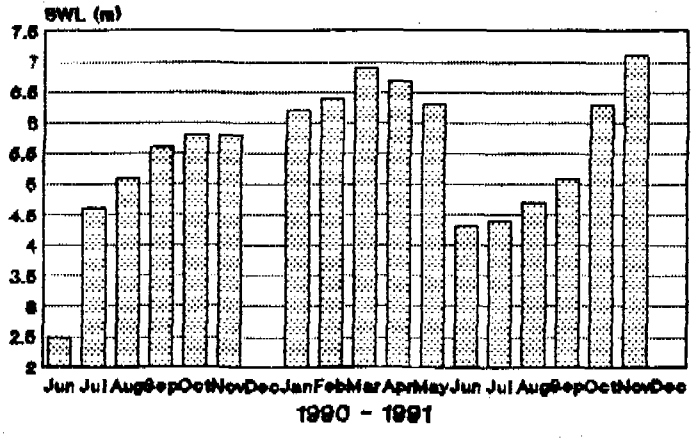
MWERA - WELL NO. 24



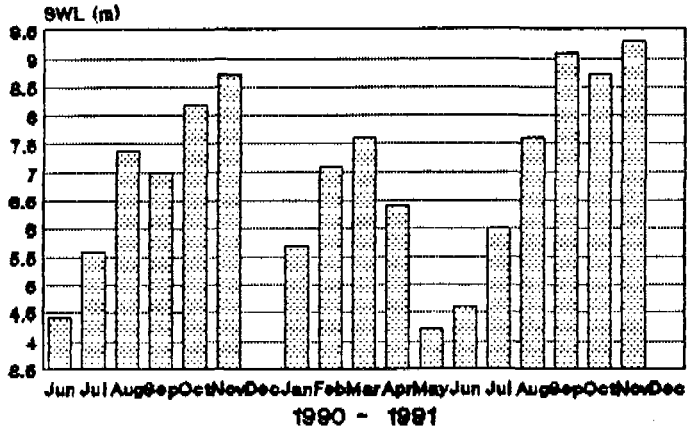
MWERA - WELL NO. 26



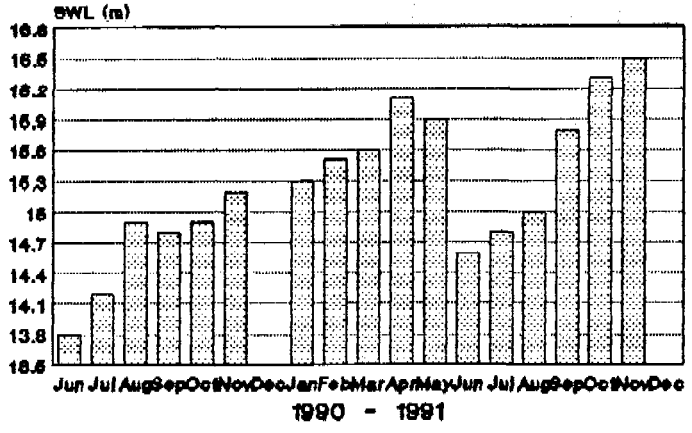
MWERA - WELL NO. 28



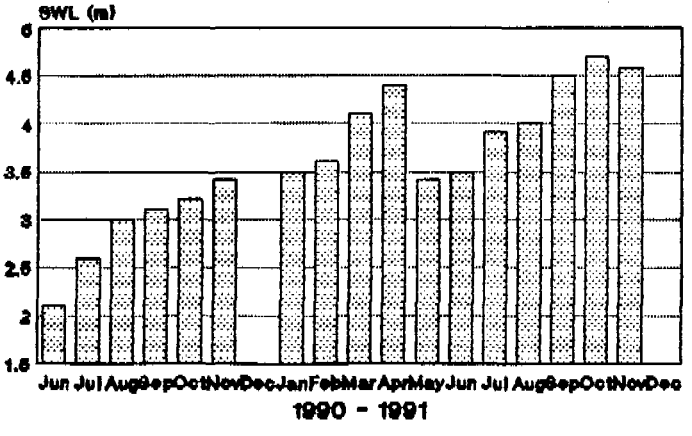
FUONI - WELL NO. 32



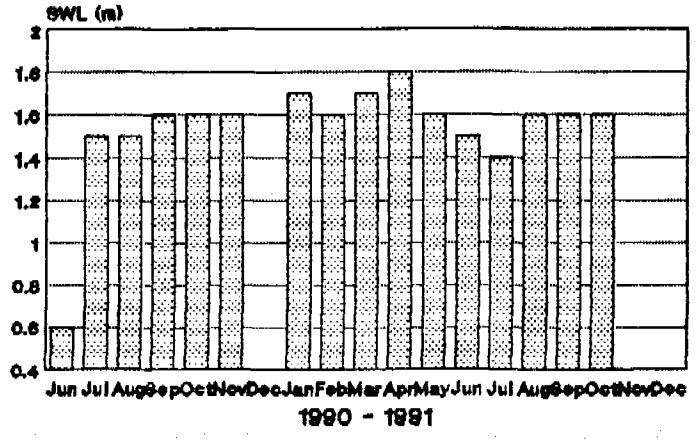
FUONI - WELL NO. 34



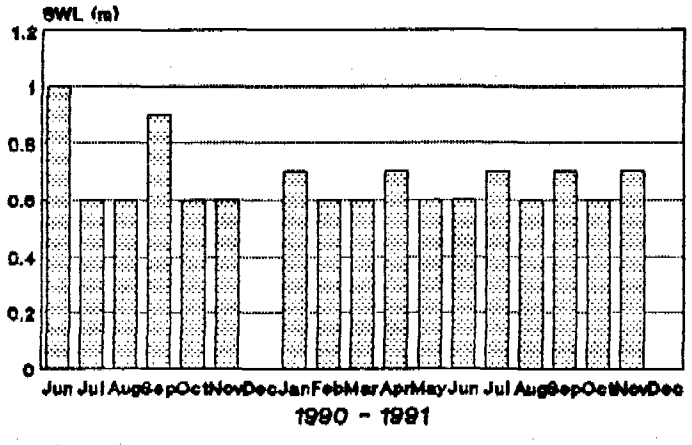
FUONI - WELL NO. 36



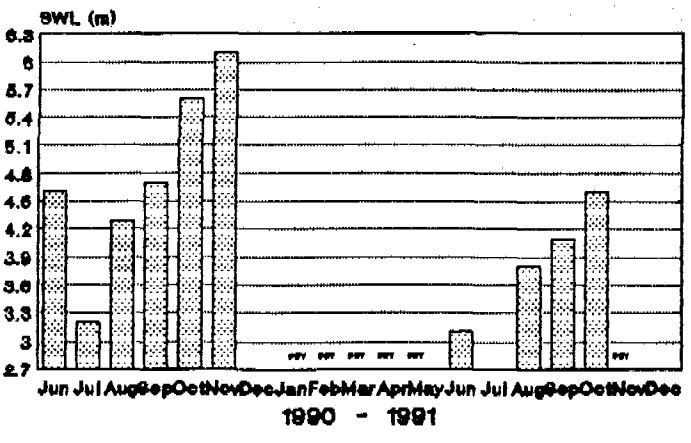
MACHUI - SPRING NO. 37



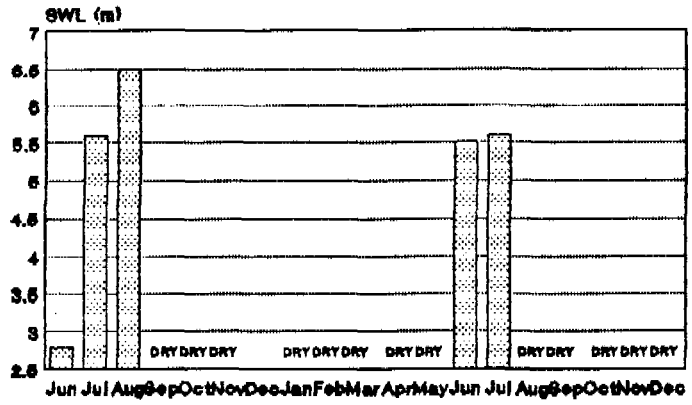
MACHUI - SPRING NO. 38



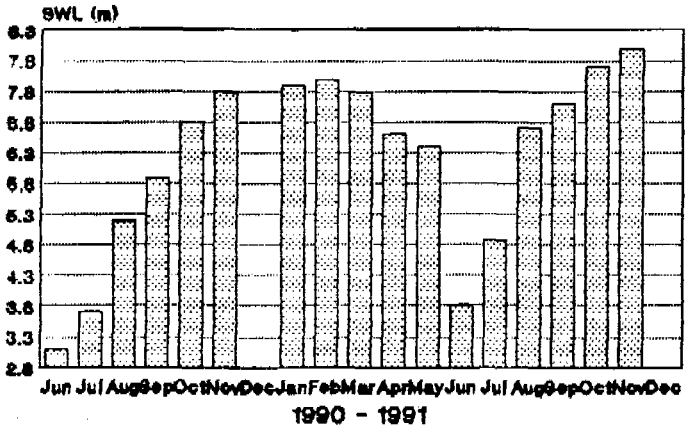
KIANGA - WELL NO. 41



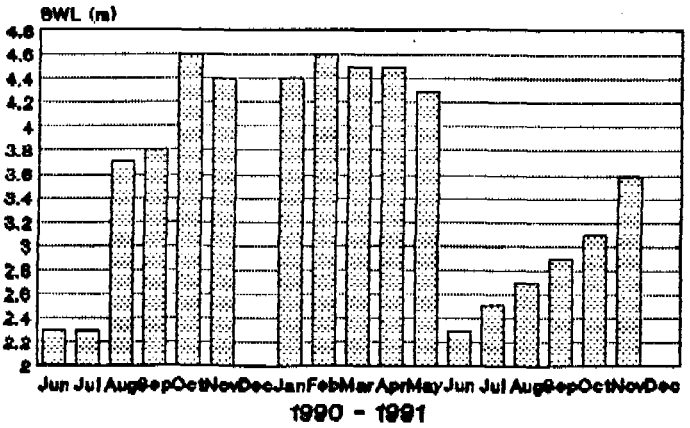
KIANGA - WELL NO. 42



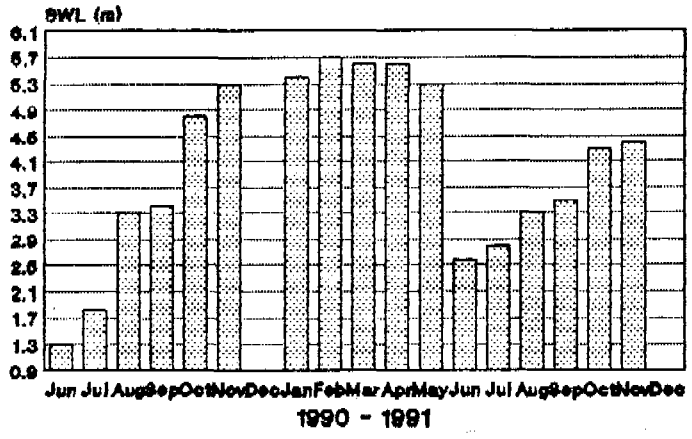
MKADINI - WELL NO. 43



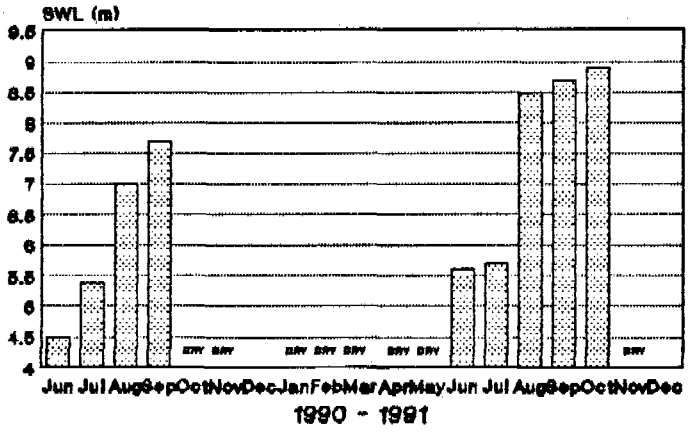
KIANGA - WELL NO. 44



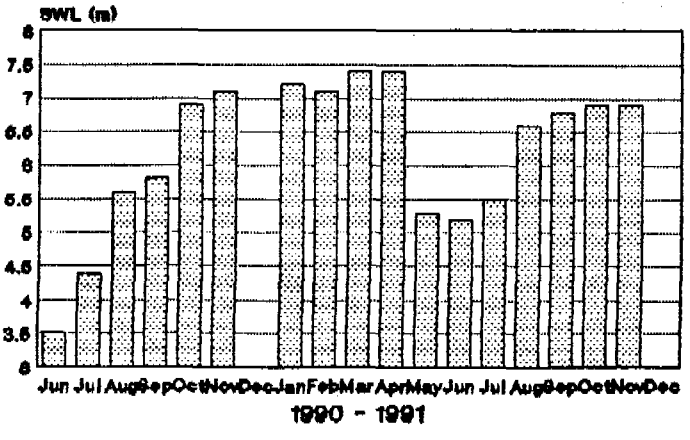
KIANGA - WELL NO. 45



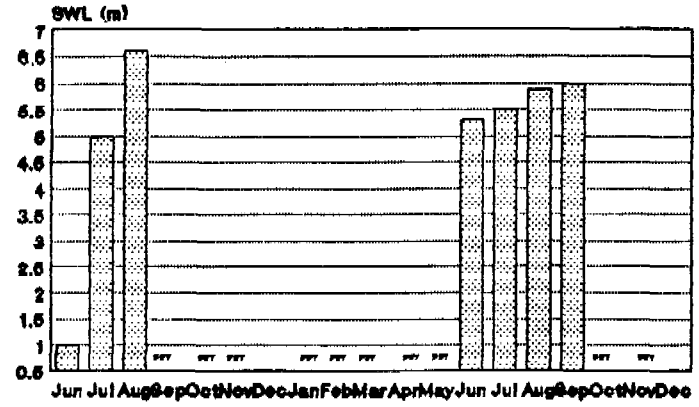
KIANGA - WELL NO. 46



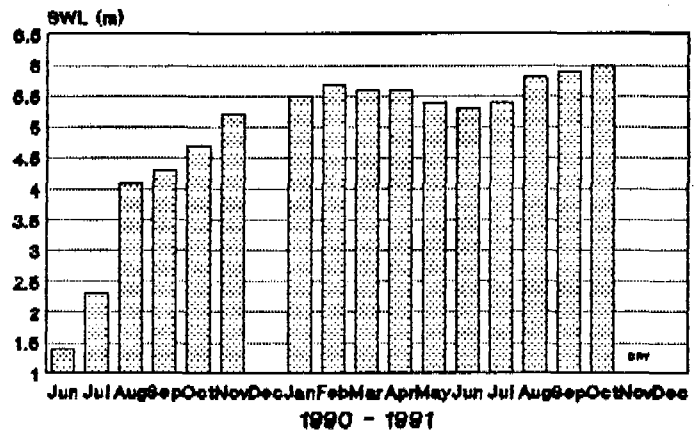
KIANGA - WELL NO. 47



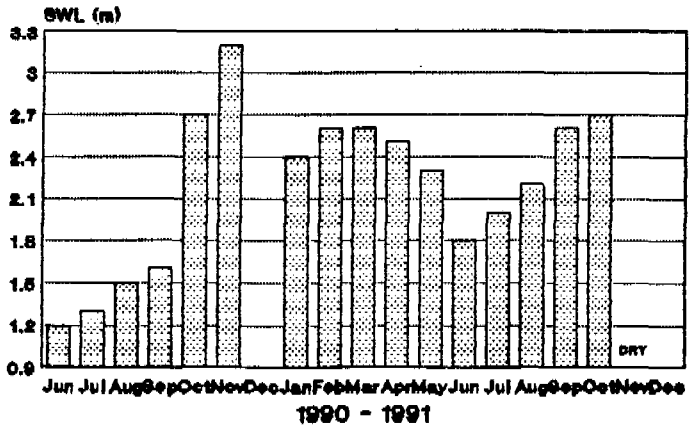
KIANGA - WELL NO. 48



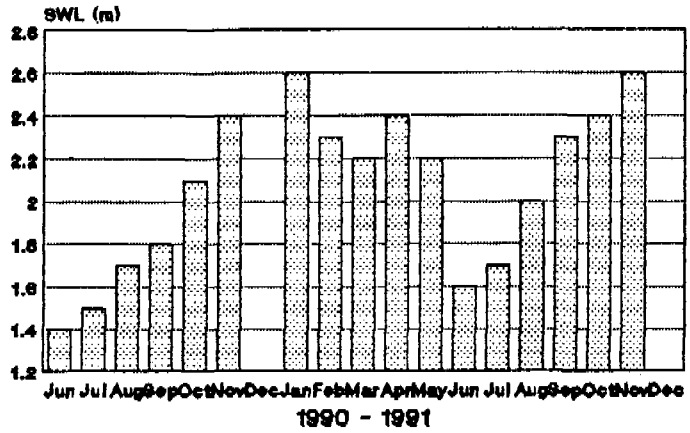
KIANGA - WELL NO. 49



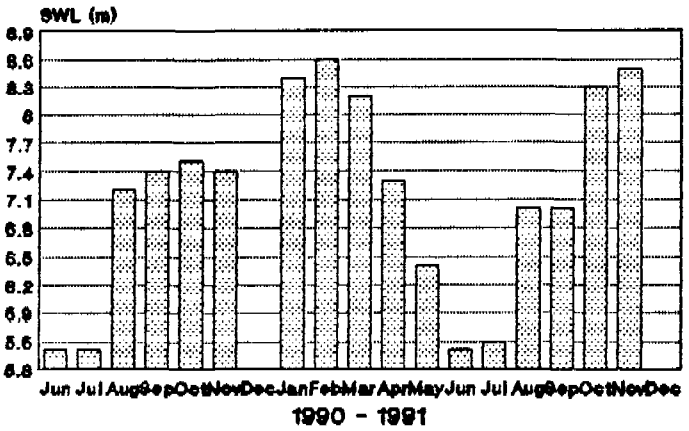
KIANGA - WELL NO. 50



DOLE - WELL NO. 52



KIDIMNI - WELL NO. 53



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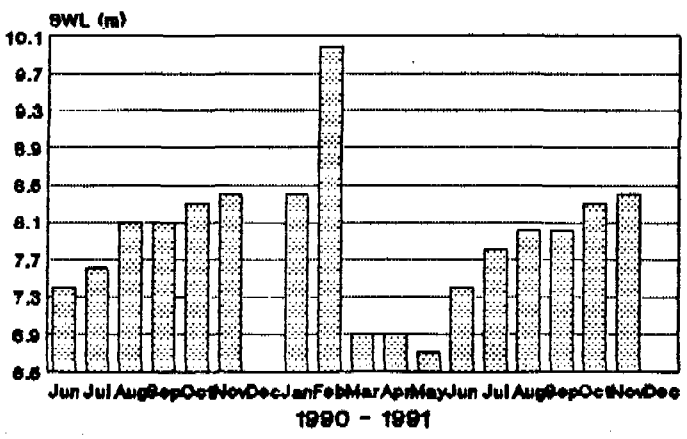

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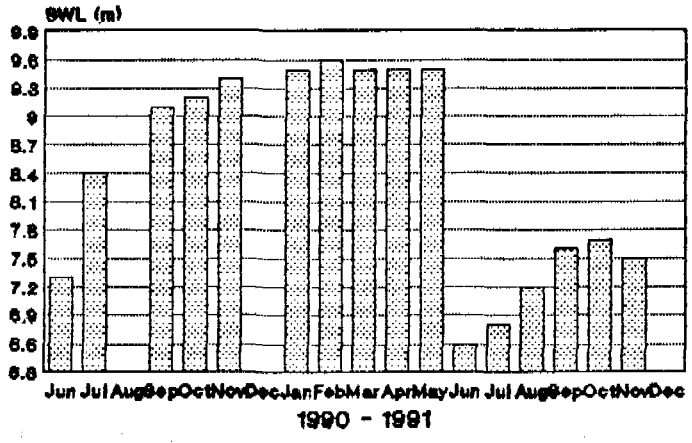

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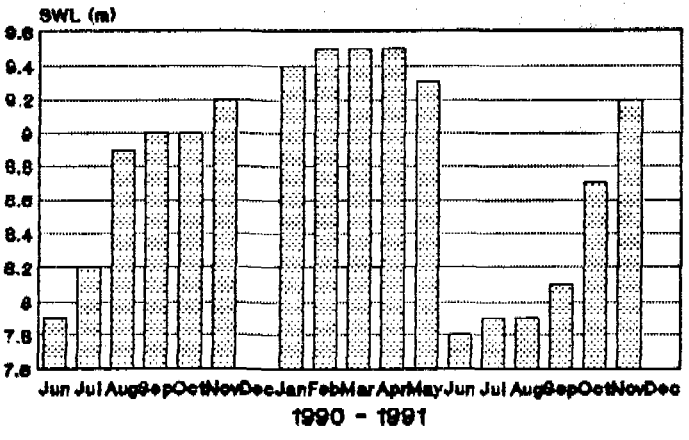
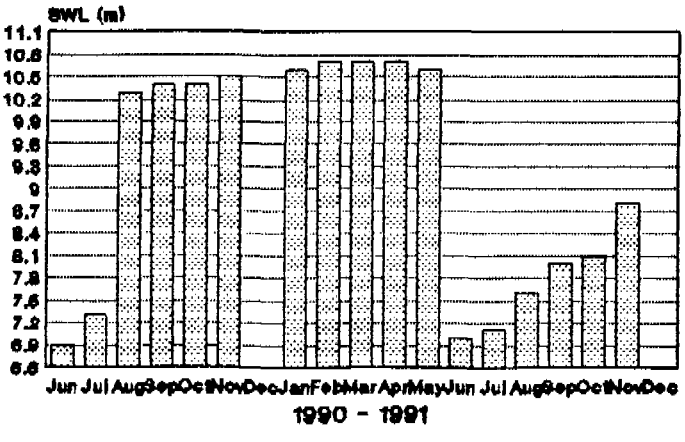
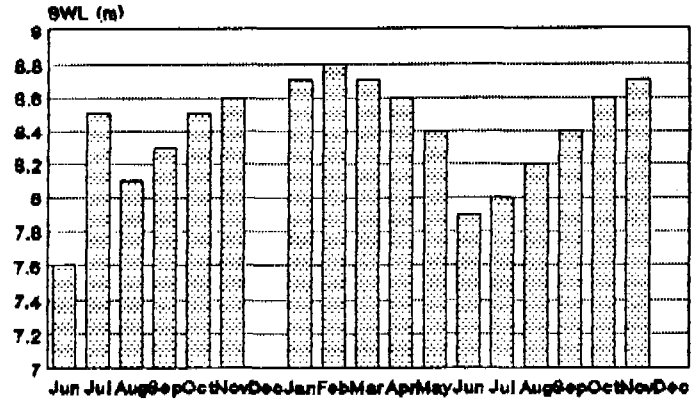


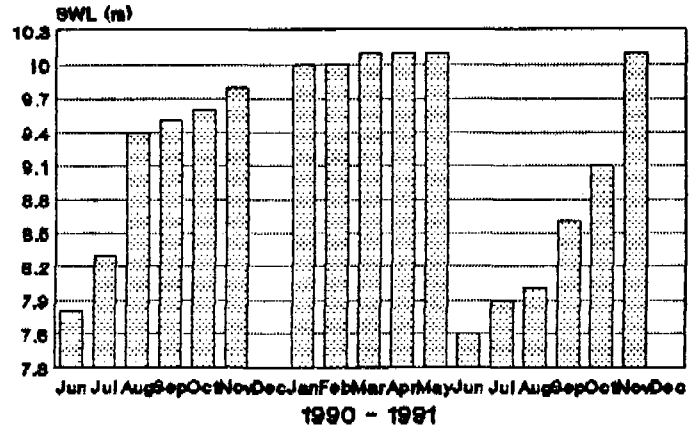
KIDIMNI - WELL NO. 57



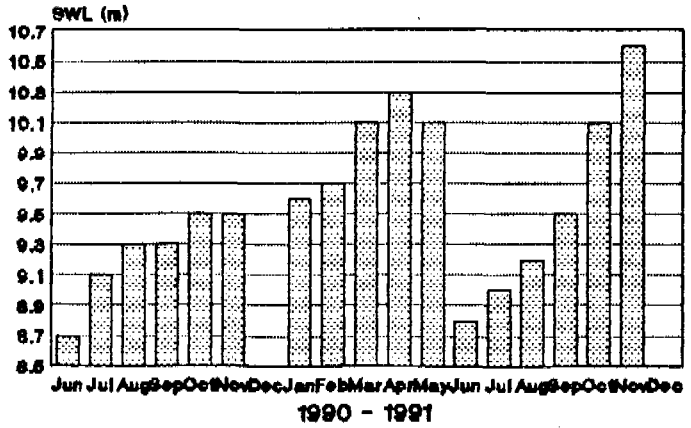
KITUMBA - WELL NO. 58



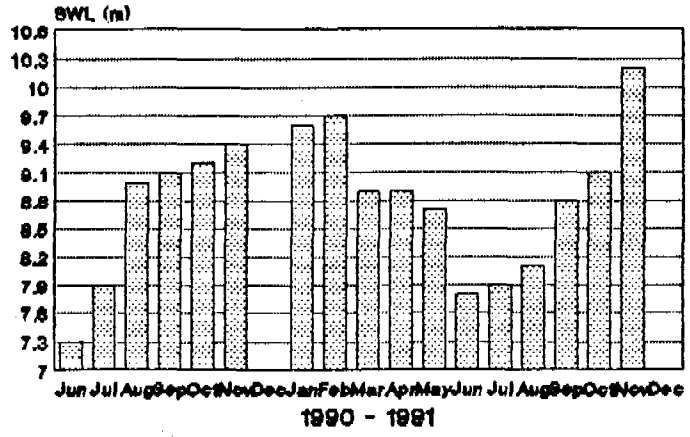
KITUMBA - WELL NO. 59



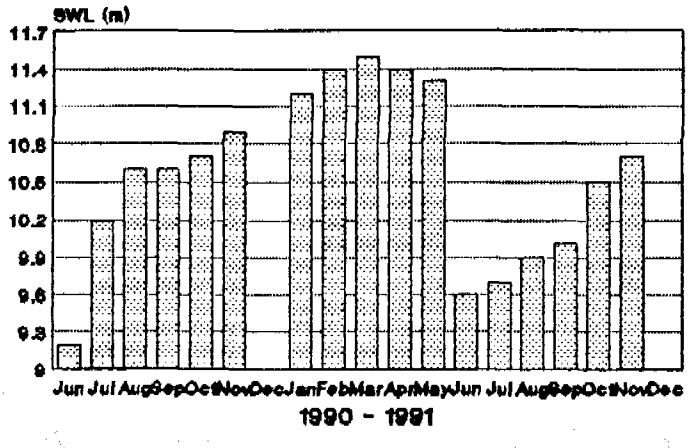
KITUMBA - WELL NO. 60



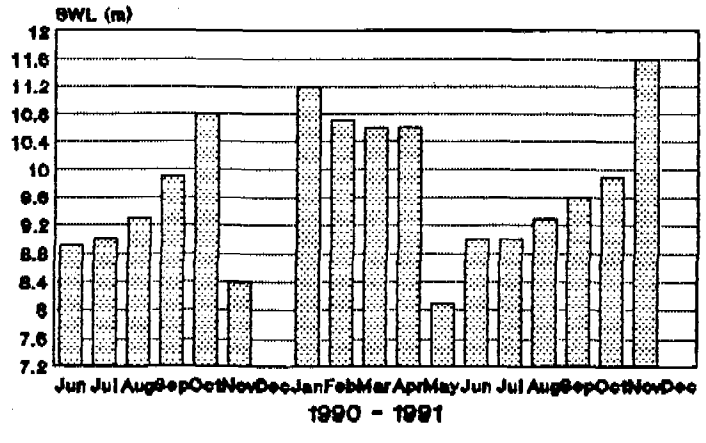
KITUMBA - WELL NO. 61



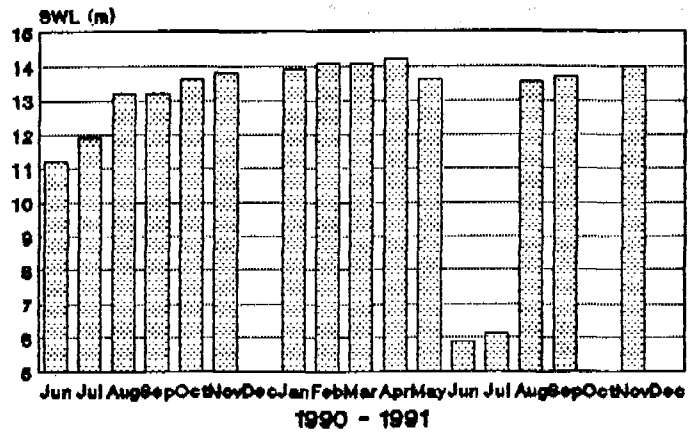
KITUMBA - WELL NO. 62



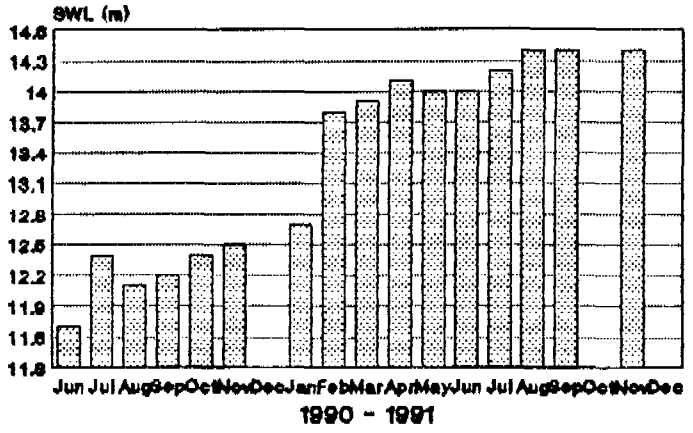
KITUMBA - WELL NO. 63



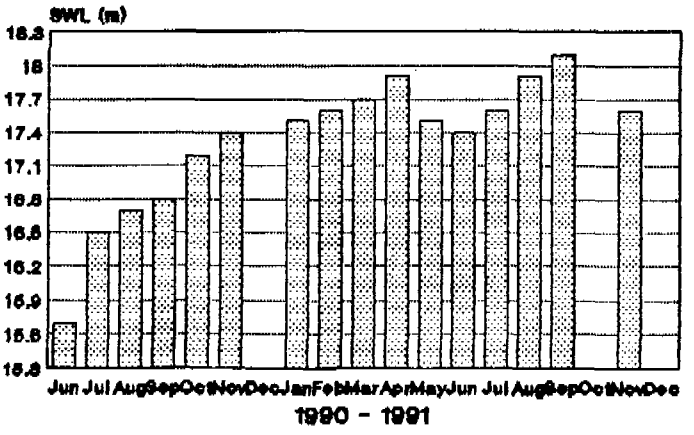
KITUMBA - WELL NO. 64



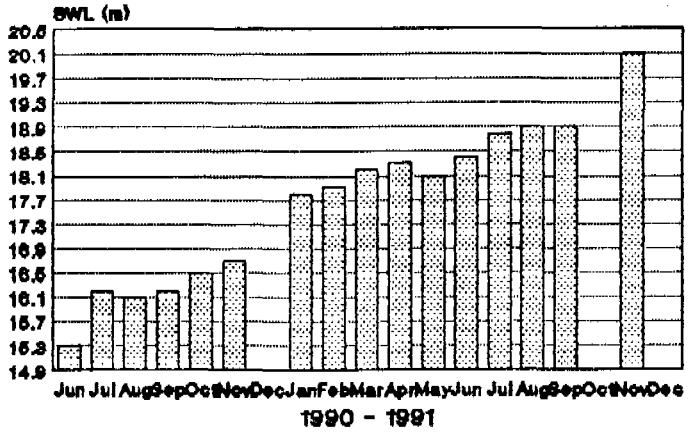
KWAMBANI - WELL NO. 65



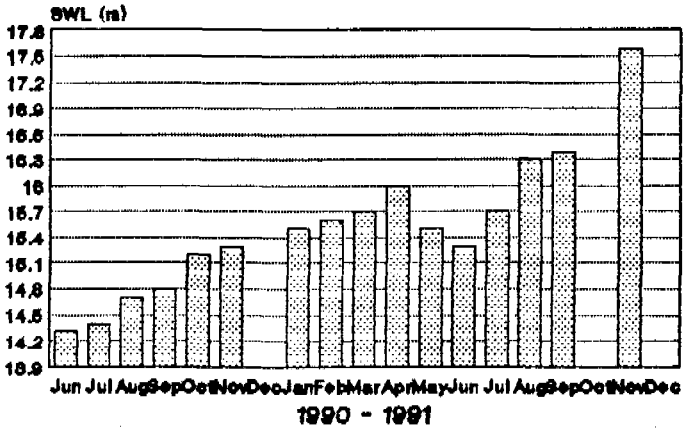
KIBOJE - WELL NO. 66



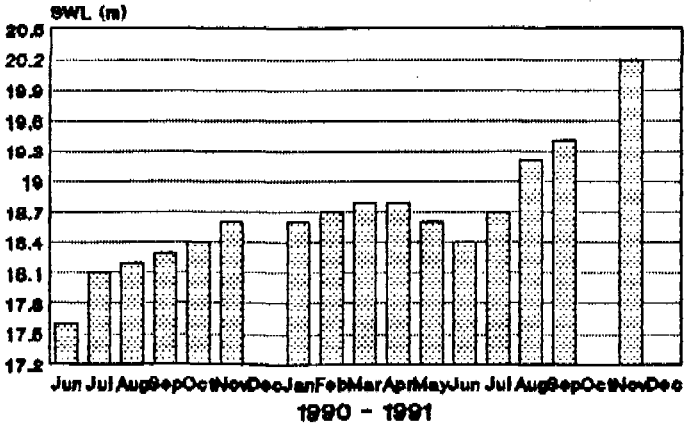
KIBOJE - WELL NO. 67



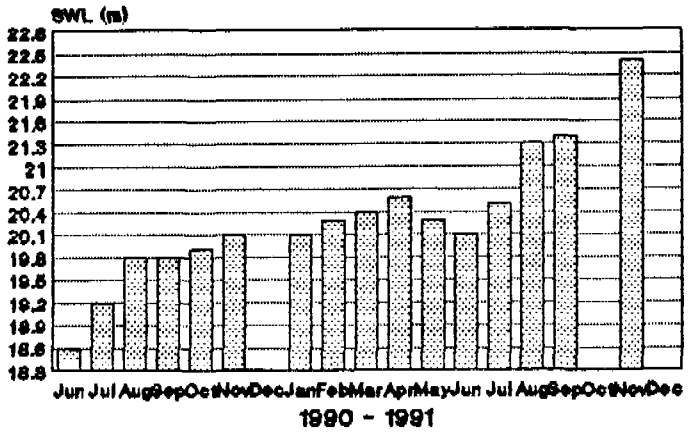
KIBOJE - WELL NO. 68



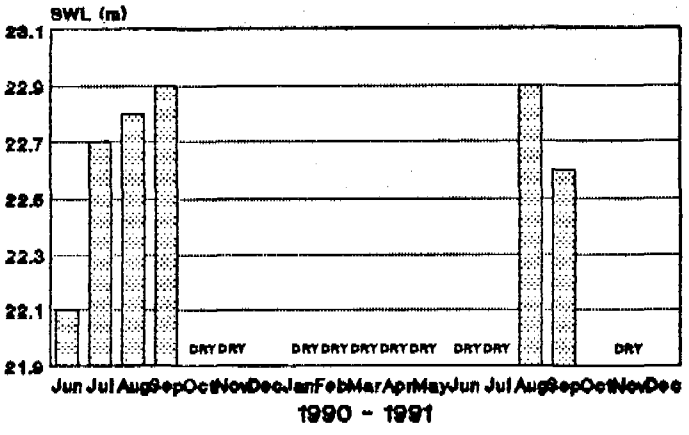
KIBOJE - WELL NO. 69



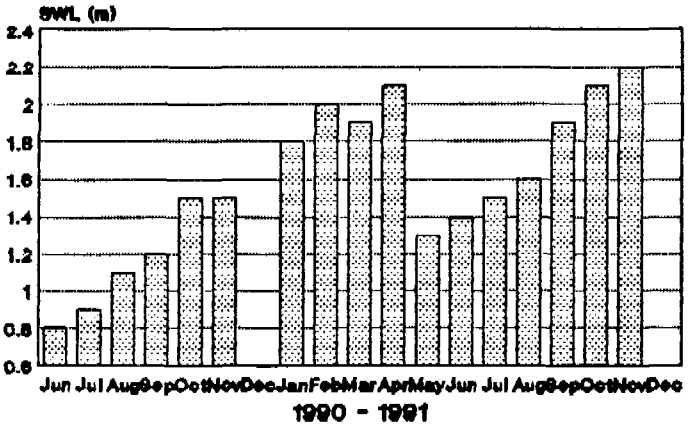
KIBOJE - WELL NO. 70



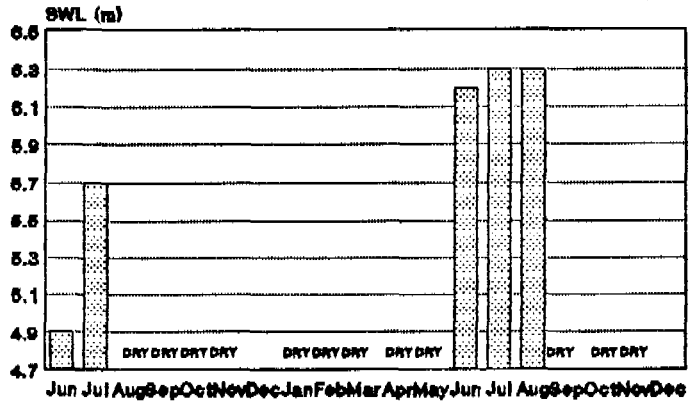
KIBOJE - WELL NO. 71



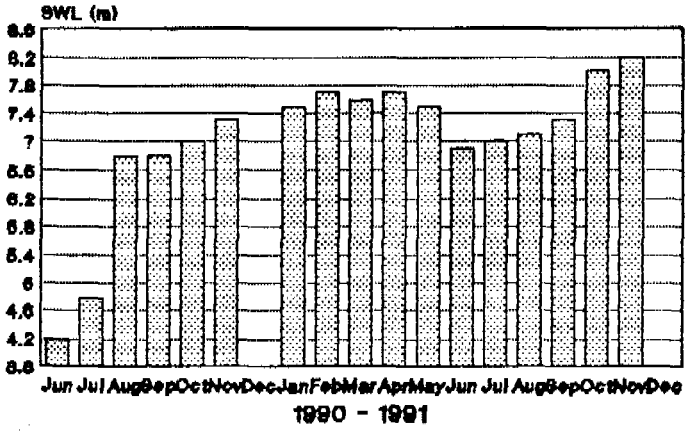
KIZIMBANI - WELL NO. 72



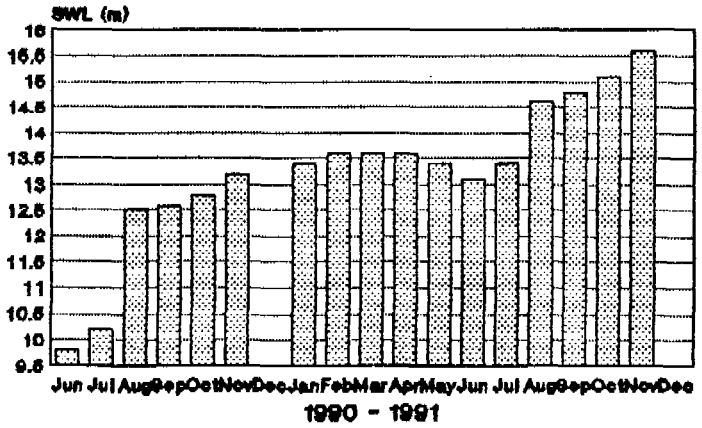
MNDO - WELL NO. 74



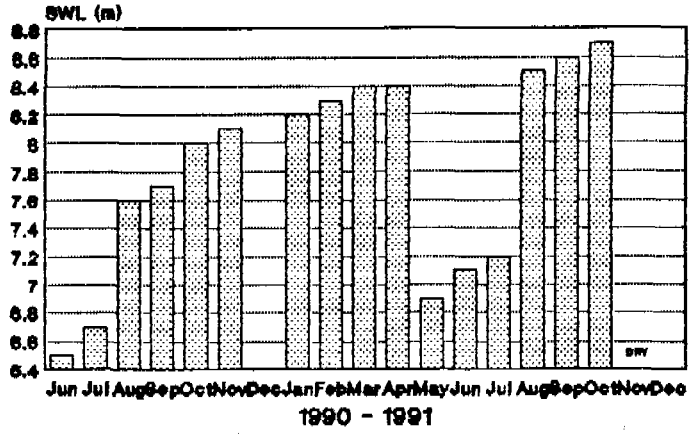
MKANYAGENI - WELL NO. 75



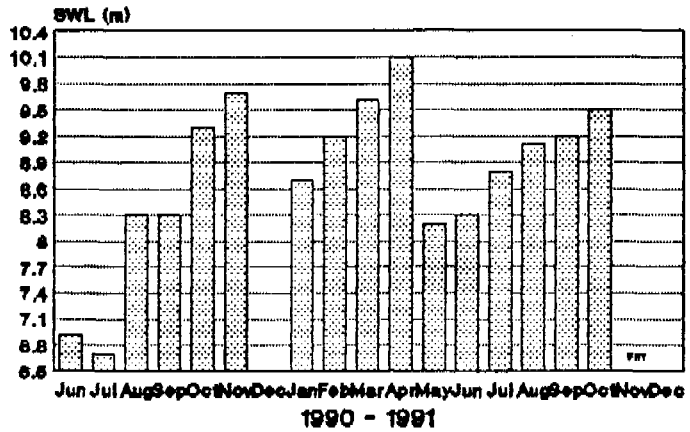
MTAONA - WELL NO. 76



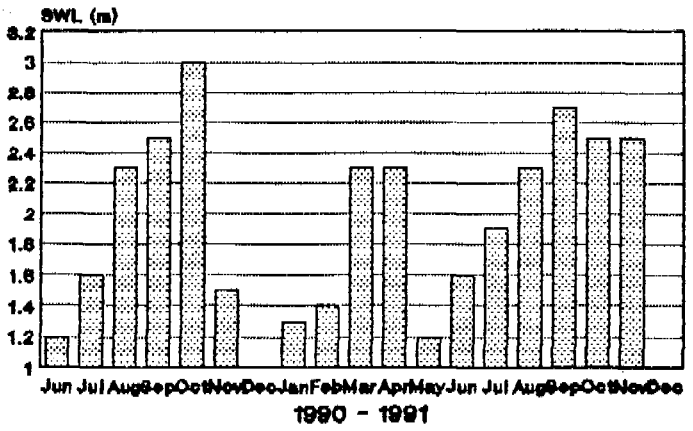
BUMBWISUDI - WELL NO. 77



BUMBWI SUDI - WELL NO. 78



BUMBWI SUDI - WELL NO. 82



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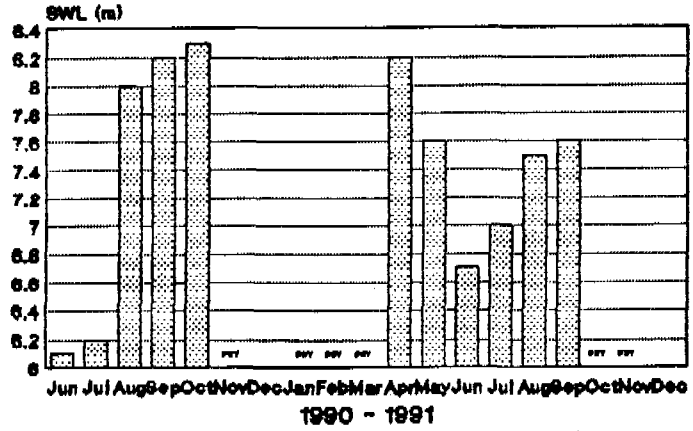
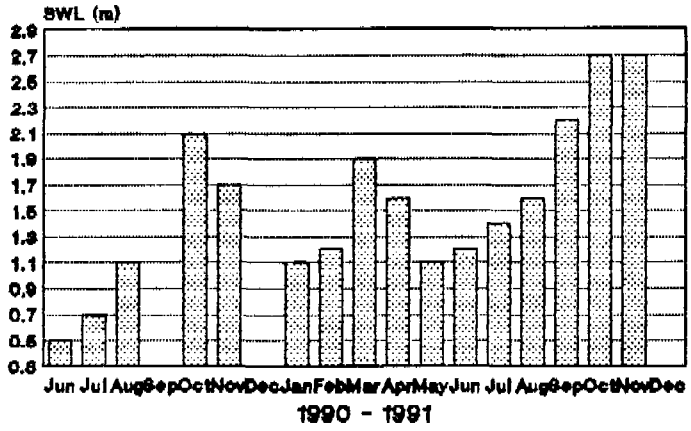
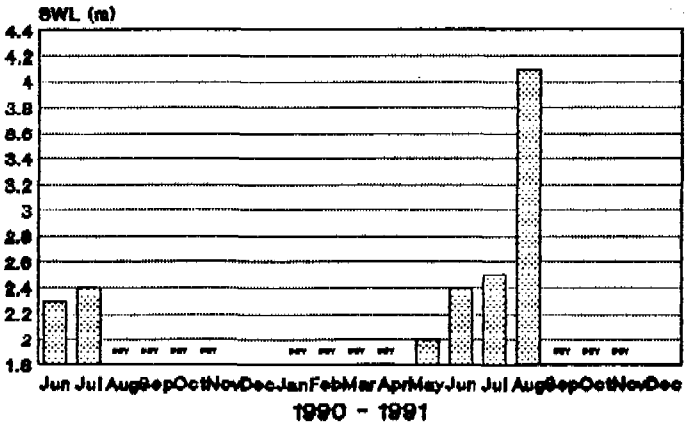


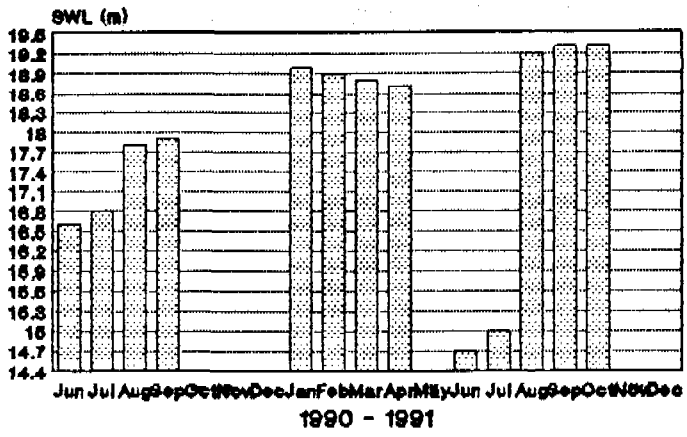
BUMBWI SUID - WELL NO. 84



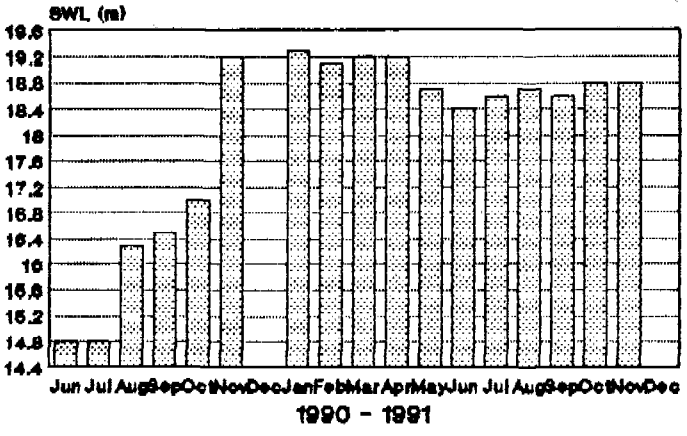
BUMBWI SUDI - WELL NO. 85



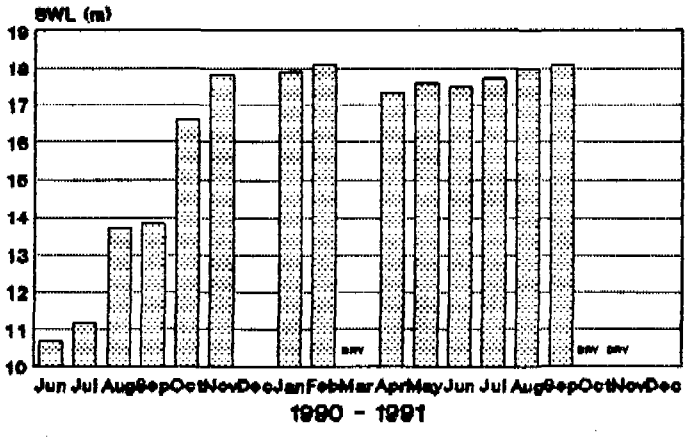
NDAGAA - WELL NO. 87



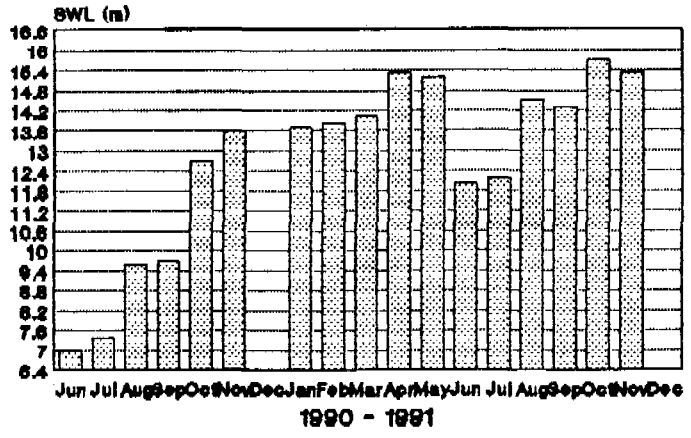
NDAGAA - WELL NO. 88



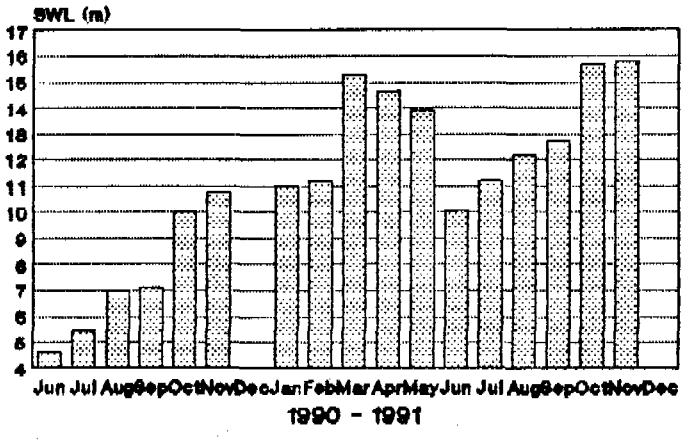
KIBOJE - WELL NO. 90



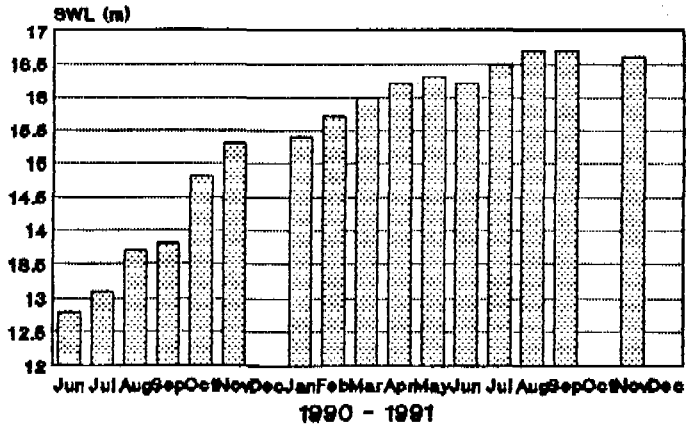
KIBOJE - WELL NO. 91



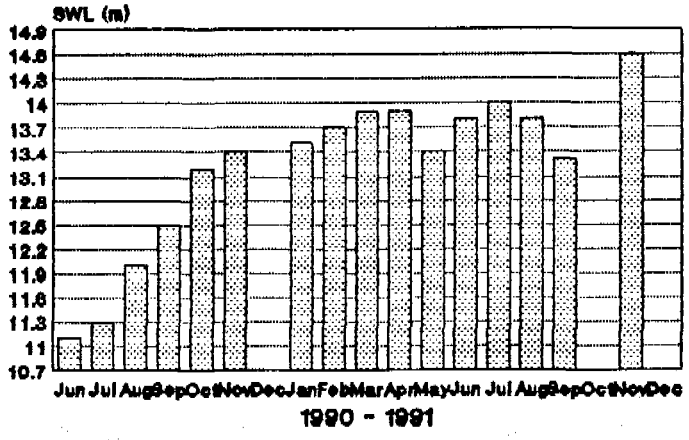
KIBOJE - WELL NO. 92



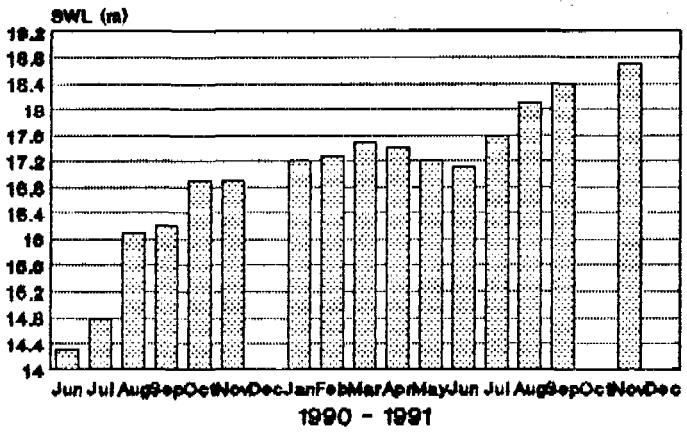
KIBOJE - WELL NO. 93



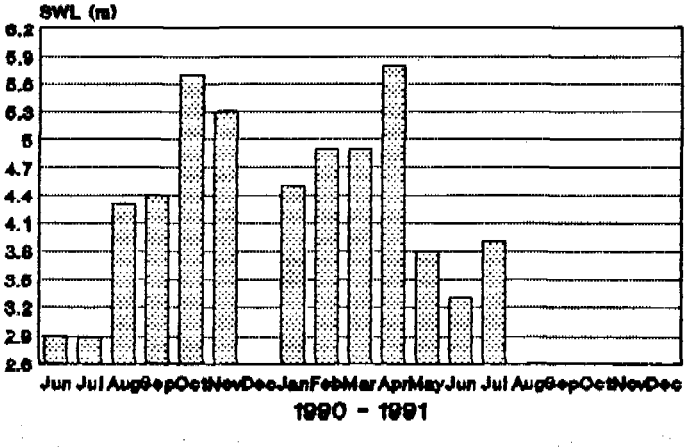
KIBOJE - WELL NO. 94



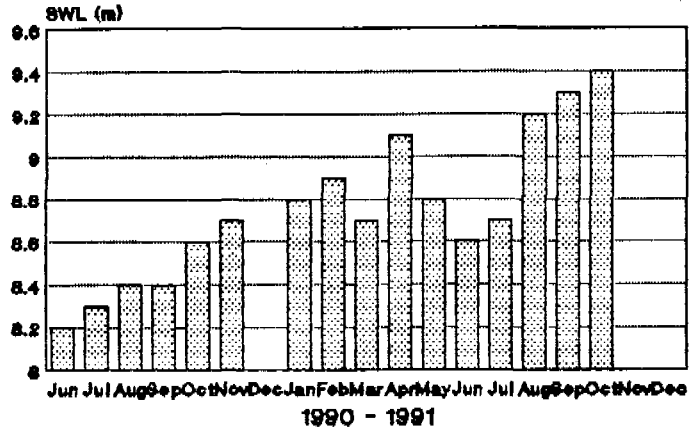
KIBOJE - WELL NO. 95



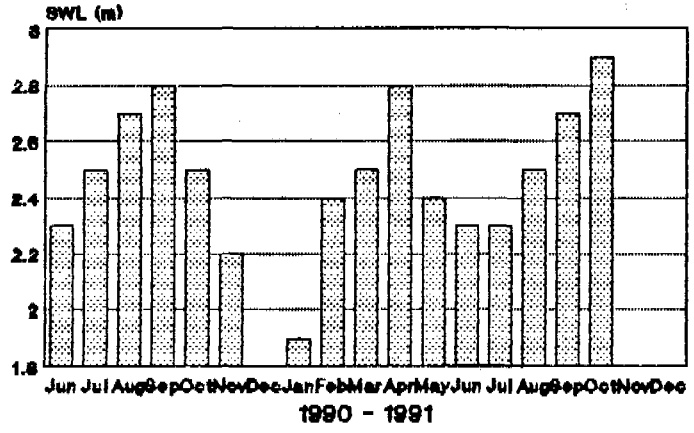
KIDICHI - WELL NO. 96



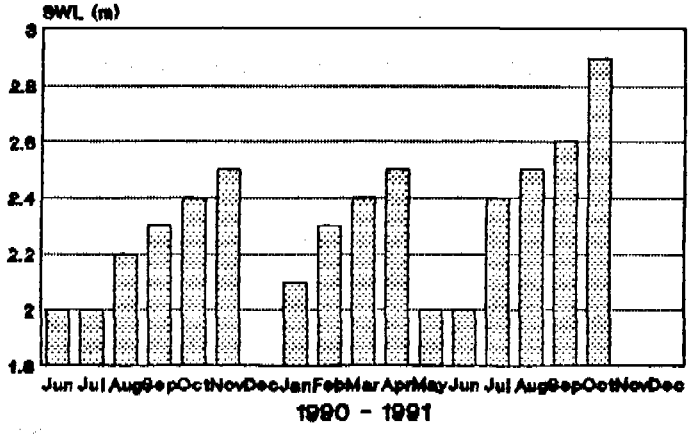
KIZIMBANI - WELL NO. 97



KINUMOSHI - WELL NO. 99



KINUMOSHI - WELL NO. 100



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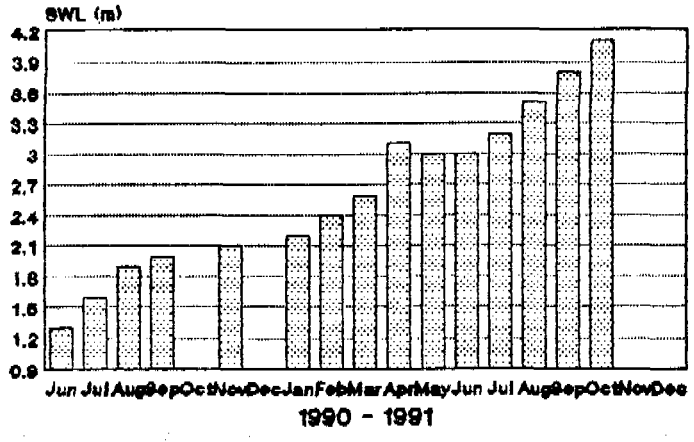
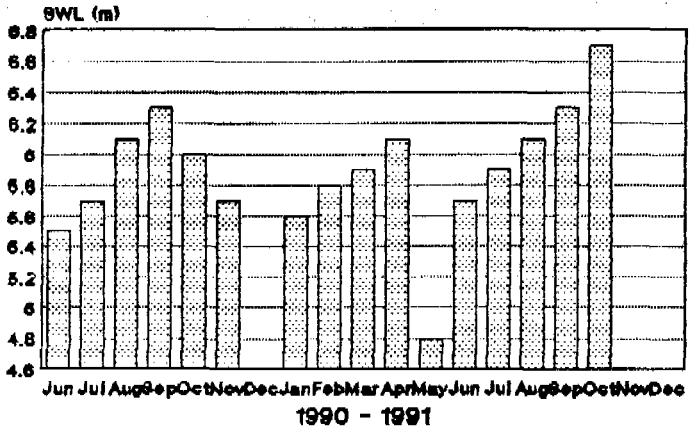
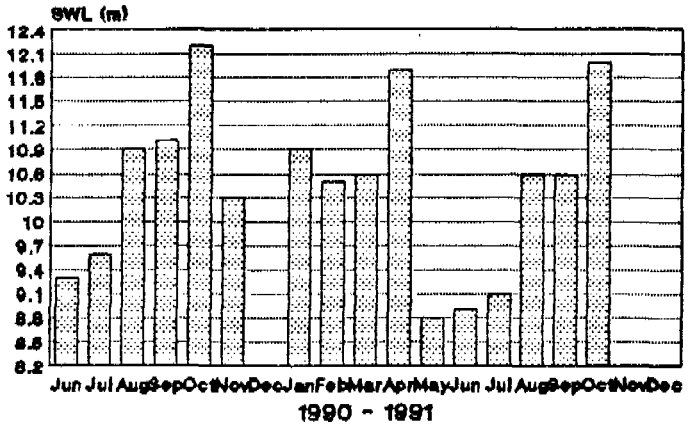


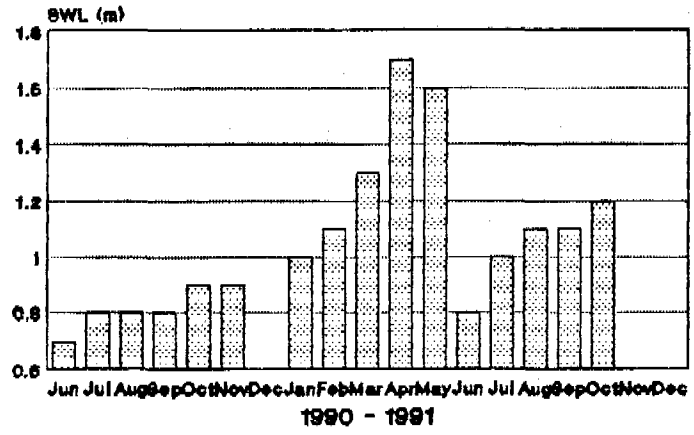
MACHUI - WELL NO. 102



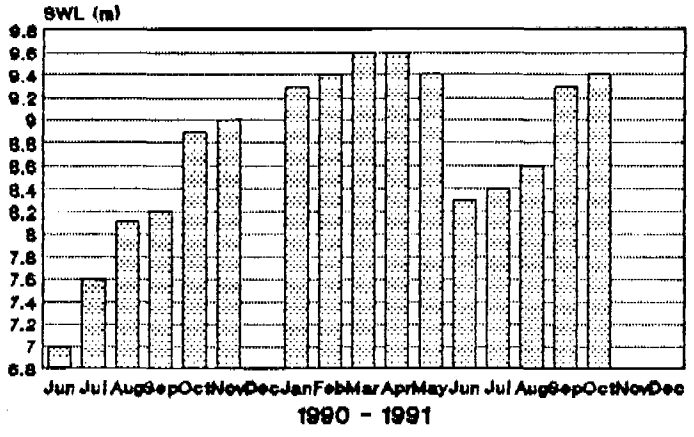
MACHUI - WELL NO. 103



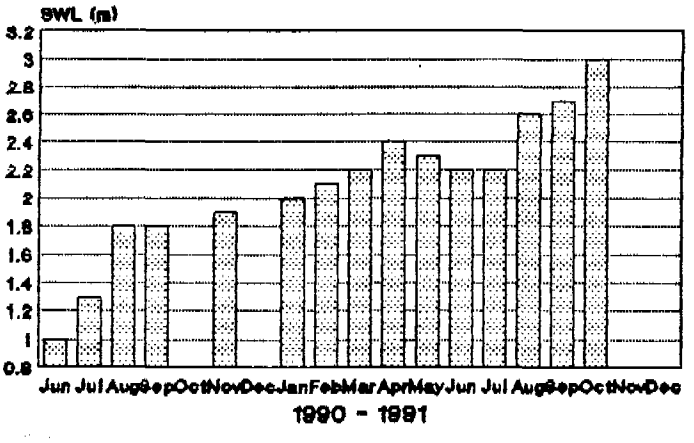
KIPANGE - WELL NO. 104



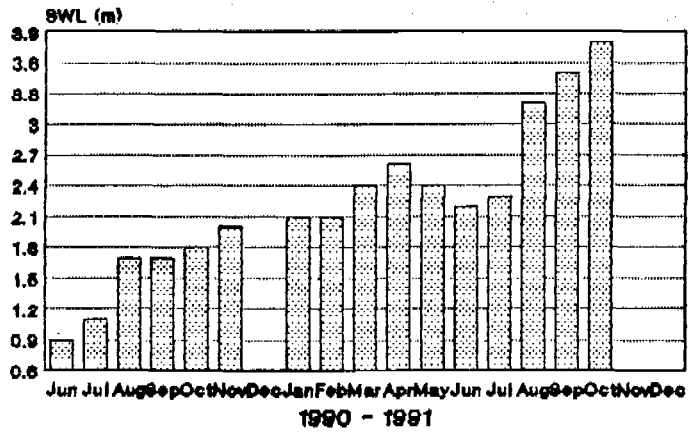
KIPANGE - WELL NO. 105



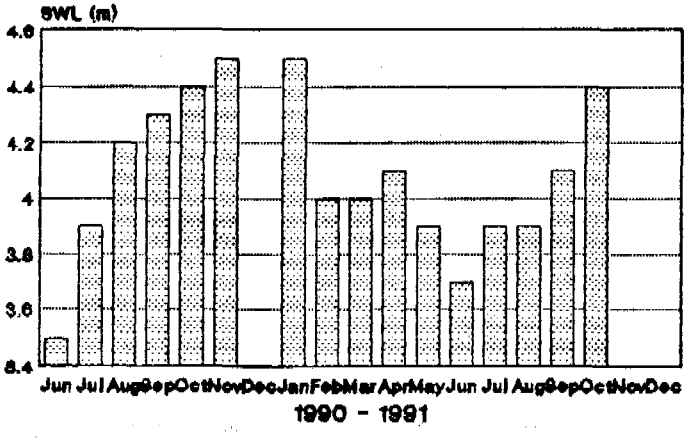
MIWANI - WELL NO. 106



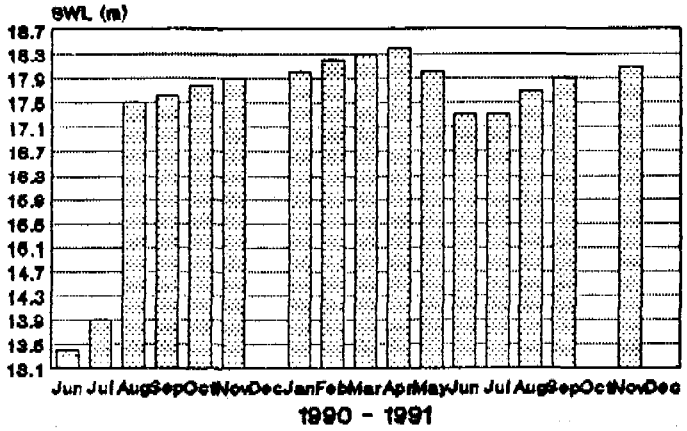
MIWANI - WELL NO. 107



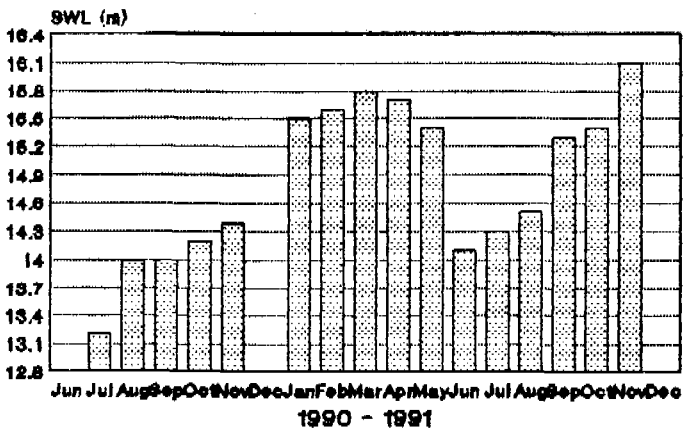
MIWANI - WELL NO. 108



KIBOJE - WELL NO. 109



KOANI - WELL NO. 111



LOCAL WELL - 1991

VARIATION OF THE STATIC WATER LEVEL BETWEEN MAXIMUM & MINIMUM SWL

NO	L. WELL NO	MAX. SWL (m)	MIN. SWL (m)	DIFFERENCE (m)
1	LOCAL WELL NO 1	5.46	DRY	
2	LOCAL WELL NO 2	4.23	3.34	0.89
3	LOCAL WELL NO 3	2.56	DRY	
4	LOCAL WELL NO 4	14.33	DRY	
5	LOCAL WELL NO 5	12.76	12.31	0.45
6	LOCAL WELL NO 6	11.04	10.57	0.47
7	LOCAL WELL NO 7	11.92	11.32	0.60
8	LOCAL WELL NO 8	20.80	19.56	1.24
9	LOCAL WELL NO 10	16.95	15.82	1.13
10	LOCAL WELL NO 11	11.86	DRY	
11	LOCAL WELL NO 12	7.67	DRY	
12	LOCAL WELL NO 13	3.73	2.70	1.03
13	LOCAL WELL NO 14	10.41	8.91	1.50
14	LOCAL WELL NO 18	7.72	6.50	1.22
15	LOCAL WELL NO 19	11.78	8.45	3.33
16	LOCAL WELL NO 20	12.12	8.57	3.55
17	LOCAL WELL NO 21	10.05	7.45	2.60
18	LOCAL WELL NO 23	16.84	13.70	3.14
19	LOCAL WELL NO 24	8.24	4.47	3.77
20	LOCAL WELL NO 26	17.72	15.79	1.93
21	LOCAL WELL NO 28	7.12	4.31	2.81
22	LOCAL WELL NO 32	9.29	4.55	4.74
23	LOCAL WELL NO 34	16.45	14.61	1.84
24	LOCAL WELL NO 36	4.71	3.35	1.36
25	SPRING NO 37	1.75	1.42	0.33
26	SPRING NO 38	0.69	0.62	0.07
27	LOCAL WELL NO 43	8.00	3.81	4.19
28	LOCAL WELL NO 44	4.61	2.30	2.31
29	LOCAL WELL NO 45	5.67	2.55	3.12

NO	L. WELL NO	MAX. SWL (m)	MIN. SWL (m)	DIFFERENCE (m)
30	LOCAL WELL NO 47	7.20	5.15	2.05
31	LOCAL WELL NO 49	6.04	5.25	0.79
32	LOCAL WELL NO 50	2.72	1.80	0.92
33	LOCAL WELL NO 52	2.62	1.63	0.99
34	LOCAL WELL NO 53	8.53	5.54	2.99
35	LOCAL WELL NO 54	10.04	6.72	3.32
36	LOCAL WELL NO 55	9.58	6.64	2.94
37	LOCAL WELL NO 56	9.50	7.83	1.67
38	LOCAL WELL NO 57	10.71	6.98	3.73
39	LOCAL WELL NO 58	8.79	7.93	0.86
40	LOCAL WELL NO 59	10.14	7.60	2.54
41	LOCAL WELL NO 60	10.64	8.80	1.84
42	LOCAL WELL NO 61	10.15	7.76	2.39
43	LOCAL WELL NO 62	11.47	9.59	1.88
44	LOCAL WELL NO 63	11.60	8.96	2.64
45	LOCAL WELL NO 64	14.07	5.94	8.13
46	LOCAL WELL NO 65	14.40	12.72	1.68
47	LOCAL WELL NO 66	17.86	17.40	0.46
48	LOCAL WELL NO 67	20.05	17.82	2.23
49	LOCAL WELL NO 68	17.62	15.31	2.31
50	LOCAL WELL NO 69	20.16	18.43	1.73
51	LOCAL WELL NO 70	22.35	20.05	2.30
52	LOCAL WELL NO 71	22.90	DRY	
53	LOCAL WELL NO 72	2.16	1.30	0.86
54	LOCAL WELL NO 75	8.72	7.05	1.67
55	LOCAL WELL NO 76	15.62	13.15	2.47
56	LOCAL WELL NO 77	8.72	7.05	1.67
57	LOCAL WELL NO 78	9.56	DRY	
58	LOCAL WELL NO 82	2.50	1.23	1.27

NO	LOCAL WELL NO	MAX. SWL (m)	MIN. SWL (m)	DIFFERENCE (m)
59	LOCAL WELL NO 83	8.20	DRY	
60	LOCAL WELL NO 84	2.72	1.10	1.17
61	LOCAL WELL NO 85	4.05	DRY	
62	LOCAL WELL NO 87	19.33	DRY	
63	LOCAL WELL NO 88	19.22	18.42	0.80
64	LOCAL WELL NO 90	18.10	DRY	
65	LOCAL WELL NO 91	15.73	11.98	3.75
66	LOCAL WELL NO 92	15.75	10.05	5.70
67	LOCAL WELL NO 93	16.63	15.41	1.22
68	LOCAL WELL NO 94	14.55	13.42	1.13
69	LOCAL WELL NO 95	18.67	17.05	1.62
70	LOCAL WELL NO 96	5.80	3.26	2.54
71	LOCAL WELL NO 97	9.38	8.61	0.77
72	LOCAL WELL NO 99	2.89	1.90	0.99
73	LOCAL WELL NO 100	2.86	2.01	0.85
74	LOCAL WELL NO 101	4.06	2.24	1.82
75	LOCAL WELL NO 102	6.70	5.60	1.10
76	LOCAL WELL NO 103	12.00	8.90	3.10
77	LOCAL WELL NO 104	1.24	0.84	0.40
78	LOCAL WELL NO 105	9.60	8.26	1.34
79	LOCAL WELL NO 106	3.02	1.98	1.04
80	LOCAL WELL NO 107	3.76	2.06	1.70
81	LOCAL WELL NO 108	4.51	3.72	0.79
82	LOCAL WELL NO 109	18.06	17.25	0.81
83	LOCAL WELL NO 111	16.05	14.31	1.93

ANNEX 10

Water table fluctuation map, Unguja

ANNEX 11

Local well monitoring, conductivity