No. 13

THE REPUBLIC OF GHANA

WATER SUPPLY DETAILED DESIGN SURVEY UNDER THE RESEARCH AND CONTROL OF DIARRHOEAL DISEASES AND IMPROVEMENT OF NUTRITION

AUGUST, 1985

Japan International Cooperation Agency

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P R E F A C E

The Japan International Cooperation Agency (JICA), entrusted with its work by the Government of Japan, has been extending technical cooperation to the Government of the Republic of GHANA on the Project of Research and Control of Diarrhoeal Diseases and Improvement of Nutrition since 1980.

As part of the above Project, JICA has decided to conduct a study on the rural water supply facilities and dispatched a survey team to the Republic of GHANA in April 1985.

After the field survey, the survey team analyzed and evaluated the findings and data obtained, and has completed this report.

Sequent on the findings and observations of this survey, I regret to state that the implementation of the project would be postponed provided that the water quality not be improved.

However, it is my vigorous hope that this report would contribute to the formulation of other safty water supply project.

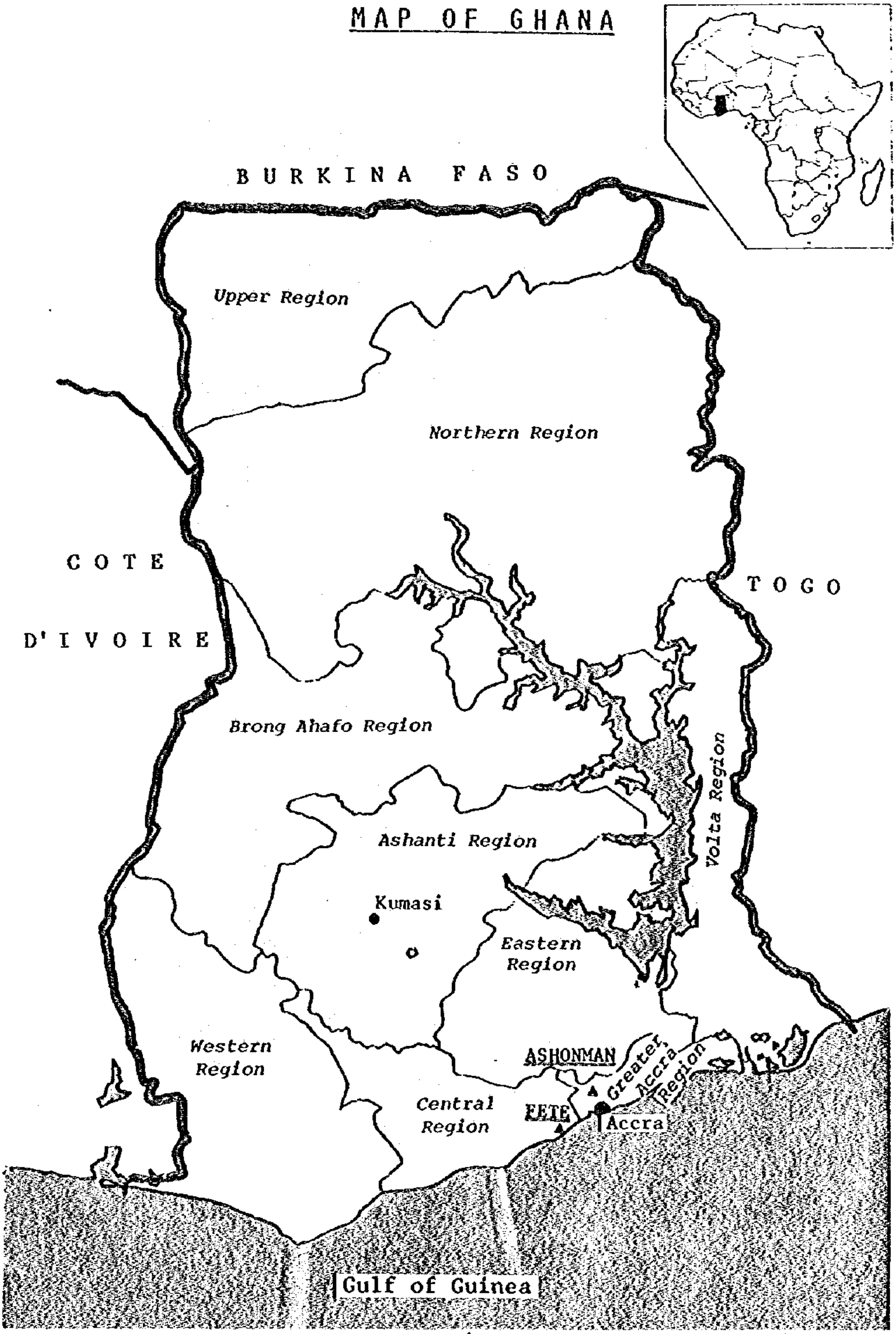
I wish to express my deep appreciation to the officials concerned of the Government of the Republic of GHANA for their close cooperation with and support extended to the team.

September, 1985

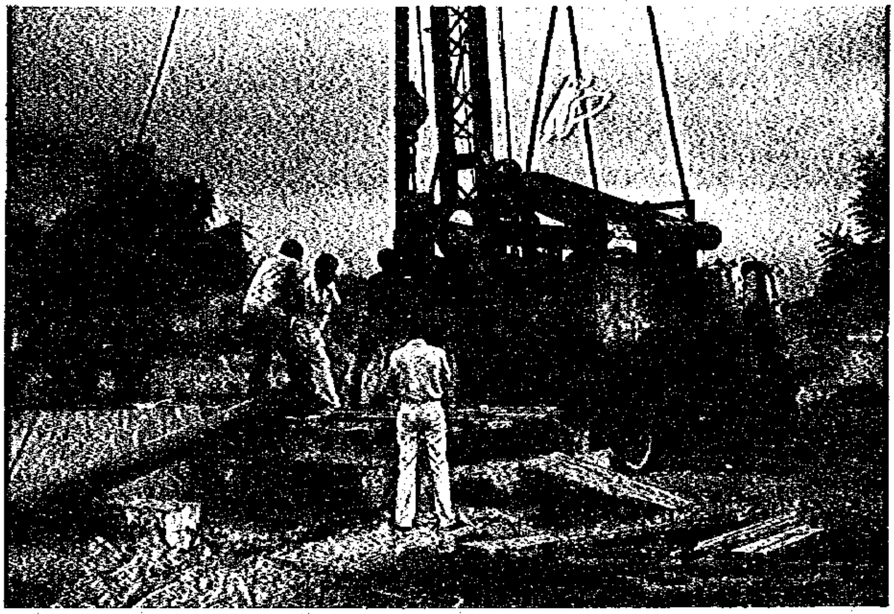
Shosuke Suenaga

Shosuke SUENAGA
Executive Director
Japan International Cooperation Agency

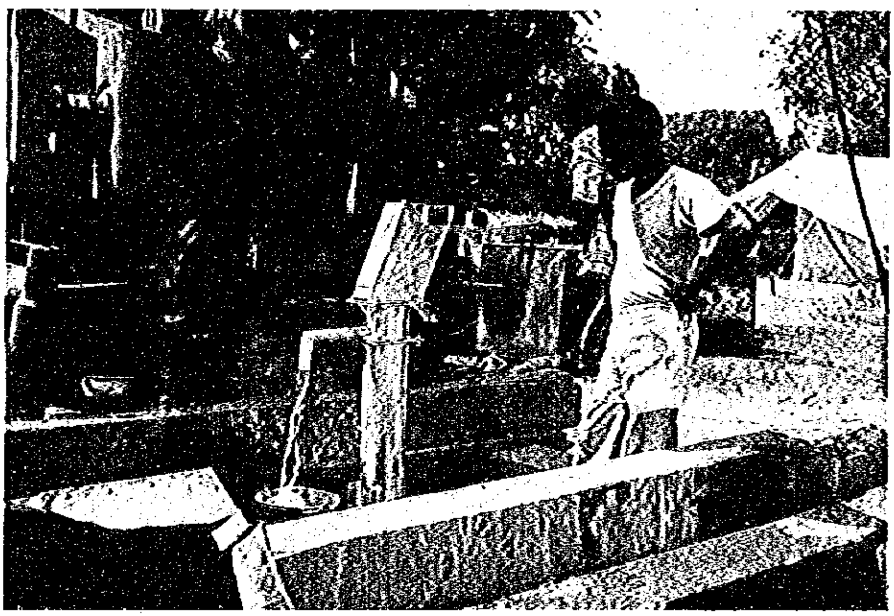
MAP OF GHANA



BURKINA FASO
Upper Region
Northern Region
COTE D'IVOIRE
TOGO
Brong Ahafo Region
Volta Region
Ashanti Region
Kumasi
Eastern Region
Western Region
ASHONMAN
Greater Accra Region
Central Region
FETE
Accra
Gulf of Guinea



Test Boring at Fete



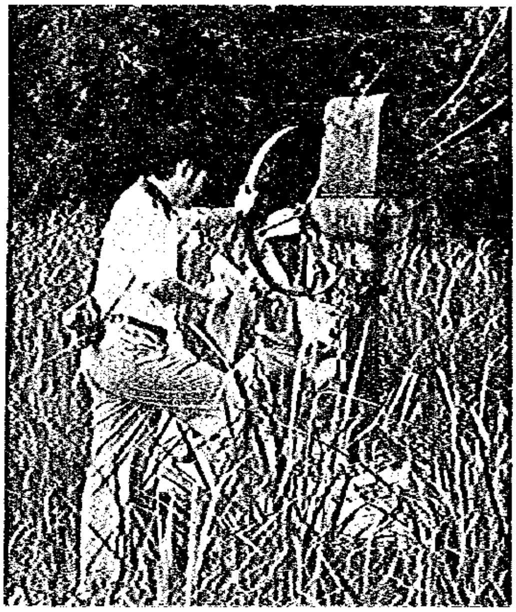
Discharge of Test Well at Fete

F E T E

Electric Prospecting

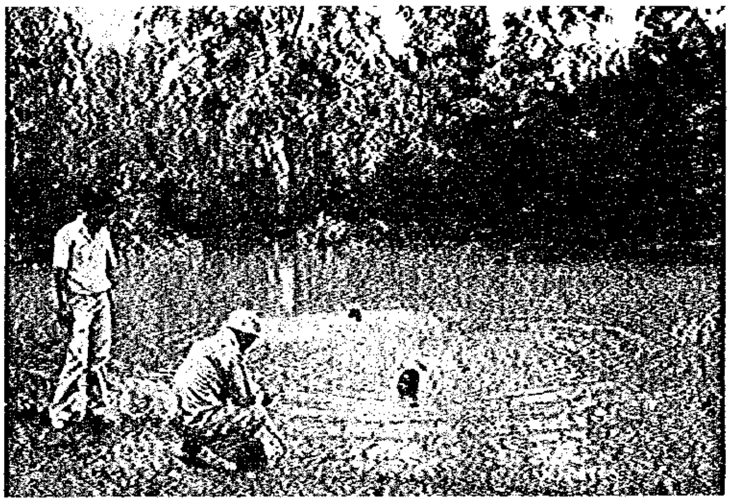
Well (III) - (V)

ASHONMAN



Old Pump Well

Pond (Poka)



Pond for Washing
(Buko)

SUMMARY

1. Objective and Contents of Survey

This water supply detailed design survey was conducted by the Japan International Cooperation Agency as a part of the project of Noguchi Memorial Institute for Medical Research in Ghana University, and its purpose is to form a suitable plan for the water supply facilities program in the target model areas of the said project.

The target areas are the Fete area, which faces the coastline, and Ashonman, a purely agricultural village north of Accra. Here, water source prospecting, a human geographical survey, as existing water supply system survey as well as electrical prospecting and a test well drilling survey were carried out on the spot in the area from April 1 to July 15, 1985.

2. Outline of the Model Areas and the Needs for Safe Water Supply

a) Fete area

The community of Fete (with a population of 2,060 persons) is located on a height 30 to 50 m in elevation which faces the seashore. On its north side extends the alluvial plain of the catchment basin of the Osonko River. The major occupations of the inhabitants are fishing and farming, and various crops are grown on the alluvial plain. For domestic water the inhabitants had mainly resorted to the wells installed in the alluvial plain about 1.5 km west of the community, but ever since these wells dried up as a result of the 1983 drought, they are compelled to purchase the water brought from Accra in water tank-lorries. The purchase of this water constitutes a heavy financial burden for the inhabitants. Also, the quantity of water that a household consumes varies greatly depending on its financial condition. There is a plan to supply water to this district through a pipeline but it is hard to say when it will be implemented or whether water will actually be supplied at all.

The geology of the Fete area is generally comprised of impermeable quartzite, and also because the ground water in the zones close to the coastline has turned into saline water, the only area in which new water sources can be developed is in the alluvial plain upstream of the Osonko River. Electrical prospecting and test well drilling surveys were therefore conducted in this area.

Aquifer was confirmed to be distributed from the weathered zone of the quartzite layer at a depth shallower than 25 m to the unconsolidated sediments layer. The water contains a lot of dissolved components so that its quality is not good, but it is still acceptable to the inhabitants as domestic water. Ground water which was confirmed at a depth below 30 m is worse in terms of both quantity and quality and was therefore excluded from the targets of ground water development.

The existing well facilities are not only quite instable in terms of quantity but have the risk of becoming contaminated from outside sources because they are artesian wells open at the top. Accordingly, by installing closed wells using as water source the ground water confirmed by the current survey, it is possible to supply bacteria-free water.

b) Ashonman area

The community of Ashonman (with a population of 225 persons) is located in a part of the Accra Plain where the land forms a gentle topography of around 50 m in elevation. Various crops are cultivated in the lowland (difference in elevation from community being 3 - 5 m) west of the hamlets. Ponds are scattered around the hamlets which serve as the main sources of domestic water for the inhabitants.

About 1 km southsouthwest of the hamlets is an abundant surface flow (2,000 m^3/day) from a spring, but because of its distance, water is hauled from it only during the dry season when the ponds are dry.

As above, the Ashonman area is favorably endowed with domestic water in terms of quantity, but not in quality, for the water is polluted.

Furthermore, a well with a jammed pump is recognized in the lowland about 500 m southwest of the hamlets. According to what we have heard, the well had been in use until the pump broke down in 1983 and the water had been quite satisfactory to the villagers both in quantity and quality.

Impermeable ground is widely distributed around the hamlets, but from the results of electric prospecting, a good aquifer was inferred to be distributed from this well toward the lowland in the southwest.

Based on what we have heard and the results of field survey, it has been judged best to install a new pump for the well in order to supply safe water to the inhabitants; this pump is scheduled to be installed shortly as a UNICEF project.

3. Basic Concerns of the Project

The utilization of ground water as a temporary water source for Fete area would cause such problems as dissolved substances and so on. However, on the assumption that the water quality be improved, the basic concerns of the project have been set up as follows.

a) Stable domestic water supply shall be secured for the Fete area from a tentative water source.

b) The water source shall be ground water.

c) The facilities shall be inexpensive in construction cost and operating expenses.

d) The facilities shall be durable and of the design easy to operate and maintain.

e) The facilities shall be of the closed type design to prevent pollution of water source.

f) The estimated quantity of water supply shall be 14 ℓ/day/head.

4. Outline of facilities

Besides the test well drilled for the survey this time, three more new wells shall be drilled. These four wells shall constitute the domestic water supplying facilities.

The principal specifications of the facilities shall be as follows:

Well:	Depth	about 30 m
	Hole diameter	150 mm
Pump:	Type	Hand pump or foot pump
	Capacity	Lift: 30 m, Pumping rate 800 ℓ/hour
Platform:	Area	11.7 m^2

5. Construction Cost

Drilling and its ancillary works shall be executed by Ghana's domestic organizations and construction contractors, but the pumps shall be procured from outside Ghana.

The construction cost (as of January 1986) shall include a price increase of 85% - using the cost escalation rate of the past one year as a reference - over the unit prices and estimates as of April-June, 1985.

As Ghana has not had any experience with the foot pump yet, its quantity was decided to be five units including one spare pump.

The construction cost was thus estimated to be as follows:

Item	Amount
Drilling work, 3 spots	¢2,625,000
Platform work, 4 spots	988,000
Total	¢3,613,900 (cedis)

Pump (ex Ghana)

In the case of the hand pump, 4 units	$7,500 (U.S.$)
In the case of the foot pump, 5 units	¥1,697,500 (Japanese yen)
Other necessary materials, 1 complete set	¥200,000 (Japanese yen)

Because of the sharp rise in prices in Ghana and the fact that drilling work takes a long time the construction cost to be settled in the currency of Ghana will have to be adjusted at the time of execution.

Water Supply Detailed Design Survey under the Research and Control of Diarrhoeal Diseases and Improvement of Nutrition

CONTENTS

CHAPTER 1 OUTLINE OF SURVEY

1.1 Circumstances that Let to Implementation of Survey

In 1967 the Ghana University requested the Government of Japan for medical cooperation in order to improve the medical situation in the Republic of Ghana. In response to this request, the Government of Japan commenced its medical cooperation in 1968. This cooperation project which has been continued systematically ever since is now in its fourth stage.

The fourth stage project intends to carry out basic, clinical and public hygienic survey on diarrhoea and malnutrition at the Noguchi Memorial Institute for Medical Research at Ghana University and to apply the achieved results to the model areas in order to improve the welfare of the inhabitants there.

Continued appeal for improvement of the water supply system in the model areas had been made for the reason that the insanitary drinking water was considered to be the major cause of diarrhoea in Ghana which is the principal theme of the project.

It was against such a background that a team of specialists was dispatched between January 29 and February 11, 1985 for preliminary detailed design survey, and that on the basis of the conclusions reached by the team, a survey mission was dispatched with a view to realize the drinking water supplying system.

1.2 Objective of Survey

The objective of the survey was to investigate the water source, human geography and existing water supply systems as well as to conduct electric prospecting, test well drilling, pumping test and other surveys and tests, on the spot, in the model areas, and on the basis of data thus obtained, to work out the suitable water supply facilities plan scheduled for implementation in FY 1985 and to work out a detailed design and cost estimation for the specifications necessary in implementing the plan in the most appropriate way.

1.3 Target Survey Areas

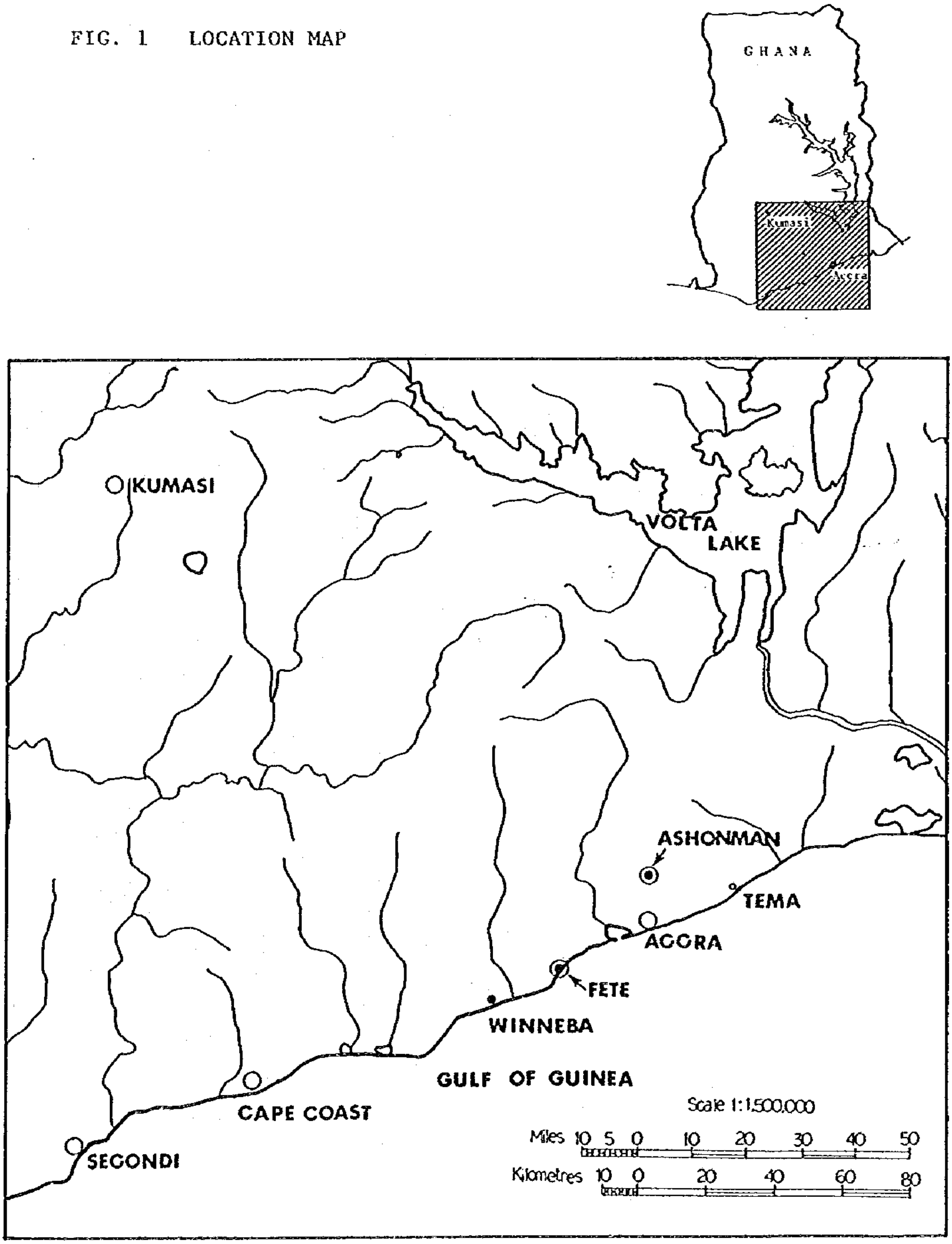
The Fete and Ashonman areas, which are two of the model areas particularly in need of clean drinking water, were selected as the target areas of this survey from among the model areas covered by the Fourth Stage Medical Cooperation Project.

The Fete area is located on hilly land facing the seashore about 60 km west of Accra, the capital city of Ghana.

The Ashonman area is located about 15 km north of the capital city Accra.

The locations of these two areas are indicated on Fig. 1.

FIG. 1 LOCATION MAP



CHAPTER 2 GENERAL DESCRIPTION OF THE REPUBLIC OF GHANA

2.1 Natural Environment and Socio-Economic Conditions

2.1.1 Natural Environment

Ghana is located approximately in the center of the Western African countries. It borders on Togo on the east, Burkina Faso on the north and the Ivory Coast on the West. Its south coast borders on the Gulf of Guinea along which its shoreline extends for about 560 km. The territory is rectangular in shape and lies between 5° - 11° N.L. and between lng. 1°E and 3°W and the total area of about 240 thousand km^2.

The territory corresponds to the comparatively stable area called the West African Craton which is subjected to very little diastrophism, and is mainly composed of Pre-Cambrian to Palaeozoic formation. The whole country thus presents a peneplain topography with very little undulation except where the Akwapim-Togo Mountain Range about 1,000 m in maximum height extends from north of Accra to near the borderline Togo. (Fig. 2.1.1)

The major river which flows through this country is the Volta River, and the Lake Volta which was created by the completion of Akosmbo Dam in 1965 by the Volta River Development Project covers an area of 8,400 km^2. Also, a few streams originating in the Ashante Region in the center of Ghana flow into the Gulf of Guinea, but these are all small in scale. (Fig. 2.1.2)

Ghana has a tropical climate with an annual mean temperature of 27°C. Its coastal area is damp, and its northern area arid and hot.

The annual precipitation in the area extending from the southwestern coast to the Ashante Region in the Center of Ghana is high, ranging between 1,500 and 2,200 mm, but it is less along the southeastern coast around Accra and also in the northern area where it is around 1,000 mm. Reflecting the difference in precipitation, the area of abundant rainfall comprises the forest zone, the coastal area around Accra the savannah zone and the northern area, the arid zone. The rainy season is between April and September, and the month of the highest rainfall is August in the northern area, and June in the southern area. (Figs. 2.1.3 through 2.1.5)

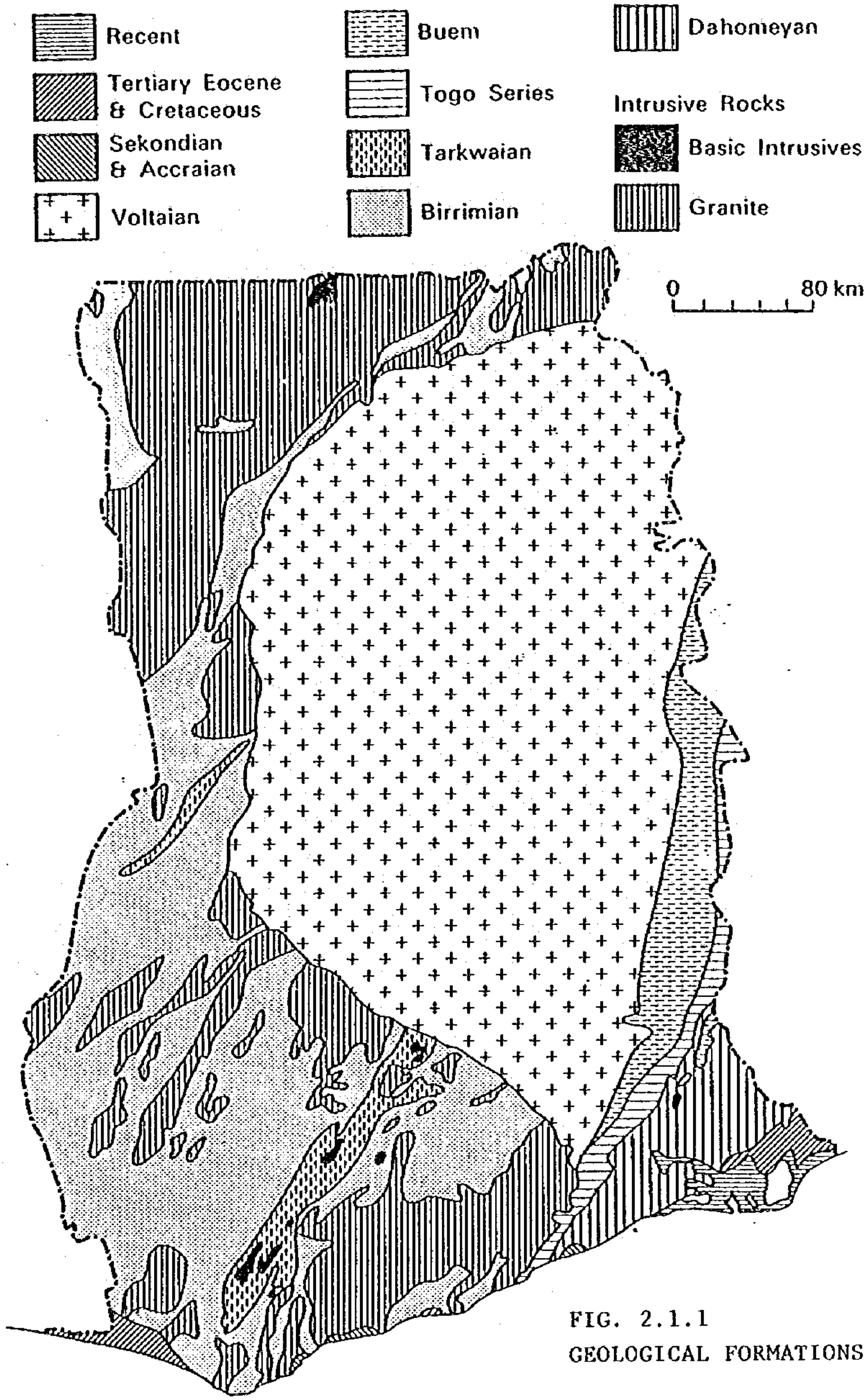


FIG. 2.1.1
GEOLOGICAL FORMATIONS

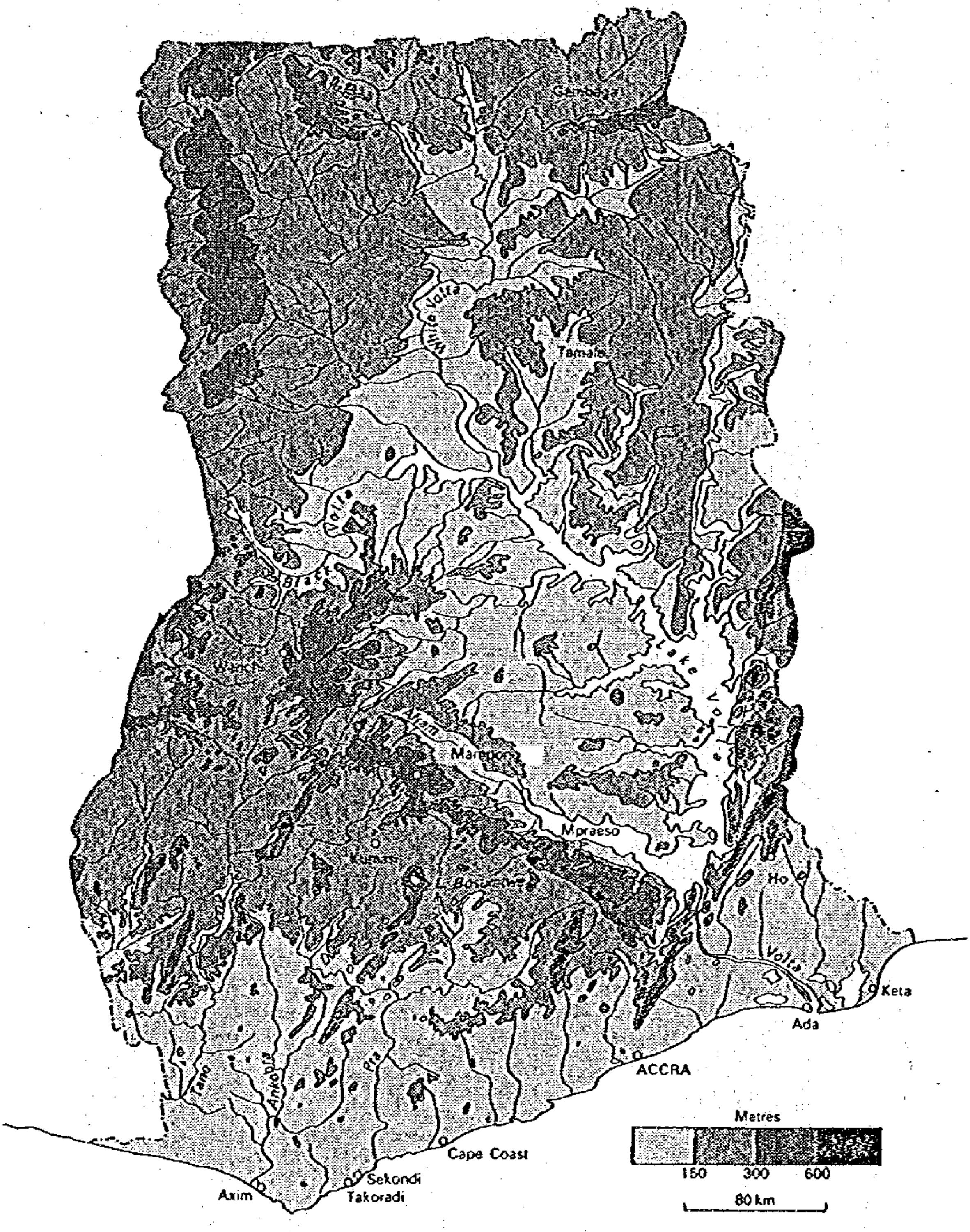


FIG. 2.1.2 RELIEF REGIONS

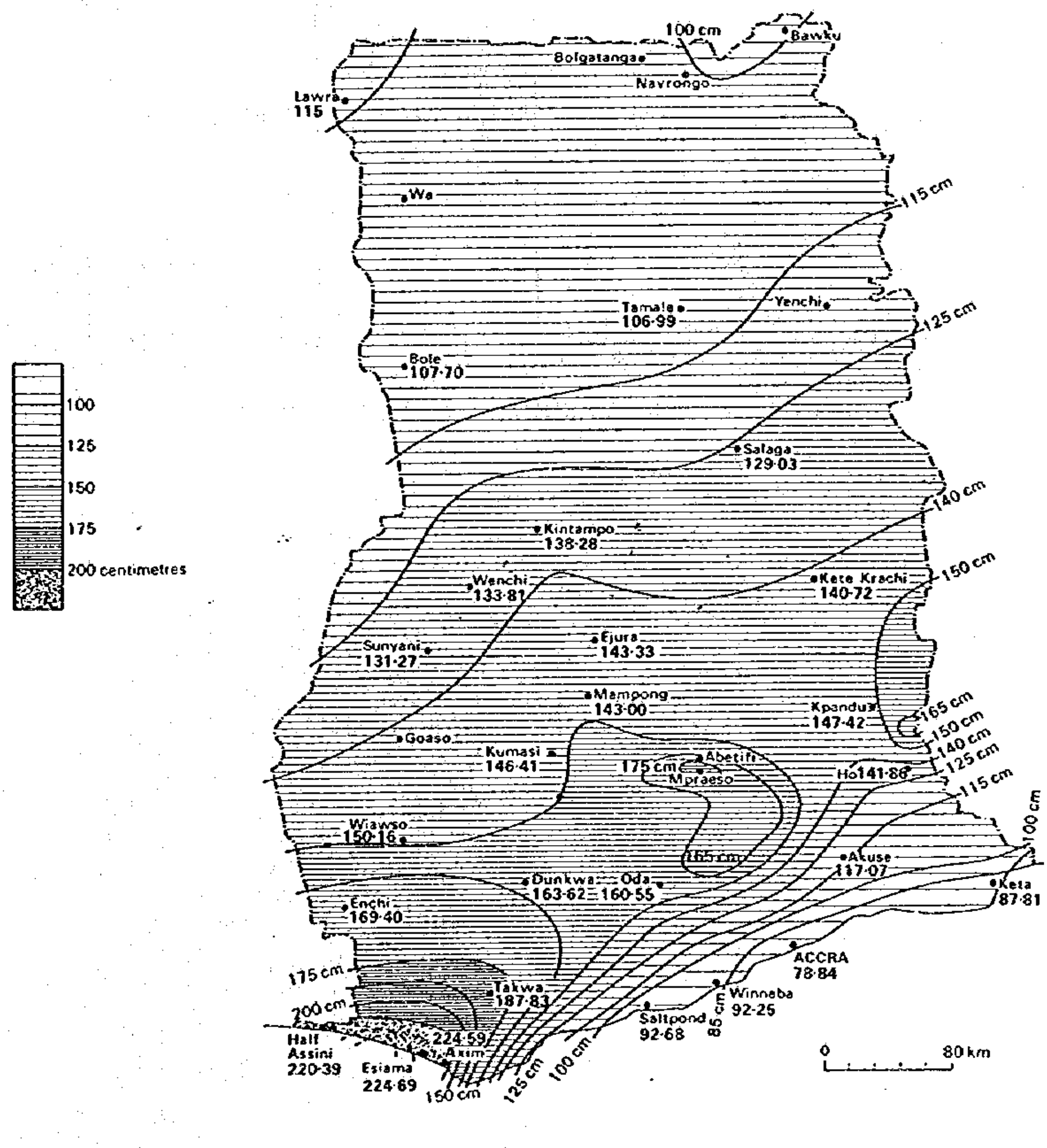


FIG. 2.1.3 MEAN ANNUAL RAINFALL

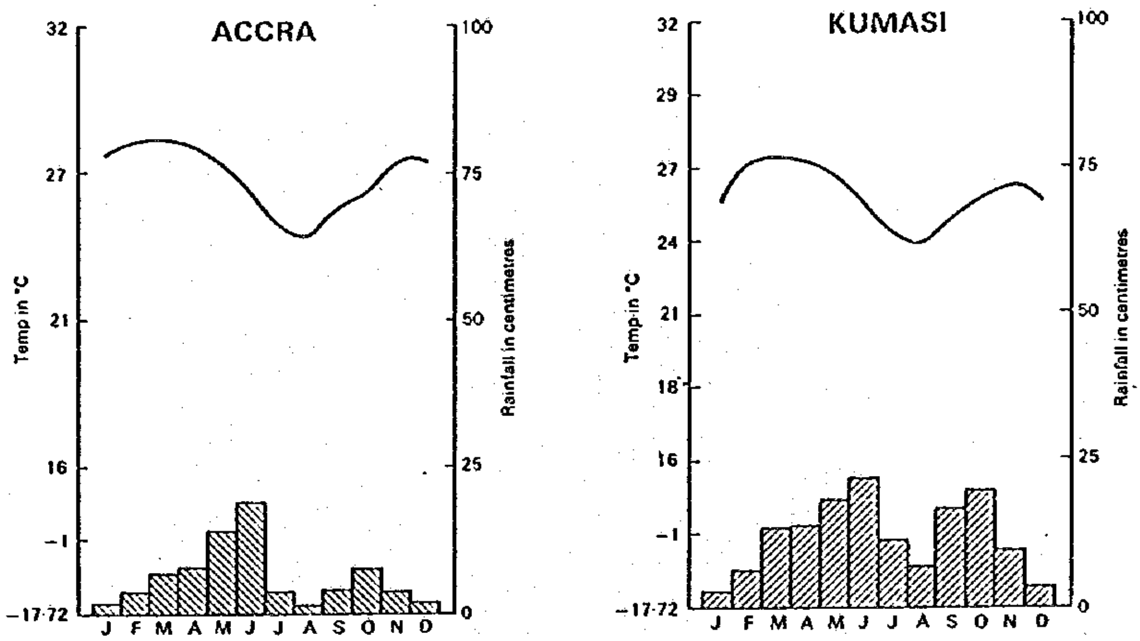


FIG. 2.1.4 ANNUAL RAINFALL AND TEMPERATURE

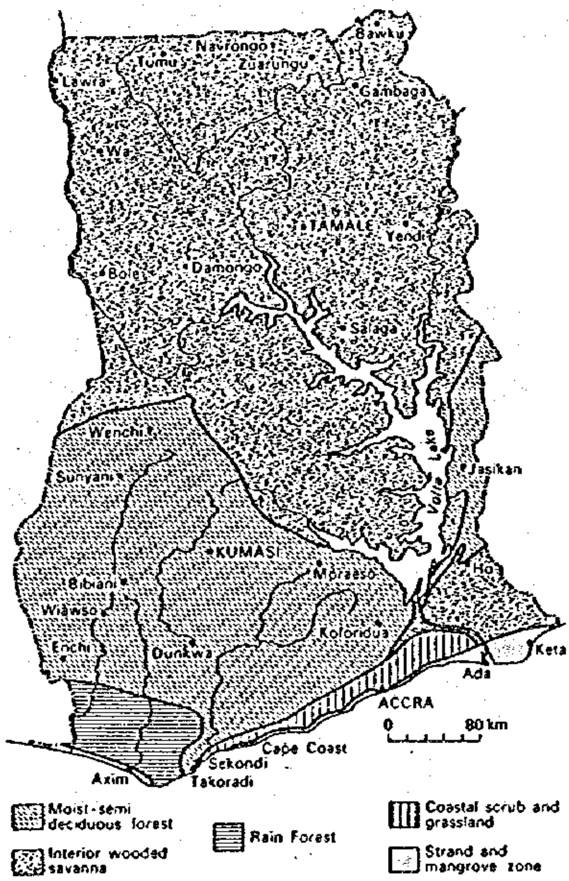


FIG. 2.1.5
VEGETATION TYPES

2.1.2 Administrative Division and Population

The country is administratively divided into nine regions as shown in Fig. 2.1.6.

The population is estimated to have been 12.7 million in 1984 with the population density of 52.9 persons/km^2. The average annual population growth during the past 14 years estimated on the basis of the 8.55 million population at the time of the 1970 Census is 2.9%.

Its people are composed of various tribes. Broadly classified, the Ga tribe, Ebe tribe, Akan tribe and Manpurusi-Bagomba tribe are the main ones.

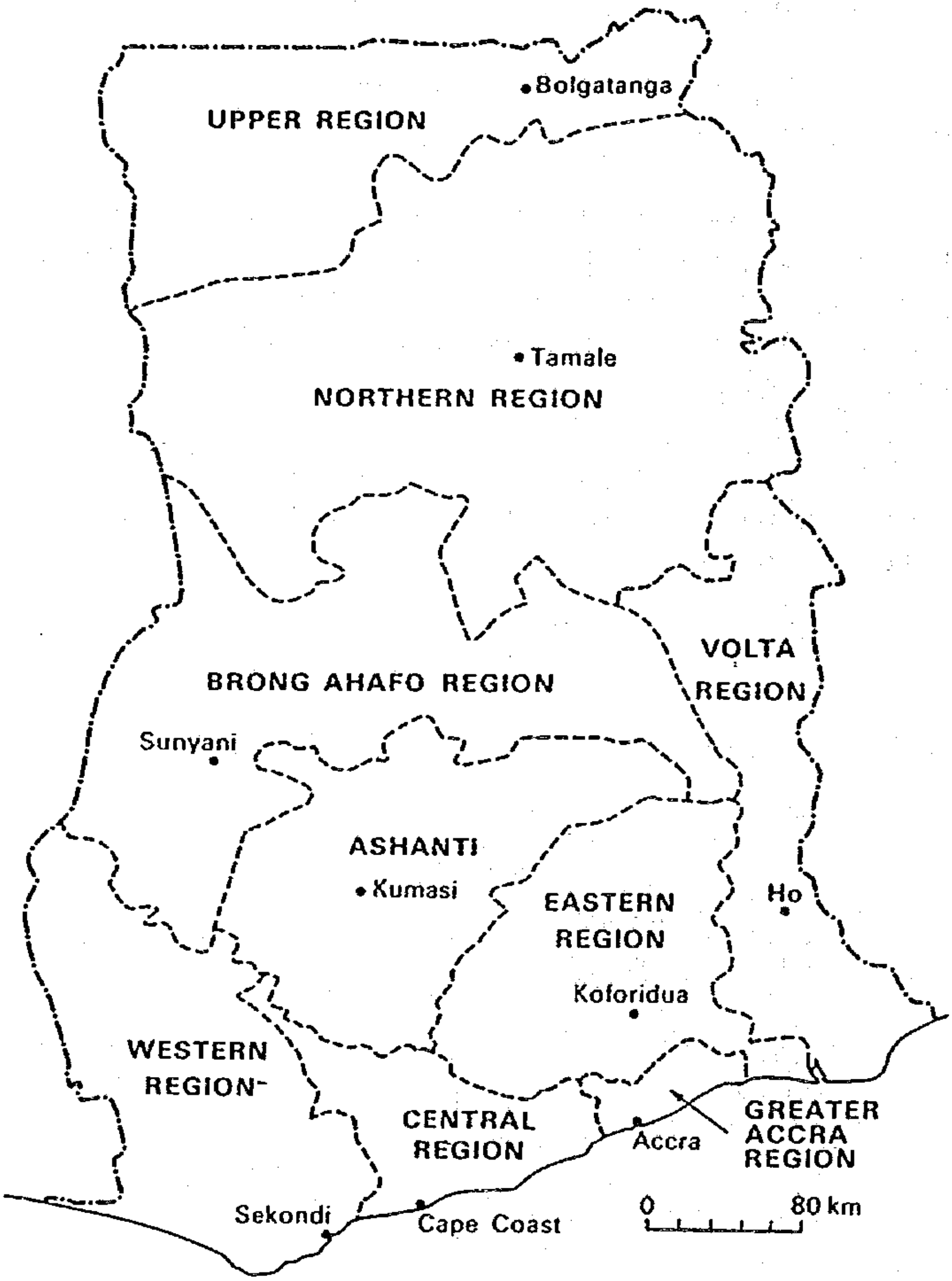


FIG. 2.1.6 ADMINISTRATIVE REGIONS

2.1.3 Economic Situation

Agriculture is the largest industry in which 61% of the country's labor force of 2,560 thousands are engaged. What is more, one third of the country's arable land is used for cultivating cocoa, the major export industry which, in export amount, outdistances all other agribultural export products such as coffee, cabbage palm, copra, banana and shear nut. Staple food crops are manioc, yam, cocoyam, plantain and rice. Also, maize, foxtail millet, guinea corn are cultivated in the northern area. The country however is unable to satisfy its domestic food demand and so food accounts for 20% of its imports.

Its mining outputs/products - excluding the processing of alumina - are gold, diamond, manganese and bauxite as shown below in the order of export amounts.

Mineral Production Statistics

	Units in:	1975	1976	1977
Gold	1,000 oz.	523.9	509.3	481
Diamond	1,000 C	2,323.3	2,470.5	1,851
Manganese ore	1,000 tons	408.7	324.5	268
Bauxite	"	314.5	260.2	265

Trading Status (in million cedes)

	1975	1976	1977
Exports	929.4	952.1	1,105.8
of which Cocoa	551.4	515.5	679.7
Lumber	77.3	75.2	87.1
Imports	909.3	969.0	1,175.9

The people of Ghana today are suffering from soaring prices under poor economic and fiscal conditions due to the nation's foreign debts issue and the deterioration of its condition concerning the balance of international payments.

In 1982 the Government announced a sharp rise in the cost of living in terms of indices, with 1977 as 100, to have been 611.8 in January 1981 and 1,046.4 in January 1982. The rate of inflation was 116.5% in 1977, 54% in 1979, 140% in 1981 and a staggering 180% in 1982. The same trend still persists today.

As a result, the exchange rate of its currency depreciated from \$1 = 2.75 cedis in the first half of 1981 to \$1 = 53 cedis by April 1985 due to repeated devaluations, and predictions are that this trend will continue to prevail.

2.2 Household Water Supply Situation

The Government of Ghana, as a result of its continued efforts in supplying household water to its people ever since its independence in 1957, has succeeded in raising the water supply pervasion rate which at the time was in the range of 5 to 10% up to 59% of its total population of 12.7 million. The population served with drinking water in the urban areas is above 90%, but in the rural areas the pervation rate is still only 37%. The population served with drinking water set out items of the size of community is as shown in Table 2.2.1.

Table 2.2.1

Population Served with Drinking Water in 1984 (in Thousand)

	Population Group					(Rural)	Total	
	Below 100	101-109	200-499	500-1,999	2,000-4,999	Rural	Urban above 5,000	Urban and Rural
1. No. of Communities (1970 census)	35,974	4,449	4,268	2,621	332	47,634	135	47,479
2. Estimated 1984 pop. (Final details of 1984 not yet out)	1,629	816	1,733	3,049	1,231	7,858	4,863	12,721
3. Pop. served with drinking water in 1984	12	80	300	1,700	860	2,952	4,557	7,509
4. % of Pop. served with drinking water in 1984	1.2	9.8	13.7	55.8	69.9	37.6	93.7	59.0

The piped water supply system which is installed for communities with a population of 2,000 or more is utilized by five million people. There are also about 6,000 wells with a hand pump which are used by two million people.

The Ghana Water and Sewerage Corporation (GWSC) which has established in 1966 is the authority responsible for supplying household drinking water in Ghana.

The policy of GWSC for supplying water to communities with a population below 2,000 is by means of a well with hand pump, one for about every 400 people. The actual amount of water supply per head per day is reportedly between 13.5 and 22.5 litres.

During the past 15 years, a number of large scale well drilling projects have been carried out in the rural communities of Ghana with the aid of various governments and local organizations. The two particularly important projects are:

(a) The Upper Region Water Supply Project (URWSP) carried out by the Government of Canada (1974 - 1981)

(b) The 3000 Well Drilling Program in Southern and Central Ghana set in motion by the financial assistance of the Government of West Germany (1978 - 1984)

2,300 wells under URWSP and 3,000 wells under the West German Government Project have already been completed in seven of the administrative regions of Ghana. (Refer to Fig. 2.2.1)

The wells with hand pumps, until then, had not been adequately maintained due to various reasons, but both the URWSP and the 3,000 Well Project place emphasis on plans for maintenance, administration and upkeep of these wells.

In April 1985 the Government issued its Five Year Groundwater Supply Development Plan (1985 - 1989). This Plan is mainly concerned with the restoration of existing water supplying systems and the new installation of hand pump systems. It is considering replacing the jammed pumps of existing wells and newly installed wells with hand pumps.

The restoration of jammed pumps is scheduled at 750 locations, of which 250 are to be implemented as a UNICEF project.

The installation of new wells with hand pumps is planned at 1,500 locations in the Brong Ahafo Region, Western Region and in the northern parts of such regions as Ashanti, Eastern and Volta. (Refer to Fig. 2.2.2)

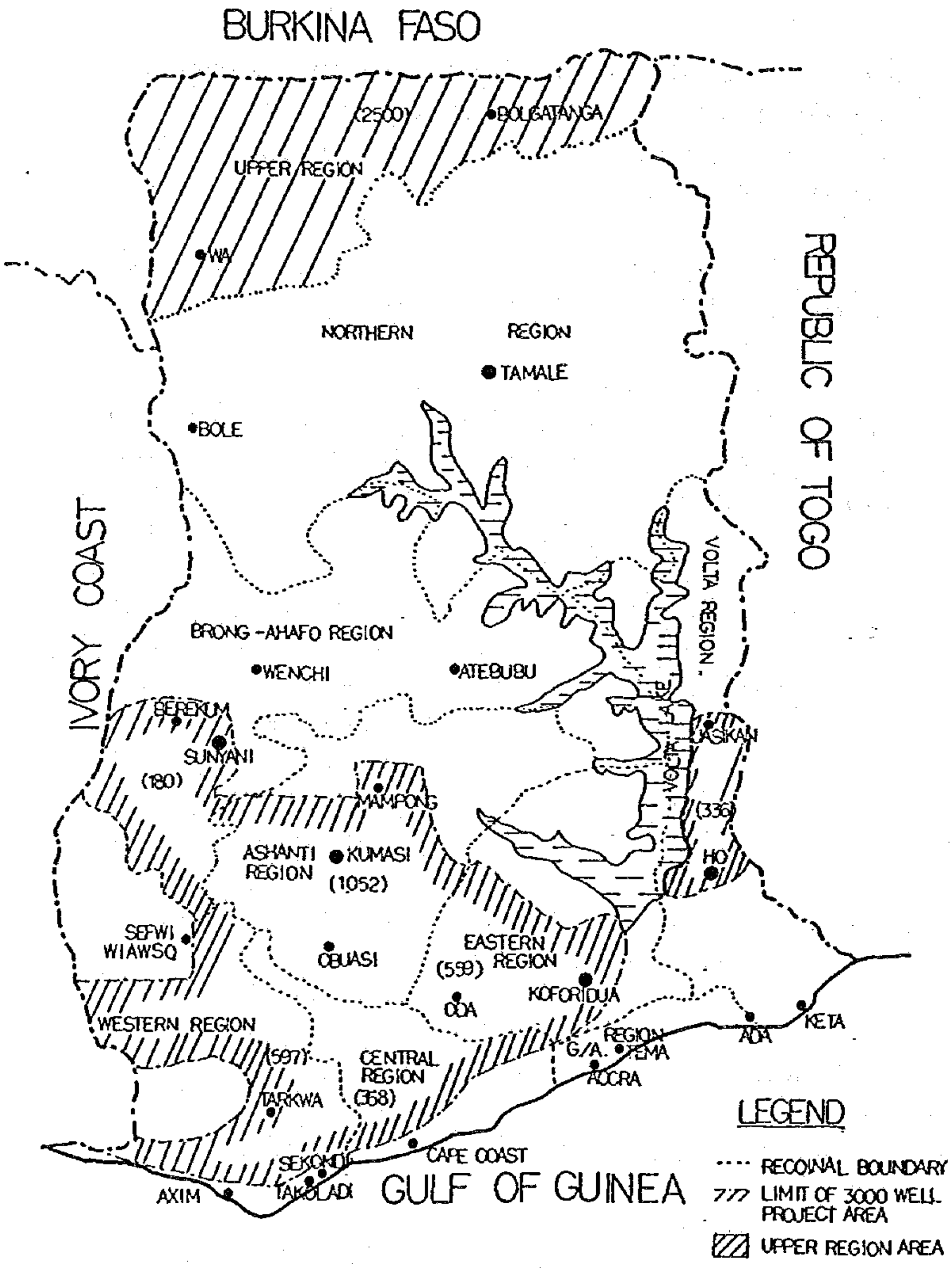


FIG. 2.2.1 MAP OF GHANA SHOWING DISTRIBUTION OF EXISTING BOREHOLES BY REGION

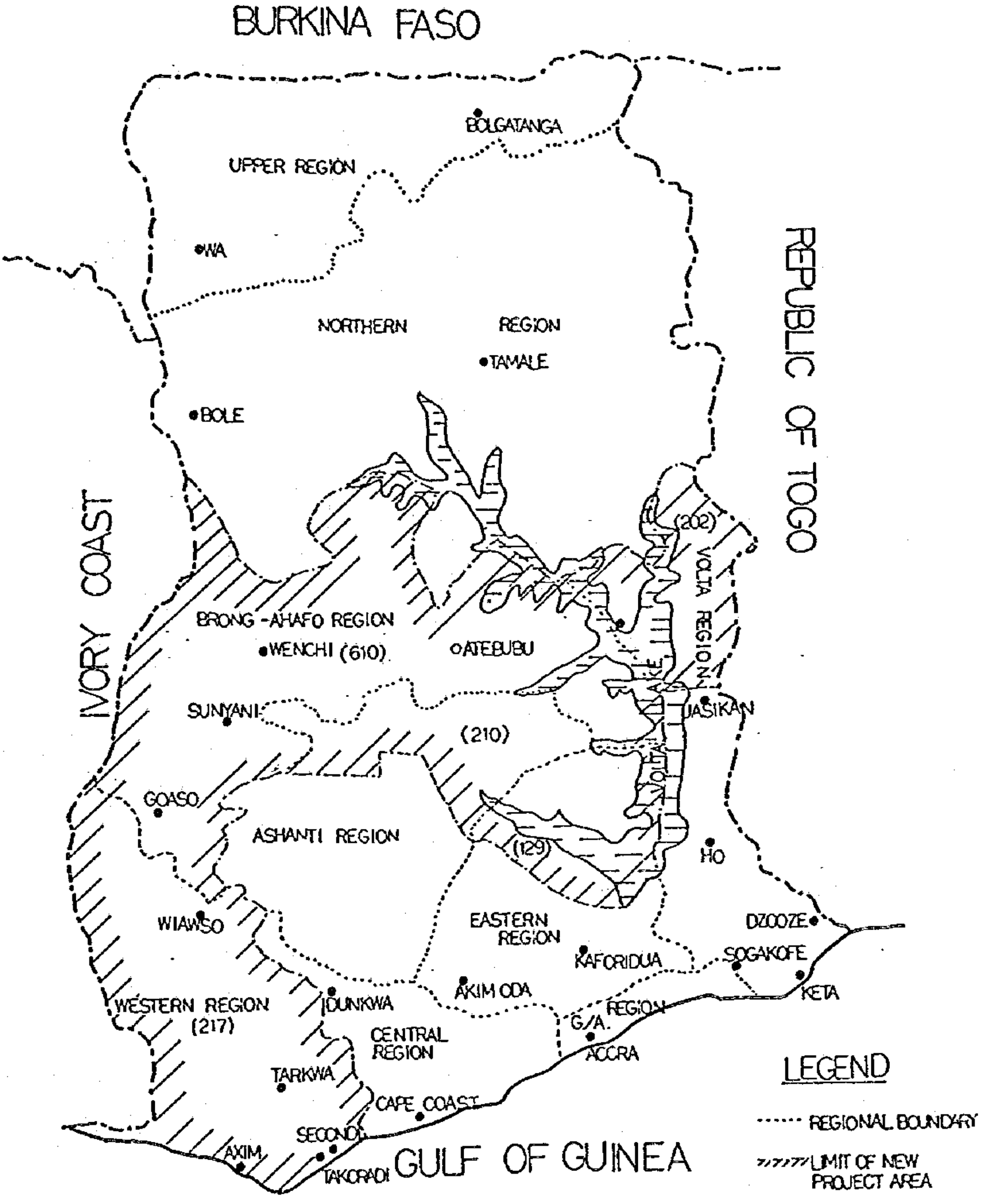


FIG. 2.2.2 DEMAND FOR WELLS IN NEW PROJECT AREA BY REGIONS

CHAPTER 3 SURVEY RESULTS

3.1 Fete Area

3.1.1 Outline of the Target Area

Location : About 60 km southwest of Accra (Refer to Fig. 3.1.1)

Administrative division: Central Region

Area : About 6 km^2

Tribe : Fante tribe (Chief: Nana Abor Ewusi XIX)

Population: 349 families, 1,790 persons (1982)
2,060 persons (1985)
For age distribution, see Table 3.1.1

Occupation of inhabitants : As the area faces the seacoast, the largest number of working males are engaged in fisheries, followed by those in agriculture. As for the working females, those engaged in agriculture and commerce account for the largest group. (Refer to Table 3.1.2)

Diseases: Major diseases are diarrhoea, malaria fever, scabies and upper respiratory infection. The results of the disease surveillance carried out in September 1983 are as presented in Table 3.1.3.

The results of tests on faeces samples have revealed one of the major causes of diarrhoea to be rotavirus infection attriubutable to a lack of sanitary habits of the inhabitants and inferior drinking water.

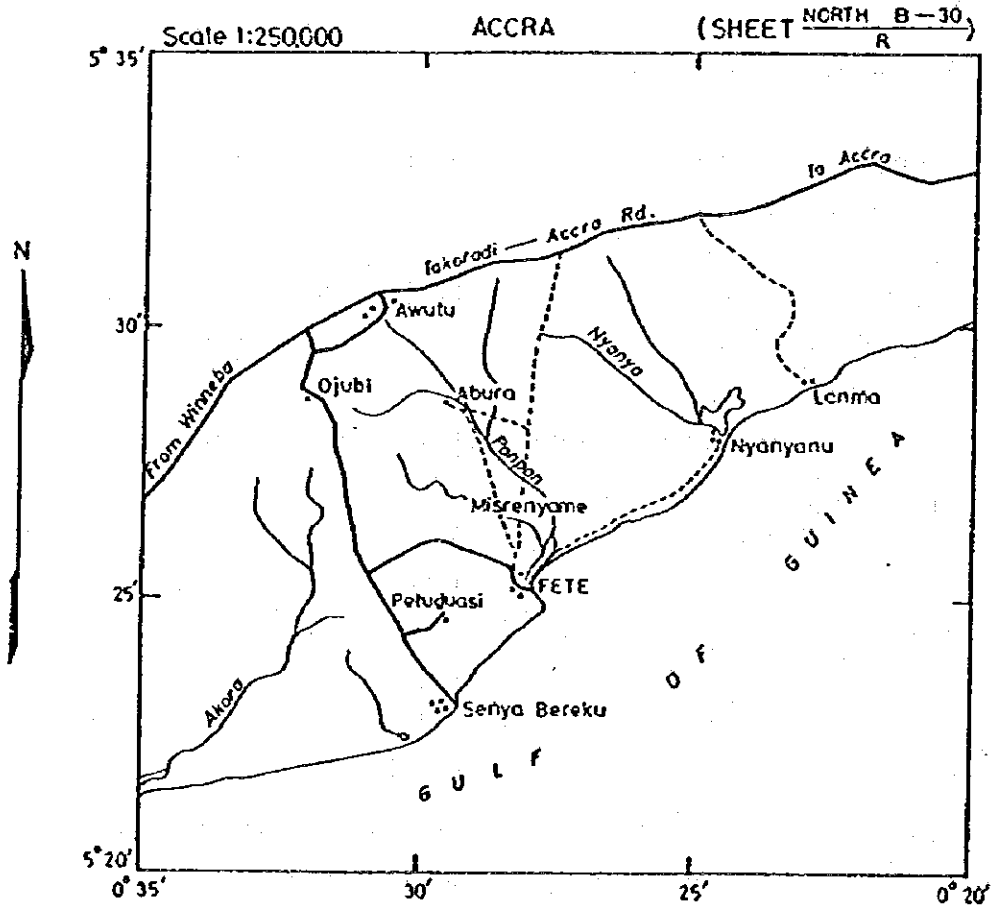


FIG. 3.1.1 LOCATION MAP OF FETE

Table 3.1.1 Composition of Fete Villages by Age Group (1982)

Age Group	Male	Female	Total
Up to One	40	42	82
1 - 4	108	135	243
5 - 9	115	104	219
10 - 14	106	120	226
15 - 24	119	173	292
25 - 34	57	123	180
35 - 44	52	99	151
45 - 64	61	138	199
65 -	53	95	148
Total	711	1,029	1,740

Table 3.1.2 Occupation (1982)

	Male	Female	Total
Farming	72 (26.4%)	312 (56.4%)	384 (46.5%)
Fishery	127 (46.5%)	7 (1.3%)	134 (16.2%)
Commerce	4 (1.5%)	216 (39.1%)	220 (26.6%)
Teaching	6 (2.2%)	4 (0.7%)	10 (1.2%)
Driver	32 (11.7%)	0	32 (3.9%)
Manufacturing	19 (7.0%)	0	19 (2.3%)
Others	13 (4.7%)	14 (2.5%)	27 (3.2%)
Total	273 (100%)	553 (100%)	826 (100%)

Table 3.1.3 Results of Disease Survey at Fete Village

Date	1/8/83	9/9/83	16/9/83	23/9/83	30/9/83
Malaria Fever	43	30	42	30	26
Scabies	8	26	12	15	12
Upper Respiratory Infection	40	23	23	24	20
Ear Pain or Discharge	1	2	2	5	1
Worms	-	2	1	1	1
Abdominal Pains	1	1	-	1	1
Eye Discharge	-	-	1	4	1
Spleen	1	17	28	7	-
Sores	3	-	-	-	-
Vomit	4	3	1	5	-
Palpitation	1	-	-	-	-
Gingival Infection	1	-	-	-	-
Headache	-	3	-	-	-
Pneumonia	-	-	-	-	1
Measles	-	-	-	-	0

WEEKLY % OF DIARRHOEAL CASES IN SEPTEMBER

Date	2/8/83	9/9/83	16/9/83	23/9/83	30/9/83
Weekly Attendance	155	156	153	133	109
# of Diarrhoeal Cases	31	23	19	23	21
% of Diarrhoeal Cases	20.0%	14.7%	12.4%	17.3%	19.3%

# of Diarrhoeal cases seen in SEPTEMBER 117 (16.6%)
# of children seen in SEPTEMBER 706.

3.1.2 Hydrogeology

(1) Topography

Along the coastal line southwest of Accra near the Fete area are many small steams flowing from northwest to southeast. Fete area is located in a hilly area on the right bank of one of these streams, the Osonko River, and the hamlets are located on a height, on the western tip of a hill facing the Gulf of Guinea. The elevation near the hamlets is 30 to 50 m, and in the hinterland, 70 to 80 m.

This hilly area and the alluvial plain in the catchment basin of the Osonko River adjoin each other forming a gentle slope. The plain is less than 15 m in elevation and forms a flat surface of 500 to 700 m in width.

The plain is generally used as farmland while the hilly area is left abandoned as wasteland because a weathered layer of rock bed is often found distributed directly underneath a thin top soil covering.

The catchment basin of the Osonko River is small and the drainage divide is 5 km upstream. The water channel in which surface water is recognized during the rainy season between May and July but not in any other months of the year, is 3 to 6 m wide. AT the time of heavy rainfalls during the rainy season, however, the lowlands seem to become temporarily submerged. At the estuary of this river is a lagoon called Kako Lagoon, and because of the gentle river gradient, sea water comes up to around 1 km upstream from the coastline during the dry season. The lagoon on the right bank of the estuary is therefore utilized for salt farms.

(2) Geology

The southern part of Ghana is comprised of Pre-Cambrian formations which are divided into several layers from Buem Formation to Dahomeyan (refer to Fig. 2.1.1). The area around Fete is located at the southern tip of the Togo Series which is distributed in belt form from the border with Togo toward the southwest, and immediately north of the Fete area are distributions of granites which belong to Middle Pre-Cambrian.

The hill on which the hamlets of Fete are located is framed with quartzite of this Togo Series which is seen outcropping here and there, but its top layer is heavily weathered and is as fragile as sand. Schistocity is recognized in this quartzite, and its strike and dip are dominantly oriented toward N 60°E/S 70-75°. Joints of N20°W/90° and N35°W/S55° are also developed orthogonal to this schistocity.

Unconsolidated alluvial sediments are distributed over this quartzite on the plain, in the catchment basin of the Osonko River. Alluvium is deposited with alternate layers of clayey soil and quartz sand.

Distributed on the sand beach along the coastline of the estuary are sand layers of uniform grain size.

(3) Meteorology

The climate along the coastline near Accra including Fete belongs to the semi-arid coastal savannah and corresponds to the Gharian area of relatively small precipitation.

Rain gauge stations are located at Pomadze which is about 18 km west of Fete and also at Kwanyako about 25 km northwest of Fete. Rainfall data of the past ten years is summarized in Tables 3.1.4 and 3.1.5.

Table 3.1.4 Monthly Mean Rainfall of the Past Ten Years

(Fete Area) (Units in mm)

Month / Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Pomadze	7.4	35.9	46.1	120.7	177.4	231.3	59.7	30.3	46.2	79.3	45.9	7.1	887.3
Kwanyako	17.2	55.3	85.8	95.1	173.8	187.9	100.1	37.2	69.8	98.0	92.5	34.2	1,046.9
Average	12.3	45.6	66.0	107.9	175.6	209.6	79.9	33.8	58.0	88.7	69.2	20.7	967.3

Table 3.1.5 Annual Rainfall of the Past Ten Years

(Fete Area) (Units in mm)

Year / Station	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Pomadze	-	763.3	*above 746.3	652.7	1,410.3	*above 1,135.7	*above 984.9	1,042.3	*above 256.8	-
Kwanyako	1,019.8	886.2	959.4	1,037.8	1,396.0	1,357.1	1,228.2	*above 705.2	632.5	-
Average	-	824.8	-	845.3	1,403.2	-	-	-	-	-

* Unknown because some of the data are missing.

If we assume the amount of rainfall in the Fete area to be the average of rainfalls observed at the Pomadze station and Kwanyako station, the annual mean rainfall is about 970 mm.

The rainy season is divided into the major rainy season which is between April and July and the minor rainy season from September through October, and the rainfall is particularly large during the months of May and June, being about 200 mm/month.

From the trend of rainfall of the past ten years, rainfall of 1,000 mm/year can be anticipated, but in 1983 it was rather reduced, having been only 632.5 mm which is about 2/3 of the annual mean rainfall.

The mean temperature is around 27°C throughout the year but relatively higher during the dry season between November and March.

Table 3.1.6 Monthly Maximum and Minimum Daily Temperature During the Past 20 Years (Accra) (°C)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean daily max. temp.	31.7	32.0	32.1	31.7	30.9	28.7	27.4	27.4	28.7	29.9	31.2	31.5
Mean daily min. temp.	22.9	23.5	23.7	23.6	23.4	22.6	21.8	21.4	21.9	22.4	22.9	23.1

(4) Conditions of existing wells

a) Distribution of wells and groundwater level

Water intake facilities which use groundwater as a water source are located at seven places in Fete. Their principal particulars and locations are as shown in Table 3.1.7 and Fig. 3.1.2.

Table 3.1.7 List of Wells in Fete Area

No.	Name	Elev. (m)	Shape (m)		Remarks
			Dia.	Depth	
1	Well (I)	7.30	1.5	3.0	Drilled in 1950 but dried up a few years later. The well is about to collapse with sediment flowing in from side walls.
2	" (II)	6.62	1.25	4.00	Constructed in 1968 but dried up in 1983.
3	" (III)	6.39	1.30	3.65	Constructed in 1968 but dried up in 1980.
4	" (IV)	6.18	1.20	3.95	Constructed in 1968 but dried up in 1983.
5	" (V)	6.21	1.25	6.65	Constructed in 1968 but dried up in 1983.
6	Dampraya (Well on the coastline)	-	3.7-4.5	3.0-3.8	Fissure water from rock bed. Used as miscellaneous water.
7	Aboano Well (Spring on the coastline)	-	-	-	Fissure water from rock bed. Used for drinking water.

Wells (I) through (V) are hand-drilled wells dug in the alluvial ground on the right bank of the Osonko River and are located about 1.5 km westnorthwest from the center of Fete Villate. This location is about 500m upstream of the boundary of the tidal compartment on the Osonko River. Well (I) was drilled in 1956 but it ran dry in a few years and has been left abandoned ever since.

Wells (II) through (V) were constructed in 1968 and were used as precious domestic water by the inhabitants but they ran dry because of the drought in 1983. However, there has been a sign of recovery in water level since the start of the current survey (April), with a little water being observed (water depth 5 - 10m) at the bottom of well (V). Then, with the arrival of the rainy season in May, water has come to be recognized in all of the wells, and their water level is still rising.

The surface water of the Osonko River has also begun to flow during this period, and the water level of the river which was initially higher than the ground water level has since become approximately the same as that of the groundwater ever since June 10. In other words, it is considered that prior to June 10 when the groundwater level was lower, ground water had been recharged not only from the ground surface by rainfall, etc. but recharged largely by the surface water of the Osonko River (Fig. 3.1.3).

As above, the ground water in the alluvial ground, where wells (I) through (V) are located, reveals that it is being recharged by rainfall and surface water and that there is a close relationship between the two. It is because of this that the recharged quantity of ground water at the time of the drought in 1983 is considered to have been extremely small and to have caused the ground water level to become low.

Incidentally, the side walls of these wells have partially caved in and there are signs of sediments having flown inside the wells. So when the neighborhood becomes submerged due to heavy rainfall, the surface water will easily flow in.

Dampraya and Aboan Wells are located at the foot of the slope of the hill facing the coastline, and both wells are distributed with quartzite of Togo Series and utilize the spring water which wells up from fissures of quartzite. The quantity of water welling up in these two wells is poor. At the time of the survey, there was only about 10 cm - 20 cm of water at the bottom of each well because many of the villagers were drawing up water from them.

b) Water quality

Water quality tests of well water in the Fete area were conducted, the results of which are as shown in Table 3.1.8.

Table 3.1.8 Water Quality Test Results in Fete Area

Name	Test Date	Tempera-ture (°C)	Hydrogen Ion Con-centration (PH)	Electric Conductivity (Ms/cm) at 20°C	Total Iron (ppm)	NH_4 (ppm)	Coliform Group	Bacterial Group	Others
Well (V)	Apr. 26	28.2	7.4	1,830	0.4	0.5	Totally colored, unsuitable	Totally colored, unsuitable	-
Dampraya (Well on the coast-line)	Apr. 12	29.2	-	2,040	-	-	-	-	Turbid and brown, for misc. use
	Apr. 26	28.8	7.2	1,975	0.1	0.1	Totally colored, unsuitable	Totally colored, unsuitable	
Aboano Well (Spring on the coast-line)	Apr. 12	31.6	-	3,130	-	-	-	-	Somewhat turbid, for drinking
	Apr. 26	29.8	7.3	2,770	0.4	0.1	Totally colored, unsuitable	Totally colored, unsuitable	

* Coliform group and bacteria qualitatively analyzed with test paper.

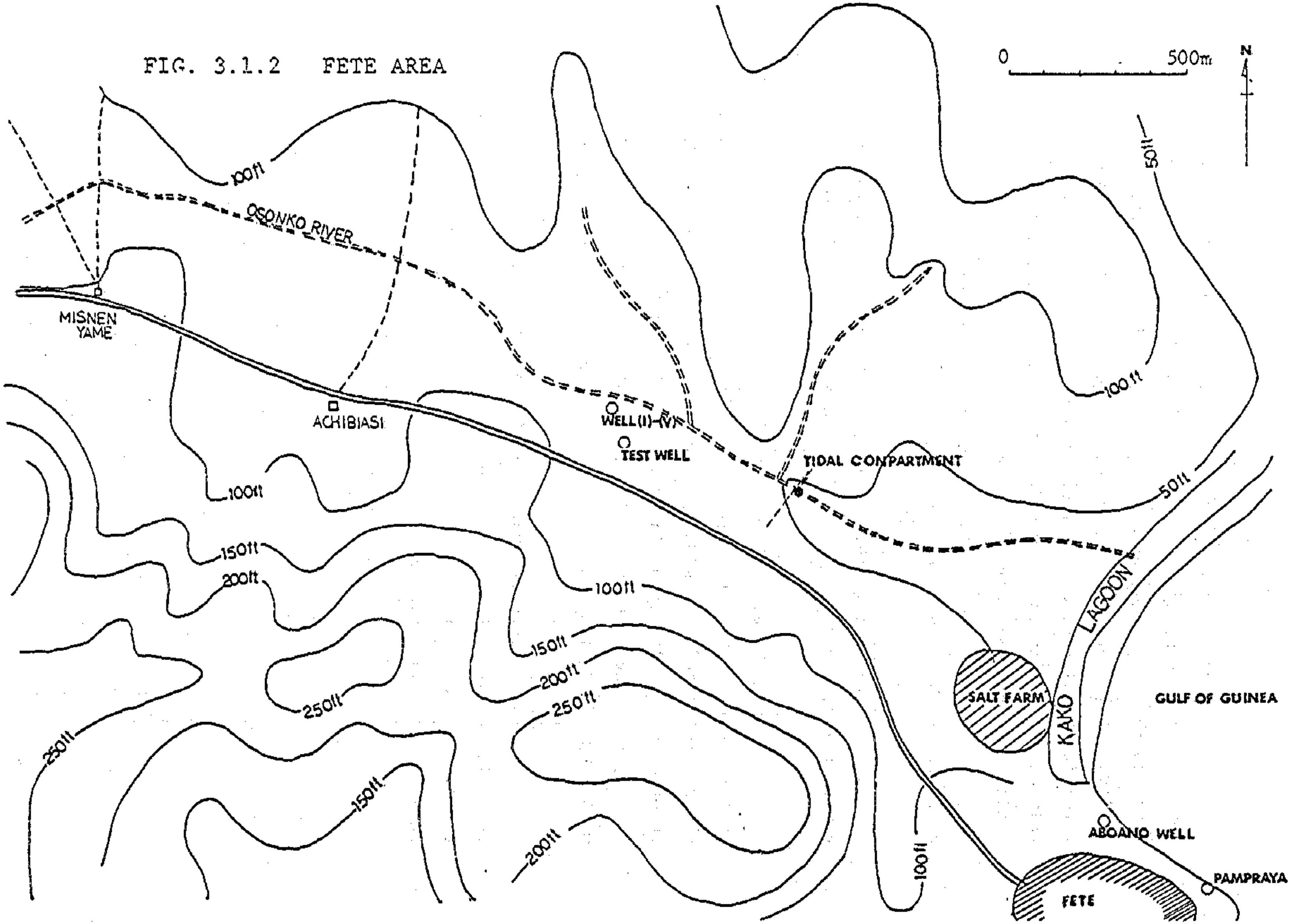
The water used by the villagers at the time of the survey in April was from Dampraya and Aboano Wells. A comparison of these two water sources indicated Dampraya to be superior in electric conductivity, total iron and NH_4, but because of the extreme hardness of its water it is unsuitable for drinking and washing and is therefore used only as miscellaneous water. Aboano Well, on the other hand, indicated a high electric conductivity value of around 3,000 μs/cm which suggested the presence of may dissolved substances, but the water is nevertheless being used for drinking.

On wells (II) through (V), electric conductivity was measured continuously, the results of which are as shown in Fig. 3.1.4.

When the electric conductivity of Well (V) is reviewed, it is seen that the measured value on April 26 was 1,830 μs/cm which changed to around 300 μs/cm after entering the rainy season in May. In other words, it can be inferred even from the aspect of water quality that the water in Well (V) is influenced by the surface water of the Osonko River (measurement on July 3 was EC = 174 μs/cm).

The surface of every well is opened and the people go inside the well to draw water. The water, therefore, tends to become polluted easily. May coliform groups and bacteria were detected, proving the water to be unsuitable for drinking.

FIG. 3.1.2 FETE AREA



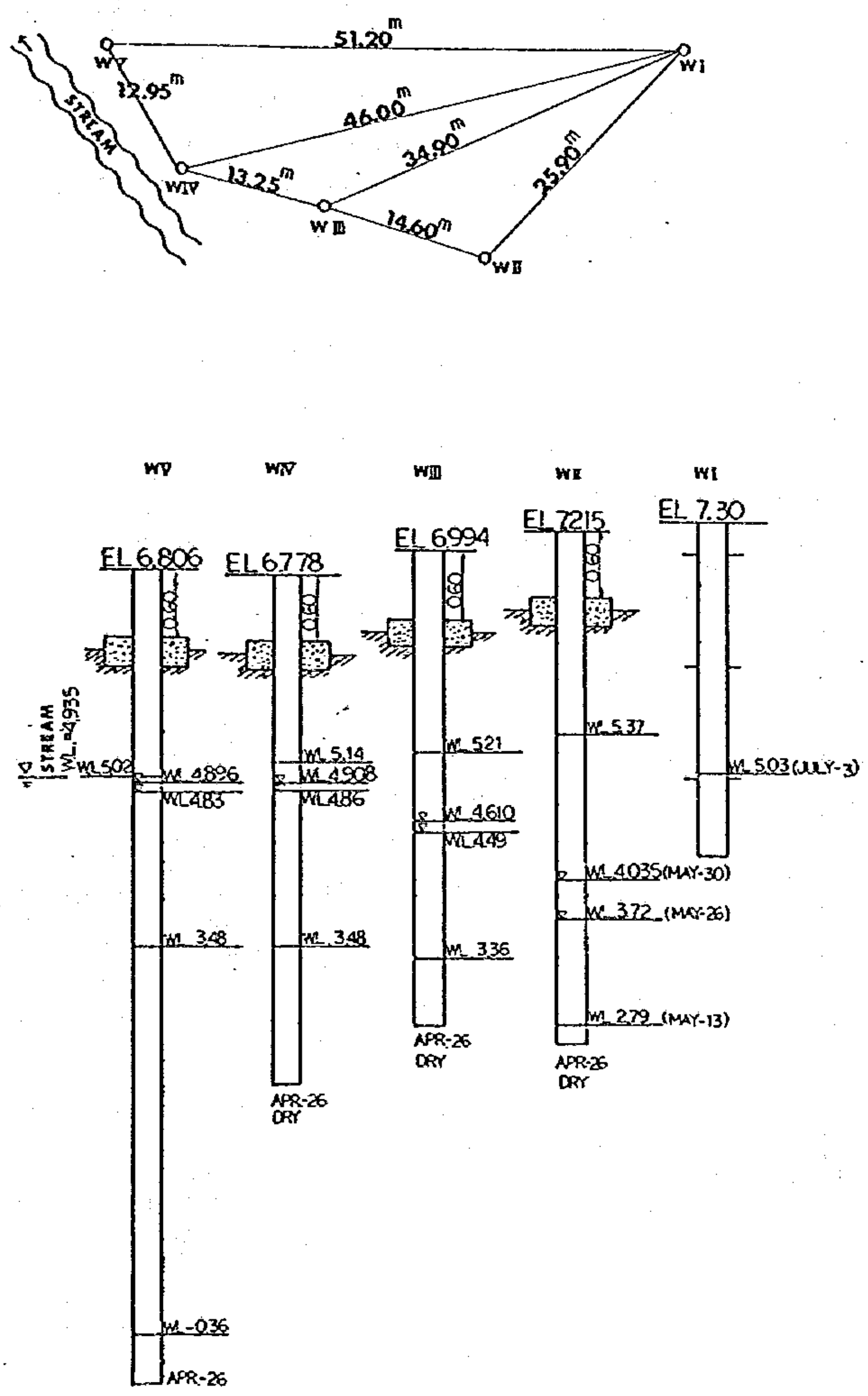


FIG. 3.1.3 LOCATION OF WELL (I) - (V)
AND VARIATION OF WATER LEVELS

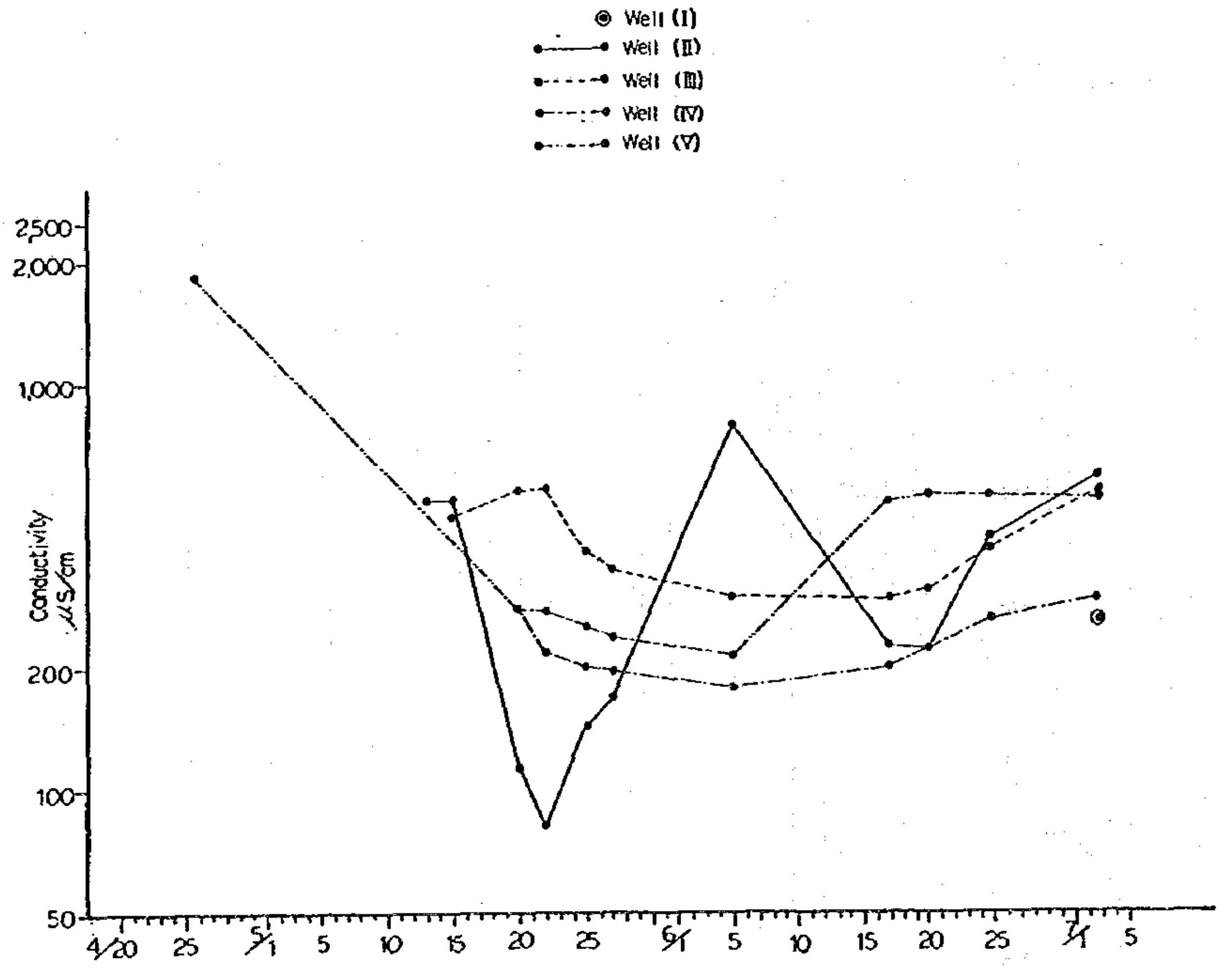


FIG. 3.1.4 VARIATION OF CONDUCTIVITIES AT WELL (I) - (V)

(5) Electrical prospecting

Electrical prospecting is a method of investigation to elucidate the hydrogeological structure of the survey area by directly linking the results of prospecting with the outcrops of geology and drilling data. Of the various electrical prospecting methods, the resistivity method was applied here.

The resistivity method is used to measure the apparent resistivity of the ground and to check its changes and infer the underground geology by making an integrated study of the results of outcrop survey and drilling data. Here, the underground resistivity was measured and interpreted by means of the vertical prospecting method.

(Survey coverage)

The topographic conditions of the Fete area can be broadly divided into the hilly zone of around 50m in elevation and the alluvial plain in the catchment basin of the Osonko River. As quartzite layer in which the occurrence of ground water is considered unlikely is distributed from the top layer in the hilly zone, the latter, or the catchment basin of the Osonko River, was chosen as the target area for prospecting. Also, as sea water travels close to around 1 km upstream from the estuary of the Osonko River, the area downstream of this point was excluded from the survey because of the high risk that the ground water there may have changed into saline water.

With due consideration to the topographical and geological conditions as above and the allowable distance for the villagers to carry water, electrical prospecting was conducted at 41 points within the range between 1 and 2 km from the estuary in the alluvial plain in the catchment basin of the Osonko River.

The prospecting spots are located as shown on Fig. 3.1.5.

(Measuring instrument and prospecting method used)

The instrument used in electrical prospecting and its specifications are as follows.

Instrument used: Model 3244 Ground Specific Resistivity Measurement Instrument made by Yokogawa Electric Machinery

Type and performance: Megger type,
Explorable depth 150 m

The measuring method was vertical prospecting by Wenner's arrangement of electrodes, and the target depth of exploration was 100 m.

For interpretation of measurement results, Sundbery's standard curve and Hummer's auxiliary curve were used.

The prospecting results were summarized in the form of a geological section on Fig. 3.1.7.

(Measurement results)

The strata in the survey area, when classified by specific resistivity, is structured mainly of three layers.

If we refer to the surface layer as "the first layer," then all three layers may be represented as follows:

	Specific resistivity (Ω - cm)	Thickness (m)	Corresponding geology
1st layer	200 - 600	1 - 5 m	Top soil, unconsolidated sediments, heavily weathered rock
2nd layer	10 - 100	10 - 20 m	Heavily weathered rock - weathered rock
3rd layer	100 - 900*	15 - 35 m	Basement complex, contains cracks

* Depth from ground surface to upper face of 3rd layer.

It is the 2nd layer that comprises aquifer. If the basement complex of the 3rd layer is to be targeted, a fractured zone would generally be detected by the distribution of low resistivity sections in the basement complex. The specific resistivity of a satisfactory aquifer is represented by the following formula.

$\rho a = F \times \rho_w$, wherein: ρ_w specific resistivity of ground water.
$F = 3 - 6$ (F stands for formation factor)

The specific resistivity of ground water in the upper surface of the aquifer based on the measurement values in the drilled holes and existing wells, is in the range of $\rho_w = 3.3 \simeq 15$ Ω-m.

From the results of electric logging, the specific resistivity of aquifer ρa is estimated to be:

$\rho a = 20 - 50$ Ω-m

As the specific resistivity of ground water tends to fluctuate in this survey area, the results of electric logging will be used as the standards for aquifer.

The range of ρa = 20 - 50 Ω-m in the 2nd layer is where the occurrence of aquifer can be anticipated. (Fig. 3.1.6). The low resistivity section generally indicates layers with low permeability like clay or silt, but when the geological distribution in this area is taken into consideration, it is inconceivable that clay and/or silt are thickly distributed as the 2nd layer. Also, as specific resistivity becomes lower toward the sea, it is conjectured that ground water with a high salt concentration is infiltrating the ground.

When the specific resistivity of the 3rd layer is reviewed, a low resistivity section is seen to be widely distributed, as in the 2nd layer. The results of drilling have revealed the basement complex of this survey area to consist of biotite granite and gneiss, and these rocks generally have the specific resistivity of at least 200 Ω-m or more. Consequently, the range within 200 Ω-m is presumed to be a localized deep weathered zone. The low resistivity section widely distributed on the side of the sea cannot be considered as a fractured zone in view of its range of distribution. It is more reasonable to consider it as the same as the region infiltrated by the ground water which has turned into saline water.

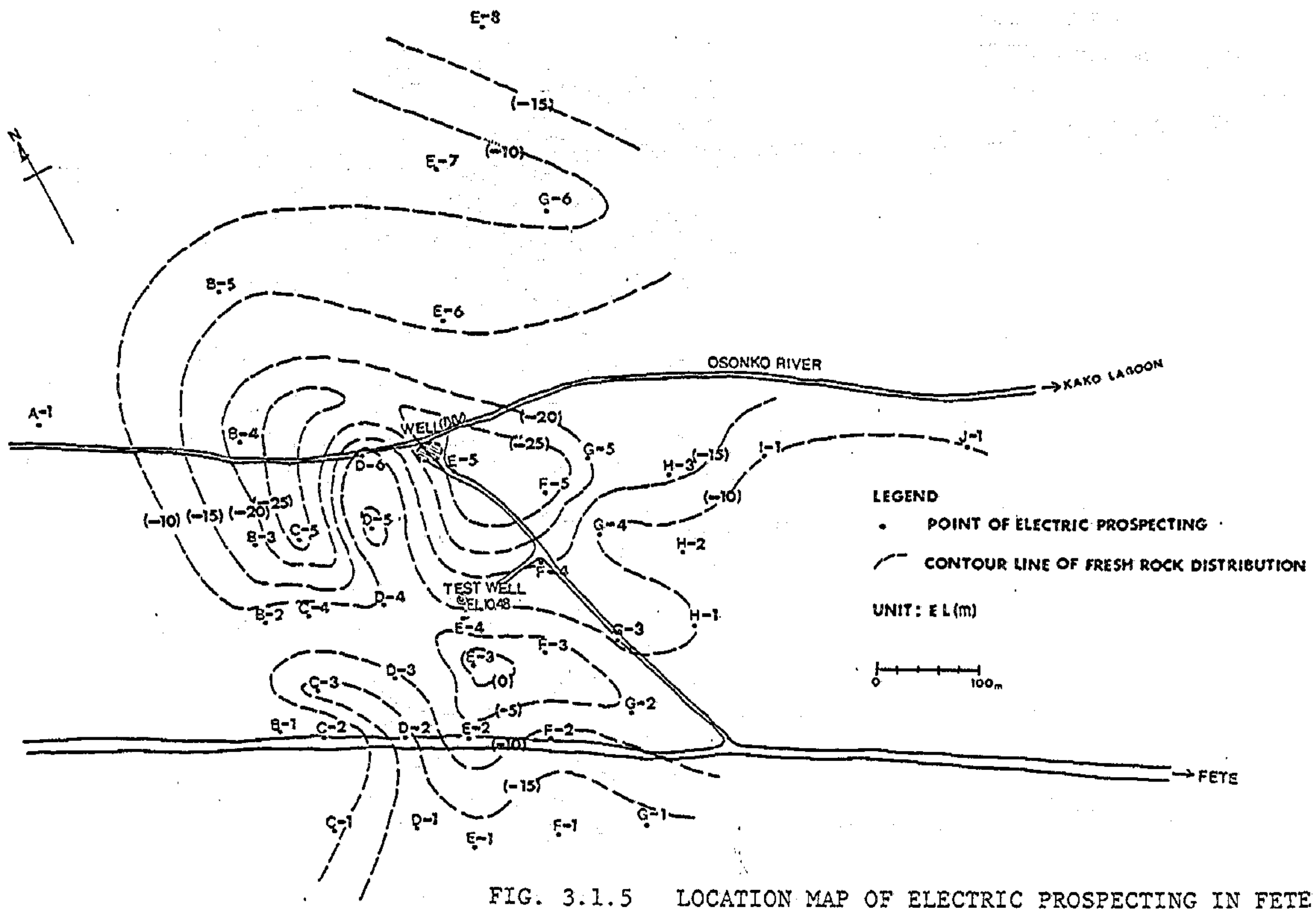
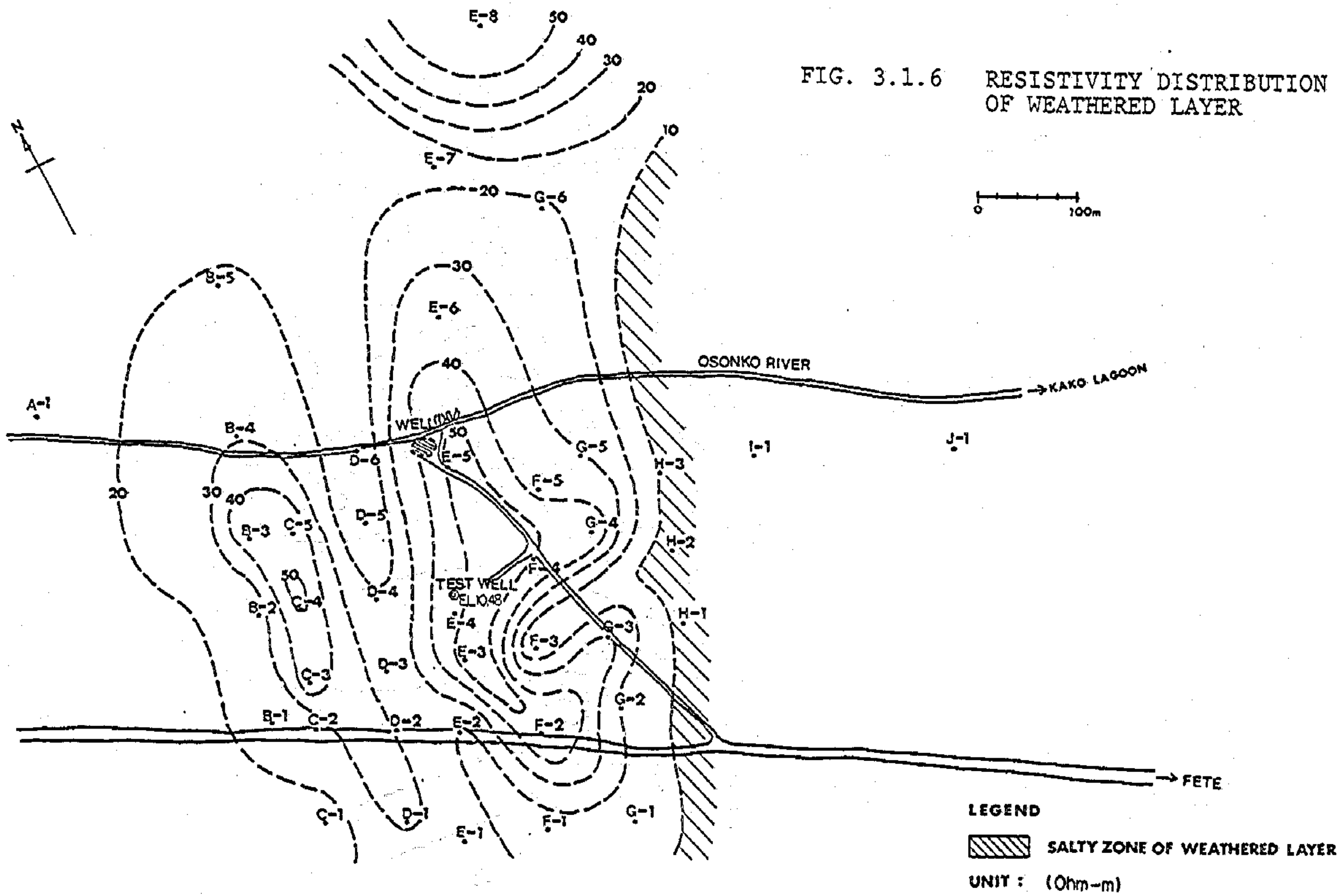


FIG. 3.1.5 LOCATION MAP OF ELECTRIC PROSPECTING IN FETE

FIG. 3.1.6 RESISTIVITY DISTRIBUTION OF WEATHERED LAYER



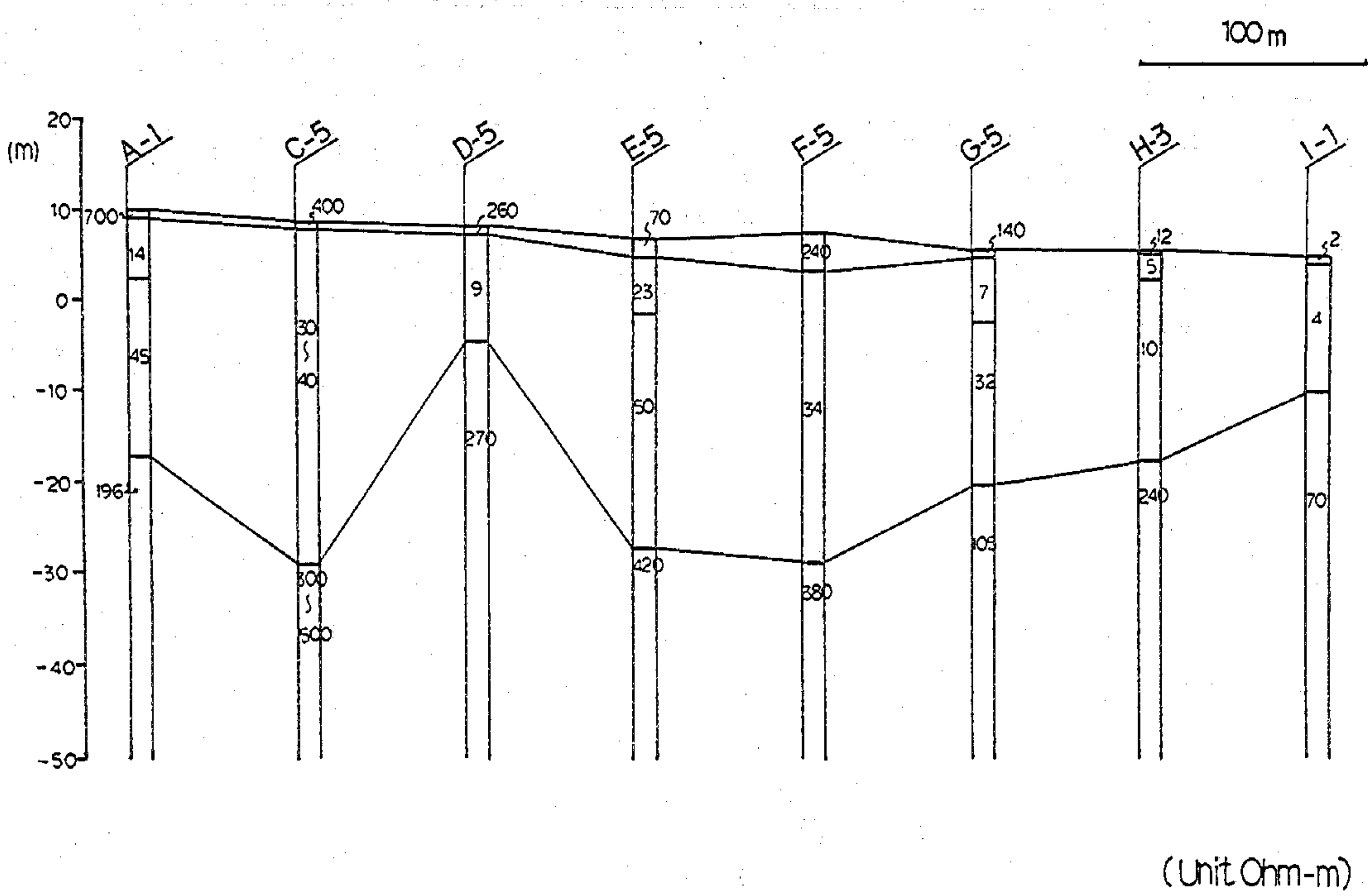


FIG. 3.1.7 (1) GEOLOGICAL SECTION BY RESISTIVITY SURVEY AT FETE (1)

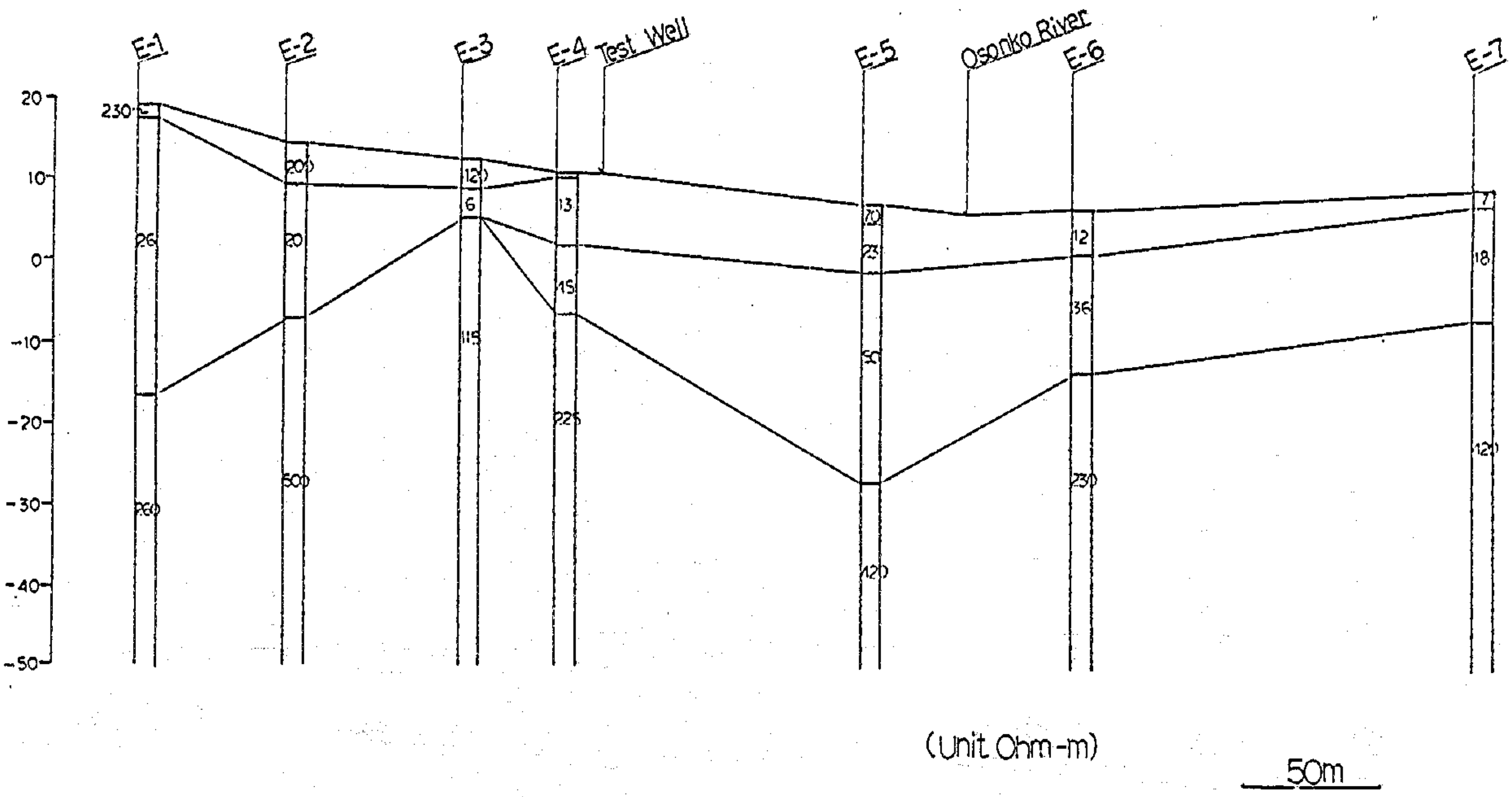


FIG. 3.1.7 (2) GEOLOGICAL SECTION BY RESISTIVITY SURVEY AT FETE (2)

(6) Test well survey

(a) Outline of survey

The test well survey, which consisted of drilling a test well and conducting a pumping test and water quality test was executed for the purpose of obtaining data for the ground water utilization plan in the Fete Village or, in other words, to choose either the shallow or the deep well and work out the ground water development plan.

The results of electrical prospecting revealed the alluvial plain in the catchment basin of the Osonko River to be comprised of the upper layer, unconsolidated alluvial sediments, a weathered zone of quartzite and the basement complex, and the layers in which the logging of ground water is possible were seen to be between the unconsolidated sediments and the weathered zone, wherein free surface water may be logged, and in the basement complex, where fissure water may be logged. If faults and fractured zones are developed, the logging of a large quantity of fissure water can be expected in the basement complex, but the results of surface reconnaissance and electrical prospecting have revealed the distribution of such structural line to be almost unthinkable. Accordingly, since the conditions with respect to aquifer were restricted to shallow ground water, the locations where weathered zone and unconsolidated sediments are distributed as thickly as possible, and where the topographic conditions are such that surface water and seepage water tend to collect easily, were considered as the targets in selecting the possible site for a test well. At the same time, areas close to the coastline, where there was a risk of the water being salinated, were excluded.

The conditions for selecting the sites for test well other than the foregoing underground hydrologic conditions are:

1. proximity to the Fete village
2. freedom from innundation during the rainy season

3. being on the right bank of the Osonko River, to enable the villagers to carry water even during the rainy season so that the villagers might utilize the test well as their own well by installing a pump in the future.

The survey was entrusted to GWSC by whom it was carried out as follows:

Survey location: As shown in Fig. 3.1.5

Survey period: From May 1, 1985 to July 10, 1985

Survey contents:

(Drilling and finishing of well)

Diameter of drilled hole: 203 mm
Depth surveyed: 60 m
Depth to which casing was inserted: 29 m (cementing between 29 m and 60 m)
Casing hole diameter: 150 mm
Depth at which strainer was inserted: 14.0 - 22.5 m, for 8.5 m
Kind of pipe: Hosing - PVC pipe
Strainer - PVC pipe with slit

(Electrical logging)

Measurement method: Bipolar method
Electrode spacing: 0.25, 0.5, 1.0 m
Instrument used: Model 3244 ground specific resistivity measurement instrument

(Pumping test)

(1) Date measured May 29 Depth 29 m
(2) " " June 15 Depth 60 m
(3) " " June 17 Depth 60 m
(4) " " July 25 Depth 29 m
(After inserting casing)

(Water quality test)

(1) Electrical conductivity, water temperature, total iron, NH_4, pH, coliform group, bacteria as necessary

(2) After completion of well, water was sampled on June 28 and examined with respect to items shown on Tables 3.1.12 and 3.1.13 at GWSC's laboratory.

(Drilling machine)

Percussion drilling machine made by Ruston Bucyrus (made in 1955)

(b) Drilling survey and electrical logging

The survey results are as shown in geological columnar section on Fig. 3.1.8.

The geology is broadly divided into alluvium to the depth of 7.50 m, weathered quartzite between 7.50 m and 18.00 m, and granite between 18.00 and 60.00 m.

Alluvium is covered with clayey top soil and the lower part is comprised of coarse grain size sediments mainly composed of fine granule and coarse sand. Ground water was not recognized in this alluvium, but should the ground water level rise, it is to be recognized that it is a stratum with a large permeability coefficient which allows ground water to be stored adequately.

Quartzite comprises a stratum which belongs to the Togo Series. It is generally exposed to strong weathering and many cracks are seen to be developed irregularly. Ground water level was recognized at a depth of about 9 m in this stratum, with the ground water being stored in these cracks. This stratum comprises the aquifer of ground water in the catchment basin of the Osonko River. The results of electrical logging aimed at this stratum indicated low resistivity of $\rho = 20 - 50\ \Omega$-m between the depths of 9m to 14m which however increased to $\rho = 50 - 100\ \Omega$-m between the depths of 14m to 18m, thus reflecting the difference in the degree of weathering. The resistivity values are generally low for weathered rock, and this is presumed to be attributable to the high salt concentration (= low specific resistivity) in the ground water stored.

Pre-Cambrian granite is distributed at a depth deeper than 18 m. The lithology in the upper section to around 39 m in depth is biotite granite, but at depths below that, gneiss-like lithofacies with intercalations of serpentine are recognizable here and there. The section between 18 to 21 m in depth is considered to be somewhat weathered, for the value of specific resistivity here sharply increases from ρ = 100 Ω-m to 450 Ω-m until a relatively fresh rock bed intersects at a depth of 21 m. The value of specific resistivity between 21 m to 37 m in depth is ρ = 450 - 550 Ω-m and this section is considered to abound in relatively numerous fissures. The resistivity decreases to ρ = 400 Ω-m between 37 m to 41 m, and when collated with the geological columnar section, it corresponds to the section that intercalates many soft serpentines. Between depths of 40 to 52 m, the resistivity value gradually rises from ρ = 400 Ω-m to 750 Ω-m, reflecting the gradual decrease in the number of cracks. The resistivity at a depth deeper than 52 m is a stable ρ = 760 Ω-m from which fresh and compact base rock may be inferred.

From the foregoing results of drilling and electrical logging, the aquifer in which the occurrence of ground water can be expected is presumed to be the weathered rock 9 to 21 m deep while granite deeper than 21 m is considered to be in the category of impermeable stratum, in view of its lithology and specific resistivity.

Moreover, electrical logging was conducted three times, from which it became apparent that the values of overlapping sections measured each time tended to decline as the drilled depth increased and that the specific resistivity of water declined in proportion to the depth. This, in other words, endorsed that many electrolytes are contained in ground water.

FIG. 3.1.8	BORING LOG	

PROJECT · LOCATION GOMOA-FETE

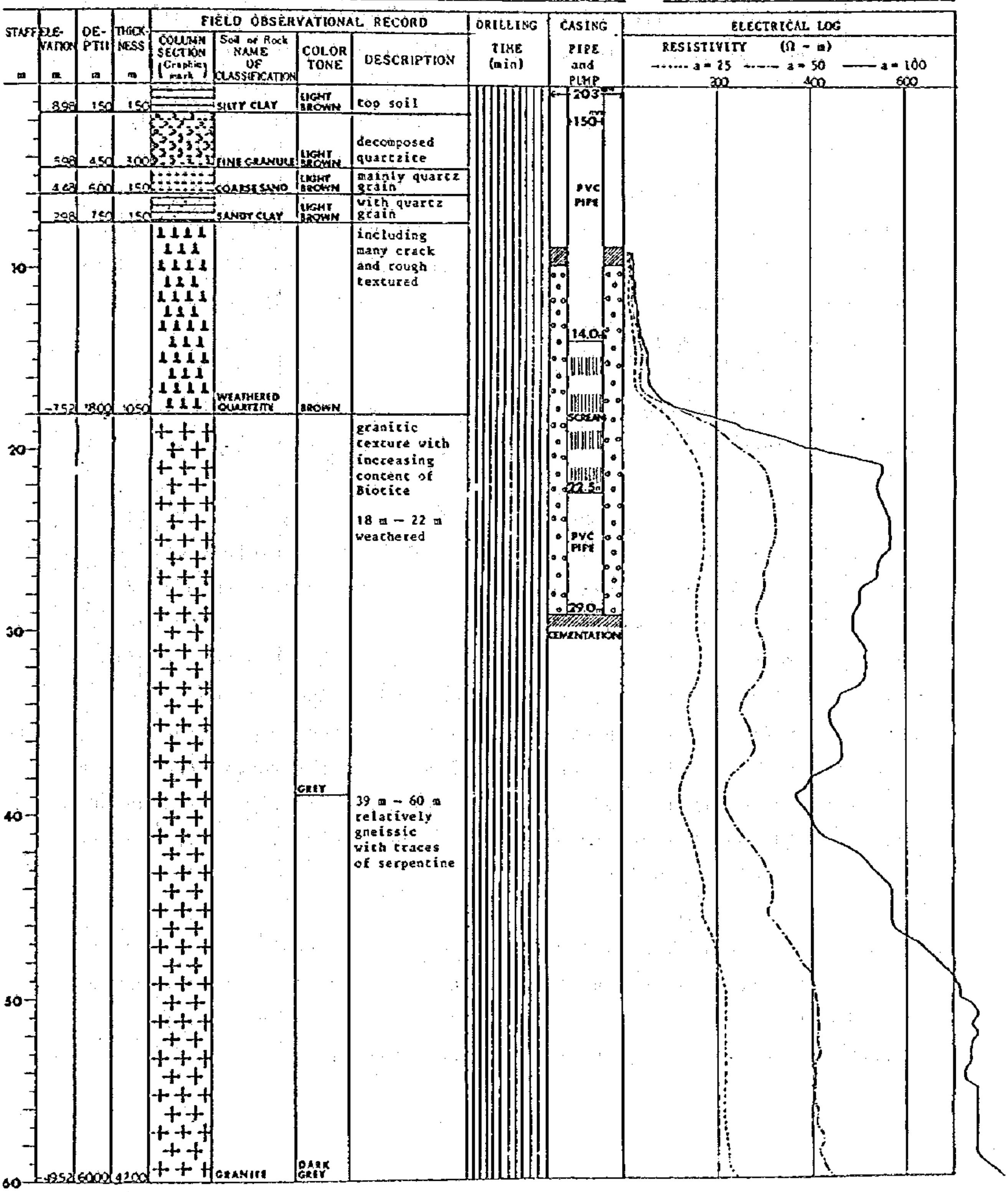
GROUND ELEVATION 10.48 m

DATE OF INVESTIGATION MAY-JUNE 1965

BORING HOLE No.1

DEPTH TO GROUND WATER LEVEL IN HOLE -9.0 (9TH MAY)

INVESTIGATED BY RYOJI IMAI



(c) Pumping test

Pumping of test wells were tested altogether four times - three times during drilling and once after their completion - in order to grasp the permeability of the shallow and deeper layers. One pumping test during drilling was conducted at a depth of 29 m, aiming for a shallow aquifer, and the other two tests were conducted at a depth of 60 m to grasp the condition of aquifers in deeper strata.

The test method employed was to pump ground water by bailer and to measure the discharge volume and changes in water level. The results obtained during pumping were systematically compiled according to the Theis method and the Jacob method, and for analysis during recovery, the recovery method was employed.

Test conditions and test results are as shown on Table 3.1.9; the summary table.

When the results of the pumping test during drilling are reviewed, it is seen that while the permeability coefficient of $K = 2.04 \times 10^{-4}$ cm/sec was obtained in the test down to the depth of 29 m, it was drastically reduced to $K = 1.03 \times 10^{-4} \sim 1.28 \times 10^{-4}$ cm/sec. in the tests at the depth of 60 m despite the fact that the test section was enlarged to three times as much, thus indicating that the permeability coefficient in the order of $K = 10^{-6}$ cm/sec only can be expected in the section between 29 - 60 m. As a reference, the permeability coefficient of the aquifer is generally classified as per Table 3.1.10, and the strata below 29 m cannot be expected to have the permeability of an aquifer at all.

The permeability coefficient at a depth shallower than 29 m is quite small, being to the order of $K = 10^{-4}$ cm/sec. It is because groundwater occurs in the weathered zone of rock bed that the permeability coefficient is quite small as an aquifer.

Table 3.1.9 Summary of Pumping Test Results

Test Date	Hole Configuration			Natural Water Level GL-(m)	Dis-charge (/min)	Pumping Duration (min)	Coefficient of Transmissibility		Coefficient of Storage	Permeability Coefficient	Remark
	Depth (m)	Hole Dia-meter (mm)	Test Section (m)				Analyzing Method	Test Results (m^2/min)			
May 27	29	203	14 - 29	8.97	180	16	Recovery method	1.84×10^{-3}	-	2.05×10^{-4}	While drilling
							Jacob	2.33×10^{-3}	Unanalyzable		
							Theis	2.75×10^{-3}	6.60×10^{-1}		
							Recovery method	3.47×10^{-3}	-		
June 15	60	203	14 - 60	8.66	57.5	60	Mean	2.85×10^{-3}	6.60×10^{-1}	1.03×10^{-4}	Wile drilling
							Jacob	3.05×10^{-3}	Unanalyzable		
							Theis	3.72×10^{-3}	1.24×10^{-1}		
							Recovery method	3.79×10^{-3}	-		
June 17	60	203	14 - 60	8.93	57.5	120	Mean	3.52×10^{-3}	1.24×10^{-1}	1.28×10^{-4}	Wile drilling
							Jacob	6.51×10^{-4}	2.67×10^{-1}		
							Theis	4.02×10^{-4}	4.02×10^{-2}		
							Recovery method	Unanaly-zable	-		
June 25	29	150	14-22.5	8.86	14.6	60	Mean	5.27×10^{-4}	1.54×10^{-1}	1.03×10^{-4}	After completion of well

The permeability coefficient after completion of the well is considerably lower than that measured during drilling at a depth shallower than 29 m. This is attributable to the quality of gravel used for completing the well and also to the performance of the strainer.

With due regard to the foregoing conditions, the hydraulic constants of the weathered zone (aquifer) distributed at a depth shallower than 29 m were determined as follows:

Coefficient of transmissibility	$T = 1.8 \times 10^{-3} m^2/min$
Coefficient of storage	$S = 1.5 \times 10^{-1}$

Table 3.1.10 Permeability Coefficient k(cm/sec)

10^2	10	10^{-3}	10^{-4}	10^{-6}	10^{-7}
(Staratum) Gravel	Sand or sand and gravel	Fine sand, silt Mixture of find sand and silt			Impermeable soil
Aquifer			Semi-impermeable layer	Impermeable layer	

(d) Water quality test

Ground water in the coastline area facing the Gulf of Guinea is known to have a generally high salt concentration, so that when making a survey of ground water it is important to acquire a grasp of the changes in water quality at every depth and in every aquifer. While the test well was being drilled, therefore, the water quality was checked with respect to the items shown in Table 3.1.11.

Electrical conductivity, which is one of the test items, is used as an indicator of the amount of electrolytic contents in the ground water. Even though its value fell below 3,000 μs/cm temporarily during May 13 and May 20 due to an inflow of rainwater while work was suspended by the breakdown of the drilling machine, it is generally 3,000 μs/cm or above, indicating that the ground water contains a large amount of electrolytic components. When the changes in value are reviewed by depth, the deeper the depth, the higher the electrical conductivity, with the value being above 4,000 μs/cm at a depth below 29 m or thereabout as the dividing line.

Considering that this measured value was obtained for ground water mixed with water of the upper section, containing relatively few dissolved components, and also that what is more, fresh granite with a small permeability coefficient is distributed in the deeper section, it is judged that ground water with electrolytic contents close to that of saline water occurs in the deep layers above fresh granite.

For completing the well, a depth below 29 m where salt concentration suddenly rises was cemented, and a strainer was provided at a depth between 14.0 m and 22.5 m. At first, electrolytic components of 4,000 μs/cm or more remained, but after continuous days of pumping the water was considerably purified, and on July 10, the water quality at a depth of around 20 m recovered to the neighborhood of 3,700 μs/cm in electrical conductivity.

Another item that might pose a problem is total iron. Total iron, which was 0.3 ppm when drilling was commenced, sharply rose as work progressed and it now indicates 5.0 ppm or more. As a reason for this increase, leaching from casing (made of iron) may be considered, which suggests the considerably high salt concentration of the ground water itself.

Coliform group and bacteria were qualitatively analyzed with test paper. The result was that bacteria was detected in every test. This is judged to have been caused not by the contamination of the ground water per se but rather by contamination via the drilling machine.

Because of a pressed work schedule, the water quality analysis at GWSC's laboratory was conducted on sample water collected on June 28 when the water still showed an electrical conductivity of 4,300 μs/cm. The analytical results are as shown on Tables 3.1.12 and 3.1.13.

On the whole, the water contains a lot of dissolved components and exceeds the allowable values of WHO and GWSC (refer to Appendix) on many of the test items. Particularly chlorine showed a high value of 1,400 ppm which greatly exceeds the tolerance limit of 600 ppm allowed by WHO and GWSC. Electric conductivity however has since declined to a level of 3,700 μs/cm as of July 10, and a stationary chlorine ion concentration of 1,400 ppm or less is considered attainable.

In the bacteriological examination, 40 colonies were counted in 1 mℓ of water, but this is not much of a problem since the Japanese water quality standard for drinking water stipulates that not more than 100 individuals should be detected in 1 mℓ of water.

As for the coliform group, the Ministry of Health and Welfare Ordinance of Japan stipulates that it must not be detected in drinking water at all, but according to the report of the findings of the Living Environment Deliberation Council of the Ministry of Health and Welfare, the limit on the number of coliform groups that can be annihilated by chlorination to make the water safe is deemed to be 50 MPN/100 ml, and the test result of 13 MPN/100 mℓ underruns this safety limit.

As above, the continuous pumping after completion of the well has considerably purified the ground water, compared with purity at the time of drilling, and it is judged that there is no bacteriological problem with it insofar as bacteria and the coliform group are concerned.

Lastly, as there are many areas in Ghana where the quality of ground water is poor, the supply of domestic water by means of ground water would become difficult if the allowable tolerances of WHO and GWSC were to be strictly observed. Accordingly, in the 3,000 Well Project carried out with the assistance of the West German Government, electrical conductivity of 3,000 µs/cm is used as a guideline and water of less than this value is used as domestic water, but even when it exceeds this value the water is used as the source of domestic water providing the consent of the local inhabitants is obtained.

In the case of the present survey area, good quality water cannot be obtained in abundance because the ground water around the Fete area is quite inferior in terms of both quality and quantity. Because of this situation, the villagers, after drinking the water from the test well on a trial basis, gave their consent for it to be used it as domestic water. (Refer to Appendix) In other words, this means that the villagers wish to be supplied with more domestic water of the same quality as the test well, and believe that new development of ground water will at least make their living environment better than it is today.

Table 3.1.11 Water Quality Tests During Drilling of Test Well

Test Item / Date Measured	State of Test Well	Temperature (°C)	Hydrogen Ion Concentration (PH)	Electrical Conductivity (at 20°C) (us/cm)	NH^4 (ppm)	Total Iron (ppm)	Coliform Group*	Bacteria*	Remark
May 9	9.15m	29.6	6.6	3,643	1.0	0.3	-	-	While drilling
" 13	"	30.0	7.6	2,086	0.5	4.0	-	-	"
" 15	"	29.0	-	2,609	-	-	-	-	"
" 20	"	29.9	-	2,459	-	-	-	-	"
" 22	18 m	30.7	-	3,784	-	-	-	-	"
" 25	"	30.2	6.8	3,832	0.5	-	-	-	"
" 27	29 m	30.0	-	4,267	-	-	-	-	"
June 5	30.5m	31.8	7.2	3,904	0.3	Above 5.0	Lightly colored overall, unsuitable	Colored, uncountable, unsuitable	"
" 15	60 m	29.5	6.8	4,369	0.2	"	Totally colored, unsuitable	100 or more, unsuitable	"
" 18	"	29.0	7.0	4,393	0.1	"	Totally colored, unsuitable	Totally colored, unsuitable	"
July 2	29 m	31.2	-	4,206	-	-	-	-	After completion of well
" 8	"	31.9	-	3,698	-	-	-	-	"
" 10	"	30.2	-	3,661	-	-	-	-	"

* Qualitative analysis by test paper.

Table 3.1.12 Physical and Chemical Examination Result

Physical Examination

Appearance	:	:	Slightly Coloured and Turbid
Odour	:	:	Odourless
Apparent Colour	:	:	35.0 Hazan Units
True Colour	:	:	<5.0 Hazan Units

Chemical Examination

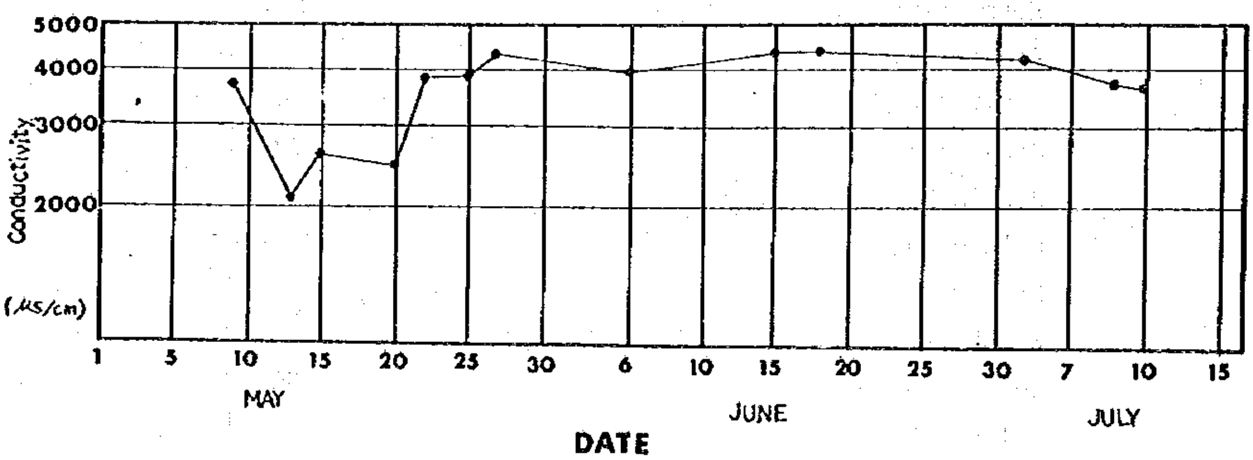
P^H	7.20
Phenalphthalein Alkalinity	N i l
Total Alkalinity	80.00
Total Hardness	540.00
Carbonate Hardness	80.00
Non-Carbonate Hardness	460.00
Calcium Harbness	260.00
Magnesium Hardness	280.00
Sulphate	222.70
Chlorides	1,400.00
Nitrous Nitrogen	0.01
Nitric Nitrogen	0.63
Silica	22.00
Total Iron	0.50
Iron in Solution	0.06
Manganese	N i l
Calcium	104.00
Magnesium	68.04
Suspended Solids (105°C)*	505.00
Oxygen Absorbed (37°C for 3 hrs)	0.80
Total Dissolved Solids (180°C)	3,135.00

* At sampling time, the sample used for water analysis is white turbid and reached as high as 505 ppm in the suspended solid (SS) content. However, subsequent to the contineous pumping, the sample has turned to be almost clear and it is expected that suspended solid content would be valued at less than 10 ppm.

Table 3.1.13 Bacteriological Examination Result

Source of Samples Gomoa Fetteh	Presumptive Test MaCkonkey's Broth 37°C	1 mℓ Total Plate Count 37°C	Brilliant Green Bile Broth 37°C	Brilliant Green Bile Broth 44°C	Indole Production 44°C	Type of Coliform Organism Isolated	M.P.N. per 100 mℓs
10 mℓ	+ + + + +		+ + + − +	+ + − + +	-----	Irreg. I	
1 mℓ	- - - - -	40					13
0.1 mℓ	- - - - -						

FIG. 3.1.9 Variation of Conductivities at Test Well



(7) Mode of occurrence of ground water

Electrical prospecting and test well survey have confirmed the weathered rock (with unconsolidated sediments in part) in which free surface ground water is stored to be distributed in the lowland in the catchment basin of the Osonko River. The layer thickness of this aquifer is influenced by the thickness of the weathered zone of the basement complex, and its boundaries undulate rather wildly. The weathered zone in the vicinity of the electrical prospecting point E-5 is the deepest and is distributed to the neighborhood of EL - 29 m.

The capacity of an aquifer is greatly influenced by the number of cracks in the rock-bed, but here, it indicated quite a low permeability coefficient on the order of $K = 10^{-4}$ cm/sec.

The ground water that occurs in this aquifer is anticipated to have completely turned into saline water up to around 1,300 m upstream from the coastline so that the area in which ground water of relatively good quality can be expected is confined to the lowland in the upstream of the Osonko River.

Recharging of ground water is presumed to be mainly by rain water, but changes in the water level of existing wells (I) through (V) prove that river water of the Osonko River also plays a large part in recharging ground water.

The ground water level around the test well is estimated to rise close to EL +5 m of the present river bed toward the end of the rainy season and gradually begin to lower from the middle of July and become the lowest around April of the following year. It then rises again when the rainy season beings in May. However, the drought in 1983 has upset this water balance and caused the water in Wells (I) through (V) to dry up.

The land around the test well on the right bank o the Osonko River comprises a slightly dissected topography from where it descends from the hilly zone and forms the ground water recharging zone. It is therefore considered to be the optimum site in the Fete area for ground water development. The unconsolidated sediments in the top layer of this zone are in a dry state and relatively porous so that even when rainfall intensity is fairly high, most of the precipitation seeps directly into the ground to be recharged as ground water instead of flowing into the water course. And, considering that river water is fed underground from the Osonko River when not raining, the quantity of ground water replenished from the waterway is presumed to approximately offset the amount of run-off into the waterway. Based on this premise, the quantity of ground water replenishment in this area can be obtained from the following formula.

(Amount of ground water replenishment) = ((amount of rainfall) - (Amount of evaporation loss)) x area

in which: Amount of rainfall = 970 mm (from meteorological data)

Amount of evaporation loss = 900 mm (based on "The World Water Balance" by A. Baumgartner/E. Reichel)

Area = 250,000 m^2 (based on the topographical map)

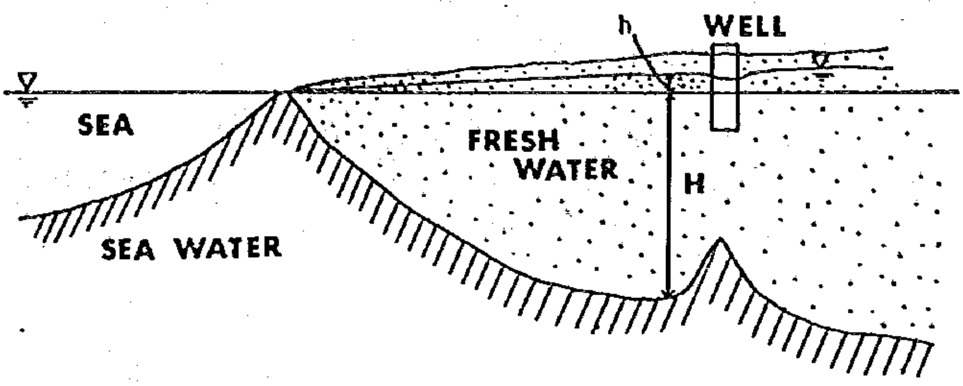
Hence, Amount of ground water replenishment = (0.97 - 0.90) x 250,000 = 17,500 m^2/year

If we assume a yield of 70% as the quantity of water available for use in relation to the quantity of ground water replenished, the available quantity of ground water is about 12,000 m^3/year. This available quantity of ground water is strictly in relation to the mean rainfall, and in the years when the rainfall drastically underruns the quantity of evaporation loss, as in 1983 for example, the ground water cannot be expected to be replenished; instead, the ground water level will keep on decreasing and even expose the upstream district to the risk of its ground water becoming saline.

Regarding the balance between the fresh water layer and saline water layer, a relationship of H = 42 h holds, due to the difference in specific gravity of sea water and fresh water. (In accordance with the Ghyhen-Herzberg rule.) In the case of the test well, the ground water level is at around EL +1.5 m so that occurrence of fresh water can be expected to the depth of around EL -60 m; but from around 29 m in depth, salt concentration becomes high, which is considered to suggest that saline water has risen to a fairly shallow depth due to the effect of the 1983 drought.

As the ground water level is only about 1 m higher than the sea level in the areas around the potential site for ground water development, there is every risk that ground water may become saline, in the event that the water level becomes lower due to chronic pumping of ground water from well and other reasons.

FIG. 3.1.10 Fresh- and Salt-water Distributions in an Unconfined Coastal Aquifer



3.1.3 Water Use Conditions

(1) Water supply scheme

The water supply scheme for the district including the Fete area, which is one of GWSC's local water supply schemes, was launched in about 1965 as the Winneba-Kwanyaku District Water Supply Scheme. The purpose of the scheme is to establish water conveyance stations at two locations, one at about 25 km northnorthwest of Fete (Kwanyaku) and another at about 18 km west on the beach (Winneba), and also to establish water conveying and distributing systems therefrom as outline below:

Area covered: About 2,200 km^2 between Senya Beraku and River Ochi Nakwa

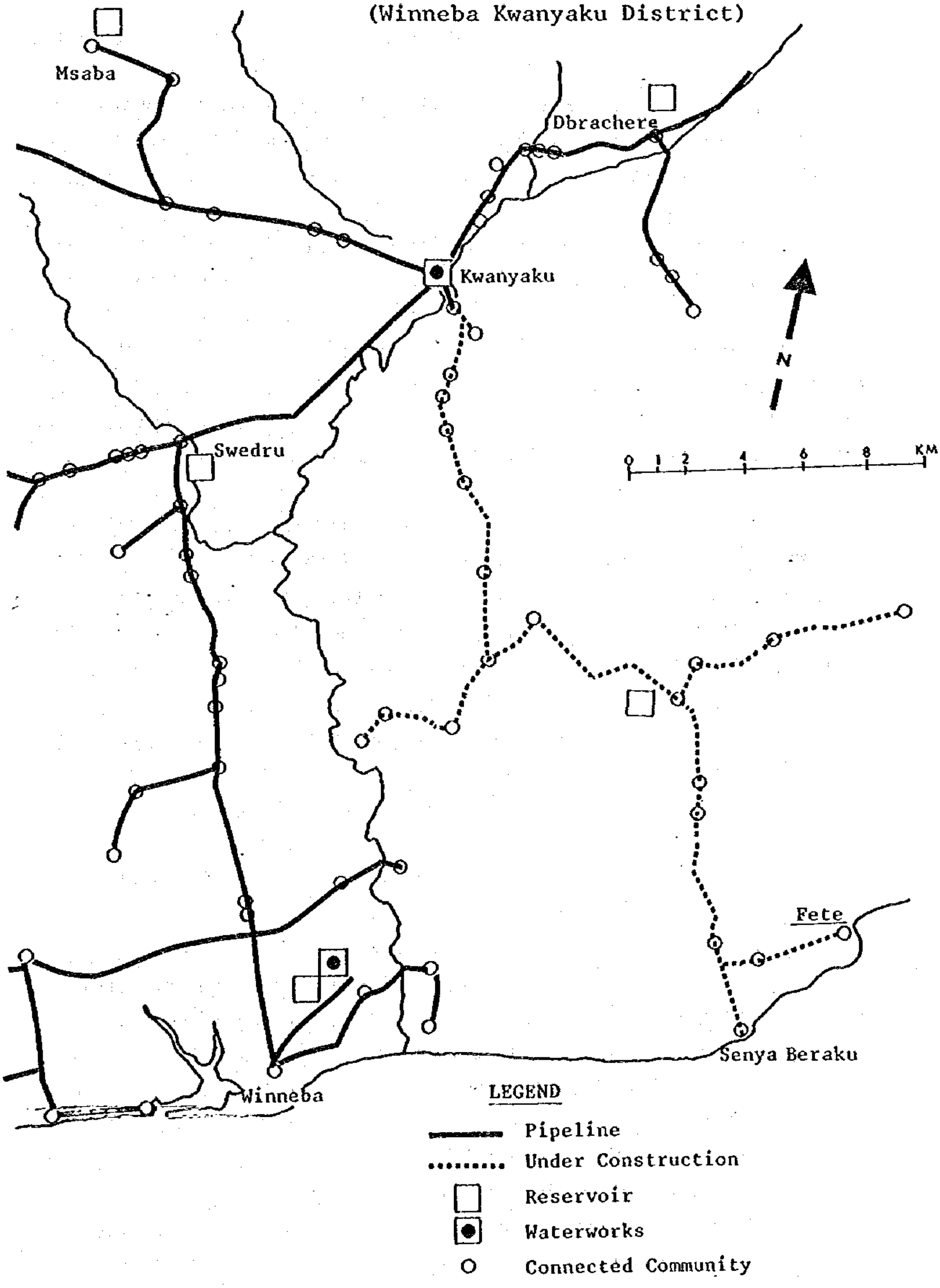
Population covered: 491,400 persons (1995 estimate. As of 1978 350,000 persons)

Quantity of water supply: Stage 1 20,565 m^3/day (1980)
Stage 2 31,931 m^3/day (1985)

This the year that Stage 2 is scheduled for completion, but the pipeline between Kwanyaku - Senya Beraku and others have not yet been completed. Instead, temporary branch pipes outside the scheme have been connected one after another which, as a result, are causing pressure drops and other obstacles. Also, the existing water conveyance facilities are insufficient to convey the necessary quantity, and to do so, water must be pressurized by installing new storage tanks. The Head of the Project Division of GWSC is also of the view that even if the pipeline should be laid toward Senya-Beraku, there is little chance that water would ever be conveyed.

Judging from the aforestated situation, the chance of tap water being supplied in the direction of Senya-Beraku (including Fete) in the near future seems quite remote.

FIG. 3.1.11 EXISTING WATER SUPPLY SCHEME
(Winneba Kwanyaku District)



(2) Water use conditions

As above, the Fete area is included in the area planned for supplying water by pipeline, but no one can tell when that water can be actually conveyed.

The present ground water sources in the Fete area are Wells (I) through (V), and Dampraya and Aboano Wells as described in Section 3.1.2 (4). But, the water of Wells (II) through (V), on which the villagers had relied upon most, ran dry due to the drought of 1983 while Dampraya and Aboano Wells near the seacoast also pose problems both in terms of quantity and quality, so that the water supply from the water sources in Fete is on the whole quite unstable.

Wells (II) through (V) were installed in 1968, and although they are about 1.5 km away from the center of the village, they had been used as precious sources of water for the villagers until they ran dry in 1983. The villagers have since been depending exclusively upon GWSC to carry domestic water in water tank lorries from Accra.

The capacity of the water tank lorry is 10,000 gallons which makes trips to Fete at a rate of three to four times a week. As the population of the village is 2,060 persons, this is equivalent to 11.4 ℓ/day when converted into mean water consumption per head per day. The water rate charged is 10 cedies per bucketful (4 gallons) of water.

The quantity of water which each household purchases from GWSC seems to vary considerably depending on its economic condition. Since the villagers were unwilling to disclose information about their family budget, they could not be solicited to cooperate in our survey on the quantity of water purchased by each household. According to the estimate of one reliable inhabitant in Fete, the quantity of water purchased by a typical family, assuming a family size of 10 persons, is around 24 gallons a day, which is 10.9 ℓ/day when converted into per head per day consumption. This means that a family spends 60 cedis a day on purchasing water which is quite a heavy economic burden.

3.1.4 Needs for Safe Water Supply Facilities

It had been pointed out that diarrhoeal virus, an infection that had widely spread in the Fete Village, was attributable to drinking water. The bacteriological examination of water sources from 1983 to 1984 confirmed this, for quite a lot of coliform group and general bacteria were detected.

Every one of these water sources are either the open surface type wells or springs, which are easily susceptible to contamination via buckets or the human body at the time of drawing water. Not only that, the water in Dampraya and Aboan Wells, which are closest to the hamlets, is fissure water from the rock bed, and because its quantity is small and there are hamlets in their recharging area, it is quite possible that the ground water itself constitutes the source of contamination. Wells (I) through (V) which are 1.5 km away from the hamlets have run dry since the drought of 1983, so that the quantity of water available from them is instable and, what is more, their structure is such that surface water of the Osonko River can easily flow into the wells before it is adequately purified, so that the possibility of contamination from surface water is also conceivable.

As above, the water sources in the Fete area pose problems in both quality and quantity, and while Wells (I) through (V) continue to be dry, the villagers must depend on the water being carried from Accra by GWSC. The water from the water tank lorry, however, is not being distributed equally among the inhabitants. Instead, the purchasing of this water is proving to be a heavy economic burden for the inhabitants while the quantity being purchased by each family also varies greatly depending on its economic status.

Water supply and distribution through pipeline from Kwanyaku is not being carried out as scheduled either. Nor is it likely, under present conditions, that water will be supplied in the near future.

When we consider the poor domestic water supply conditions as described above, it is judged that if the spreading of water-based infectious diseases like diarrhoea is to be prevented, it is of the utmost necessity to secure safe water for domestic use from some tentative water source at least for the duration until water begins to be distributed through pipeline.

The test well survey this time has confirmed the occurrence of ground water which can be developed. The quality of that water is not good because it contains many dissolved components, but it is at least better than the water quality of the existing water sources and acceptable to the villagers as domestic water. This ground water is also judged to be uncontaminated by the coliform group and other bacteria which are the causes of water-based infectious diseases.

Therefore, should a problem of water quality be solved, this ground water must be sought as the source of domestic water in Fete, and as far as facilities are concerned it is necessary to install a well-structured system, precluding man and water from coming into direct contract with each other in order to preserve water quality.

3.2 Ashonman Area

3.2.1 Outline of the Target Area

Location : About 15 km north of Accra (Refer to Fig. 3.2.1)

Administrative division : Great Accra Region

Area : About 7 km^2

Tribe : Ga tribe (Chieften Aryee Anang)

Population : 41 families, 225 persons (as of December 1984) For age distribution, please refer to Table 3.2.1

Occupation of inhabitants : Mainly agriculture. Principal crops are cassava, yam, cocoyam, plantain, banana, etc. (Refer to Tables 3.2.2 and 3.2.3)

FIG. 3.2.1 LOCATION MAP OF ASHONMAN

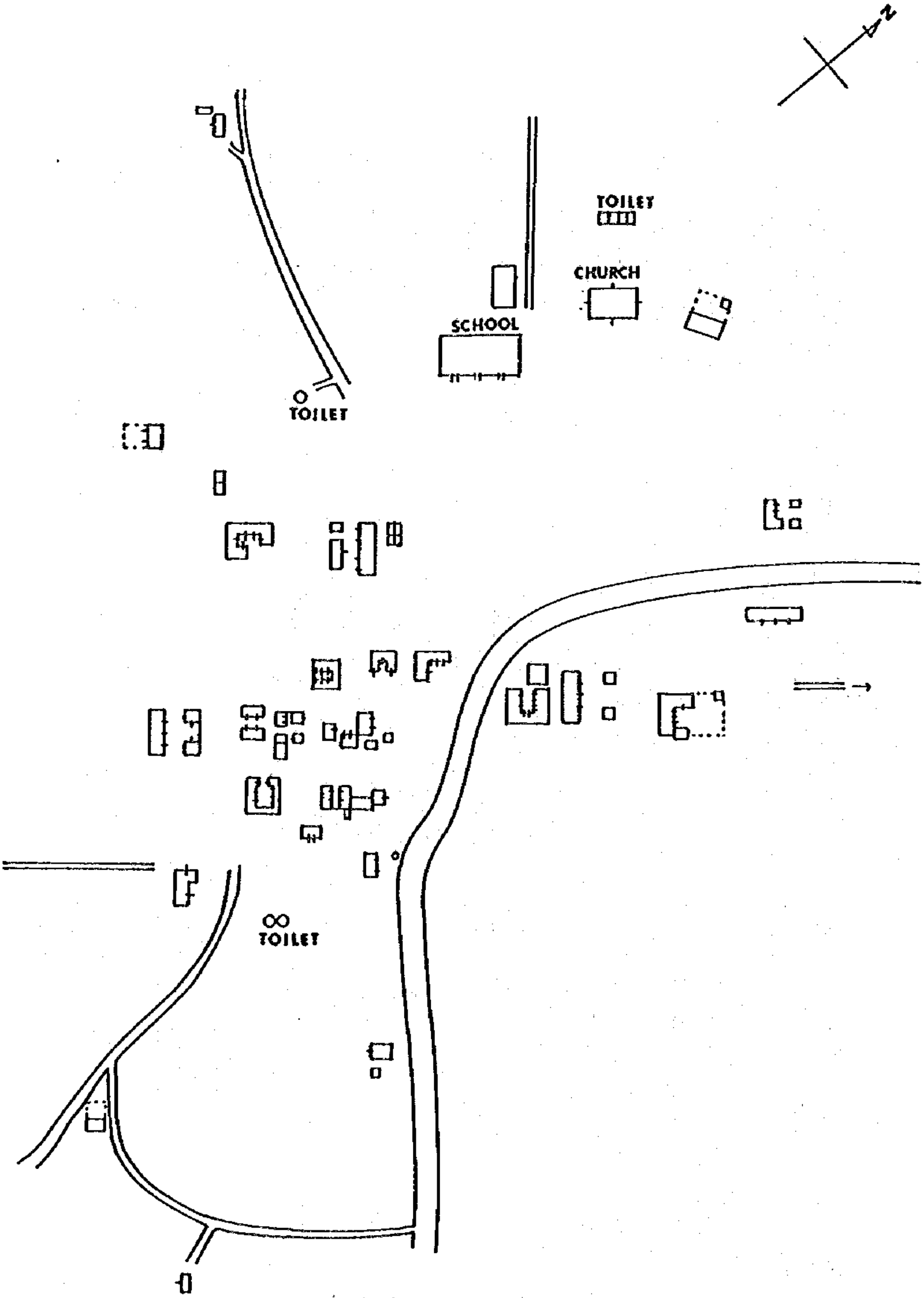


FIG. 3.2.2 ASHONMAN VILLAGE

Table 3.2.1 Classification of Males and Females by Age Ground in Ashonman Village

	MALE TOTAL VILLAGE	% TOTAL	FEMALE TOTAL VILLAGE	% TOTAL	TOTAL	% TOTAL
0-4	17	13.9	17	16.5	34	15.1
5-9	19	15.6	15	14.6	34	15.1
10-14	14	11.5	5	4.9	19	8.4
15-19	15	12.3	14	13.6	29	12.9
20-24	14	11.5	10	9.7	24	10.7
25-29	12	9.8	5	4.9	17	7.6
30-34	4	3.3	9	8.7	13	5.8
35-39	5	4.1	7	6.8	12	5.3
40-44	3	2.5	1	1	4	1.8
45-49	5	4.1	0	0	5	2.2
50-54	0	0	4	3.9	4	1.8
55-59	1	0.8	3	2.9	4	1.8
60-64	4	3.3	4	3.9	8	3.6
65-69	3	2.5	5	4.0	8	3.6
70-74	1	0.8	2	1.9	3	1.3
75-79	4	3.3	1	1	5	2.2
80-84	0	0	0	0	0	0
85	1	0.8	1	1	2	0.9
TOTAL	122		103		225	

Table 3.2.2 Economic Activities of Males 20 Years and over

MAIN ACTIVITY	NO. OF PERSONS ENGAGED IN.	SUBSIDIARY ACTIVITIES	NO. OF PERSONS ENGAGED IN.
FARMING	42	FARMING	11
TEACHING	2	MASONRY	2
CARPENTRY	1	CHARCOAL MANUFACTURING & SELLING	1 1
DRIVING	5	EVANGELIST	1
TAILORING	1	HERBALIST/FETISH	1
FARM ASSISTANT	1	CARPENTRY	1
BASKET WEAVING	1	HORTICULTURE	1
CATECHIST	1	AKPETESHIE MANUFACTURING	1
DRAUGHTMANSHIP	1	GOLDSMITHING	1
BLACKSMITHING	1	LABOURER	1
		BASKET WEAVING	3
TOTAL	56		22

Table 3.2.3 Economic Activities of Females 16 Years and over

MAIN ACTIVITY	NO. OF PERSONS ENGAGED IN.	SUBSIDIARY ACTIVITY	NO. OF PERSONS ENGAGED IN.
FARMING	35	TRADING	19
KENKEY SELLING	9	FARMING	7
TRADING	14	KENKEY SELLING	2
SEWING	1	BAKING	1
WARD ASSISTANT	1	SEWING	1
HOUSEWIFE	1	MIDWIFERY	1
LABOURER	1		
TOTAL	62	TOTAL	31

3.2.2 Hydrogeology

(1) Topography

The Ashonman area is a part of the Accra Plains (around 50 m in elevation). A mountain range (Akwapin Mountains) of around 200 m in elevation rises in its west and extends from northnortheast to southsouthwest.

The topography of these plains is very gentle with only slight undulations, but in the east and west of Ashonman village are lowlands with a northnortheast - southsouthwest strike. The difference in elevation between the village and the lowlands is around 3 to 5 m. The lowland on the west forms a very gentle slope - so gentle that it can hardly be called s slope - which seems to become inundated during the rainy season, and except for the stream (ONIASI) which originates from the spring which will be described later, there seem to be no other topographic depression in the form of a valley that seems likely to become a real stream. This lowland on the west side is covered with unconsolidated sediments which have generally turned into soil, and it is used as farmland by the Ashonman villagers.

On the other hand, the lowland on the east forms a valley which is even entered on the topographic map (on the scale of 1/62,500) published by the Government of Ghana. At the time of the survey during April and May, no surface water was recognized, but the valley has a fairly large catchment basin. This valley directly dissects the basement complex, and since only a little of the unconsolidated sediment is distributed in the area near Ashonman, it is left abandoned as wasteland.

(2) Geology

The southern part of Ghana consists of a Pre-Cambrian system which is classified into several formations from Buem-Formation to Dahomeyan. (Refer to Fig. 2.1) These formations are distributed in belt-form from northnortheast to southsouthwest, and the basement complex distributed underneath the Ashonman area is a Dahomeyan formation of the Lower Pre-Cambrian Period. The Akwapin Mountains in the west of Ashonman are framed by the Togo Series, which are mainly composed of metamorphic rocks such as quartzite and phyllite. The area including the Dahomeyan and Togo Series which is near the boundary forms a lowland. Its surface is covered with unconsolidated sediment, but fissures like fractured zones are believed to be penetrate beneath it.

The area in which Ashenman village is located rises 3 - 5 m above the surrounding lowlands, and the top layer is covered with lateritic soil of reddish brown color. This weathered zone however is thin, and abandoned quarries called TEBU are seen scattered everywhere around the village. Rocks indicating distribution of extremely hard siliceous acidic gneiss are seen outcropping in these TEBUs. The strike and dip of the schistosity of this acidic gneiss are mostly N40°E/30S and are approximately in agreement with the geological structure of this area.

(3) Meteorology

The climate of Ashonman area belongs to the same semi-arid coastal savannah as the coastal area of Accra, and the annual precipitation is relatively small at around 820 mm.

Rain gauge stations are installed at Pokoase which is about 8 km west of Ashonman and at Legon which is about 8 km southeast of Ashonman. Tables 3.2.4 and 3.2.5 summarize the rainfall data for the past 10 years.

Table 3.2.4 Monthly Mean Rainfall During the Past 10 Years
(Ashonman Area)

(Units in mm)

Month / Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Legon	7.4	24.3	56.1	87.5	147.4	156.3	74.3	27.5	45.1	74.0	33.5	16.5	749.9
Pokoase	10.2	43.3	61.9	70.1	154.2	173.0	65.2	45.9	71.6	114.2	68.0	16.7	894.3
Mean	8.8	33.8	59.0	78.8	150.8	164.7	69.8	36.7	58.4	94.1	50.8	16.6	822.1

Table 3.2.5 Annual Rainfall During the Past 10 Years
(Ashonman Area)

(Units in mm)

Year / Station	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Legon	857.6	610.2	556.7	* Above 644.0	* Above 804.9	935.6	794.8	846.5	389.6	917.0
Pokoase	984.5	773.4	714.8	987.4	* Above 1,061.0	1,273.2	948.8	* Above 736.5	445.8	* Above 687.6
Mean	921.1	691.8	635.8	-	-	1,104.4	871.8	-	-	-

* Unknown because some of the observation data is missing.

The rainy season is divided into the heavy rainfall season which is between April and July and the light rainfall season between September and October. The amount of rainfall is particularly large in the months of May and June during which heavy rainfall of more than 150 mm a month have been recorded.

The record on annual precipitation of the past ten years shows considerable dispersion. Particularly the amount of rainfall in 1983 was quite small, having been about half the mean annual precipitation.

The monthly mean temperature ranges between 26°C and 27.7°C, and the area is haracterized by the small changes in temperature throughout the year.

(4) Electric prospecting

Groundwater is considered to occur either in the unconsolidated sediments which generally have a large permeability coefficient, or in rock bed areas, in the weathered zone or fractured wherein cracks have developed. In the case of Ashonman area, the area which extends from a height on which hamlets are distributed down to the lowland which lies on its east is distributed with a relatively fresh rock bed with little cracks at shallow depths so that the occurrence of groundwater can hardly be expected.

Accordingly, electric prospecting with the target set on the analytical depth of 30 m to 50 m was conducted in the lowland which extends on the west of the village. The prospecting method employed was the Wenner's four pole method, and for analysis, Sundbery's standard curve and Hummer's auxiliary curve were used. Eight points were used altogether, five points of A-1 through A-5 in the lowland southwest of the village and three points, B-1 through B-3, in the lowland of the village. (Refer to Fig. 3.2.3)

(Results of prospecting along survey line A)

Point A-1 is closest to the village, and adjacent to this point is an old, abandoned pump well with a jammed pump. Point A-5 on the other hand is close by the woods where there is a spring.

The analytical results of prospecting along survey line A are as shown in Fig. 3.2.4, Geological Section by Resistivity Survey.

The geology can be classified into three strata in the light of the values of resistivity. The topmost stratum indicating $\rho = 6$ to $135\,\Omega$-m at a depth of 1.3 m to 2.7 m is considered to be clay-like layer in which the occurrence of groundwater is almost hopeless.

The middle stratum distributed to the depth of around 10 m is judged to be either a strongly eathered zone of siliceous acidic gneiss or unconsolidated sediments like sand, gravel, etc., and indicates a resistivity value which suggests the occurrence of groundwater. The acquifer which comprises the source of the spring near point A-5 is considered to correspond to this stratum. The resistivity value of this stratum is $\rho = 63 - 116\,\Omega$-m, and judging from its layer thickness, the areas around point A-3 and point A-5, are considered particularly promising for groundwater development.

The lowest stratum which generally indicates high resistivity values is judged to be unweathered rock so that the occurrence of groundwater can hardly be expected. In some parts, however, like at point A-1 near the old pump well and at point A-4, the resistivity is low at $\rho = 900 - 1{,}200\,\Omega$-m which strongly suggests that a fractured zone with well-developed cracks may be penetrating it locally.

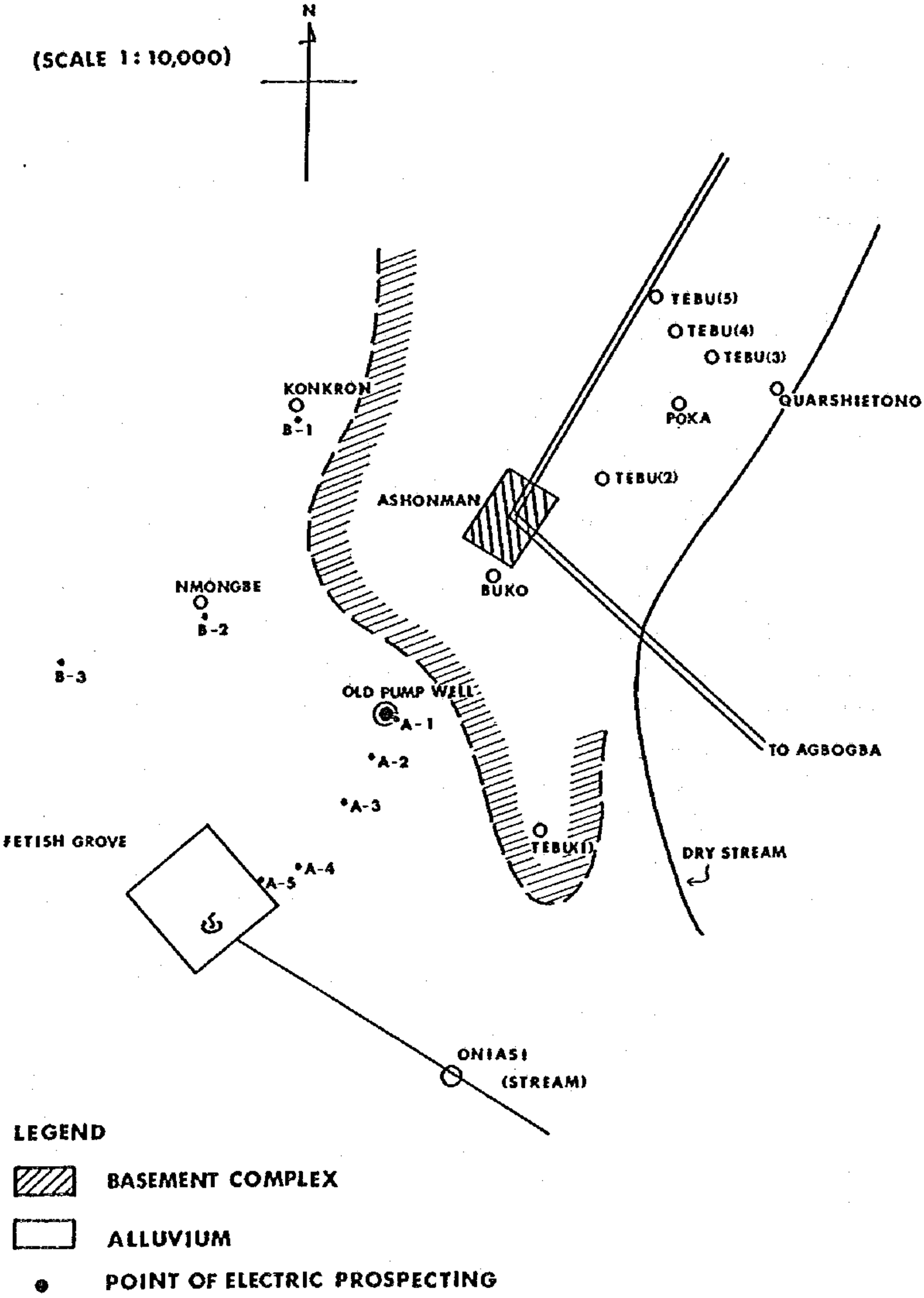


FIG. 3.2.3 ASHONMAN AREA

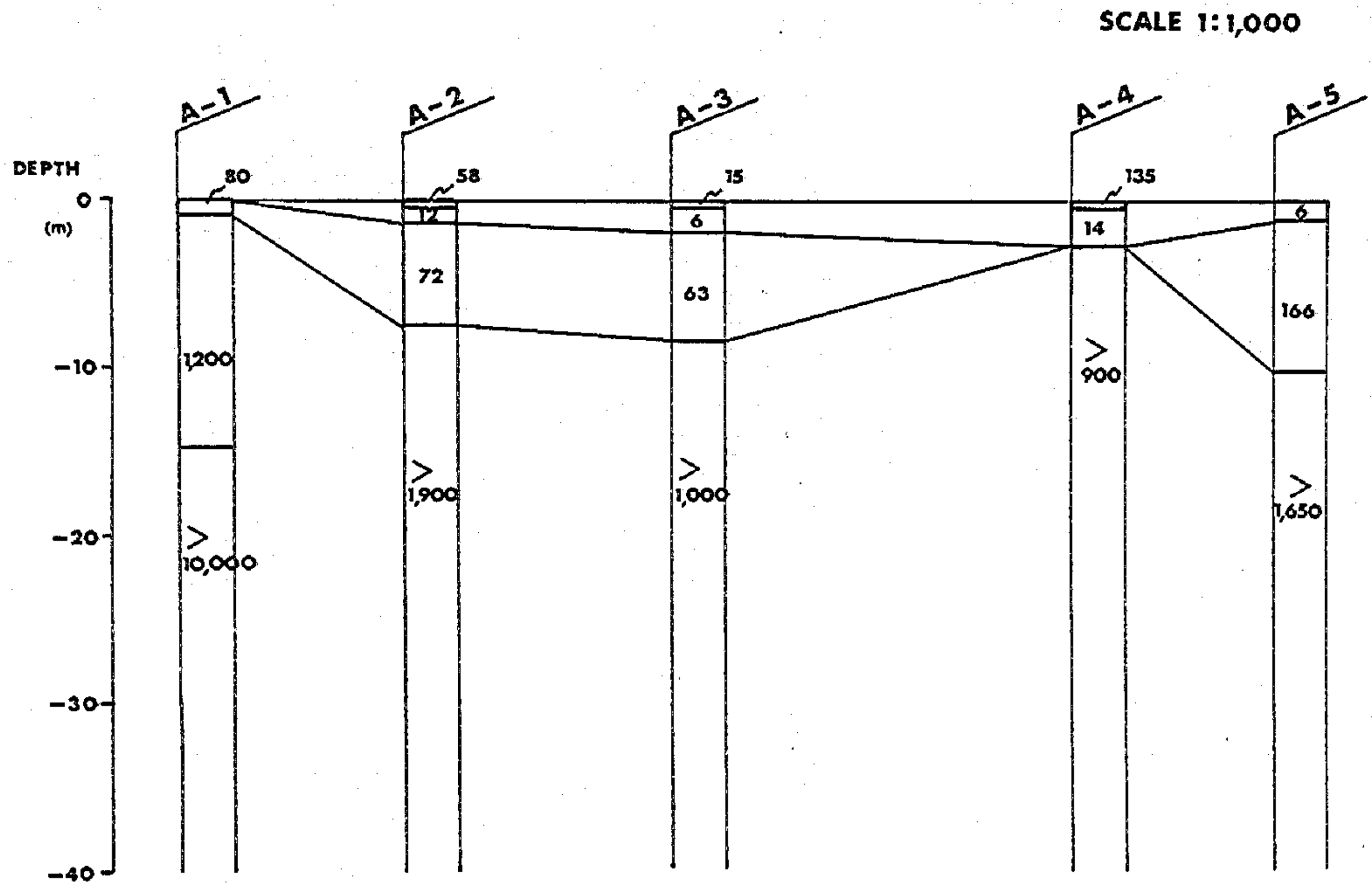


FIG. 3.2.4 GEOLOGICAL SECTION BY RESISTIVITY SURVEY AT ASHONMAN

(Results of prospecting along survey line B)

The analytical results of prospecting along survey line B are as shown below.

	B-1		B-2		B-3	
	Depth (m)	Resistivity (Ω-m)	Depth (m)	Resistivity (Ω-m)	Depth (m)	Resistivity (Ω-m)
1st stratum	0-0.5	20	0-0.82	37	0-0.42	53
2nd stratum	0.5-1.7	8	0.82-12.5	4	0.42-9.0	7
3rd stratum	1.7-10	32	12.5-	26	9.0-	17
4th stratum	10-	95	-	-	-	-

Along survey line B, layers of generally quite low resistivity values continue down into the deeper parts, which suggest that impermeable clay-like sediments are probably thickly deposited. Any stratum with a resistivity value high enough to suggest the existence of an acquifer could not be identified. The stratum that shows $\rho = 95$ Ω-m at a depth deeper than 10 m at point B-1 is considered to be the weathered zone of the basement complex.

(5) Mode of occurrence of groundwater

The acidic gneiss of Dahomeyan formation which is the basement complex of Ashonman area and the quartzite of Togo Series distributed in the Akwapin Mountains are classified as impermeable rock beds. This unweathered basement complex is distributed from a depth close to the surface layer in the village and int he lowland in its east so that the distribution of any aquifer is quite unlikely.

Meanwhile, as a result of electric prospecting conducted in the lowland which extends on the western side of the village, a stratum with a layer thickness of less than 10 m and satisfying the requirements for the occurrence of an aquifer was confirmed to be distributed at a depth of 10 m or less in the area around the spring of "Fetish Grove" in the southwestern side of the village. This stratum is probably either strongly weathered rock with developed cracks or partly intercalating alluvial basal sand and gravel layers. As this area happens to correspond to where the boundary lies between Dahomeyan and Togo Series, the distribution of fissures originating from the fractured zone full of cracks is also conceivable.

Considering that aquifer was found distributed only along survey line A where electric prospecting was conducted and not along survey line B, it is more proper to consider this quifer as being a localized structural crevice rather than as one widely distributed in the lowlands on the western side.

Also, we are told that the quantity of water from this spring is approximately constant throughout the year regardless of the rainy season or the dry season. It is therefore probably subsoil water and not surface water or groundwater which is directly affected by the amount of rainfall. In other words, the extensive area that lies west of the village and which includes the Akwapin Mountains is where the groundwater is built up.

3.2.3 Household Water Situation

(1) Conditions of existing water sources

The sources of household water in Ashonman area can be broadly classified into the reservoirs which collect meteoric water, and groundwater.

In Table 3.2.6, the reservoirs were grouped into A and B. All of TEBU (1) through (5), POKA and QUASHIETONO which were grouped as A are the caves of abandoned quarries of roadbed aggregates which had been operating in the early 1960s, and geologically they are located in the rock bed zone distributed with lateritic soil in the surface layer. As for distance from Ashonman village, TEBU (2) is only 150 m away, but the other reservoirs at the abandoned quarries are about 500 m from the village. The capacity of each reservoir is around 500 m^3.

On the other hand, the reservoirs grouped as B are at BUKO, KONKRON and NMONGBE. These reservoirs were artificially built in the lowlands distributed with unconsolidated sediments and had served as the precious water sources for the villagers since long before the Group A reservoirs came into use. The capacity of every Group B reservoir is smaller than any of the Group A reservoirs, being around 100 m^3 each. As for distance from the village, BUKO is the closest, being located about 100 m from the village while the others are about 500 m away.

As for groundwater, there are woods of 200 m square at about 1 km southwest of the village, and in the woods is a spring from which groundwater wells up. These woods are known as "Fetish Grove" to which human access is tabooed. The water from this spring forms a waterway and flows southeast. At about 1,050 m south of the village is a spot called ONIASI which is where this water can be taken in. The daily discharge is said to be approximately constant regardless of the rainy season or the dry season. On April 27, it was about 2,000 m^3/day.

We were told of the existence of a spring called TENSHIE near NMONGBE but due to lack of precise information as to location and other details we were unable to identify it.

There is also a well with a jammed pump (Old Pump Well) in the lowland about 400 m southwest of the village. This pump, which was made in England, is now abandoned because its parts were unobtainable in Ghana. This well was drilled by an Englishman in 1958 and had been in use until the packing of the pump failed in 1983. Since the wellhead is closed at present there is no way of knowing what the condition is like inside the well, but it is presumed to be a well 10 cm in diameter drilled by a boring machine.

While the pump was in operation prior to 1983, it is said to have supplied the villagers with adequate water.

Table 3.2.6 List of Water Sources Available at Ashouman Area

No.	Name	Destance from village (m)	Kind	Shape, capacity, etc.	Purpose of use	Condition when surveyed	Remarks
1	TEBU (1)	550	Reservoir A	15 m x 25 m x 3 m 15,600 m^3	All purpose household water	Water depth 0.1 - 0.2 m as of April 27	For bathing and washing during April when water level is low. No water during January - March
2	(2)	150	"	-	"	No water	
3	(3)*	(450)	"	Larger than TEBU(1)	"	Water available; in use	Current water level higher than TEBU (1)
4	(4)*	(450)	"	Smaller than TEBU(1)	"	Water available; in use	
5	(5)*	(500)	"	Smaller than TEBU(1)	"	Water available; in use	
6	POKA	(400)	"	Oval shaped, 10 m x 25 m x 2.5 m (depth)	"	Water depth, several tens of cm as of April 13	
7	QUARSHIETONO *	(550)	"	About the same capacity as POKA	"	Water available; in use	
8	BUKO	100	Reservoir B	About 80 m^3	For bathing and washing	0.5 m as of April 13	Water level drops during dry season but water is always available.
9	KONKRON	450	"	Oval shaped, 3 m x 5 m x 20 m (depth)	All purpose household water	1.5 m as of April 13, no water as of April 27	Water is always available according to the villagers but no water on April 27.
10	NMONCBE	550 - 600	"	10 m x 10 m x 2 m (depth)	"	Water depth 0.8 m as of April 27	No water in January - February
11	ONIASI	1050	Flowing water	Discharge about 2,000 m^3/day	"		Constant discharge throughout the year. During draught season, people living 2 - 3 miles away come for water.
12	OLD PUMP WELL	400	Well	Well diameter 10 cm, depth unknown	-	Pump out of order	Constructed by an Englishman in 1958 and was operating until two years ago.
13	TENSHIE	Unknown	Spring	-	-	Overflows if unused	Said to be near NMONCBE but its location unidentified.

Notes: *: Estimated. Reservoir A is the cave at the abandoned quarry of aggregates (around 1959).
Reservoir B was dug by human labor.

(2) Water quality of existing water sources

Water quality tests were performed at the water surces in Ashonman area, the results of which are as shown in Table 3.2.7.

According to visual observation of the condition of each water source, the water which was either green in color or unclear due to suspended mud suggested the mingling of a large amount of impurities in all reservoirs. The water of ONIAI, on the other hand, was clear and even small fishes were found to be living in it.

Electric conductivity shows the quantity of dissolved constituents contained in water. In the reservoirs, its values were in the range of EC = 100 - 400 μs/cm which are relatively small compared to the 715 μs/cm of ONIASHI.

However, the analytical results of total iron and ammonia in reservoir waters were 4 - 5 ppm or more for total iron and 0.6 - 4 ppm for ammonia whereas the water of ONIASI indicated quite small values of 0.1 ppm for both.

Both escherichia coli and general bacteria are contained in large amounts in every source of water so that none of them are quite satisfactory in quality of water, but when the degree of discoloration of test paper was compared, the water of ONIASI was found to be the most hygienic of all. The water from ONIASI was sampled at a point about 500 m away from the origin of spring and it probably became contaminated by the bacteria contained in the soil during the course of its flow.

As above, stagnant water is inferior to the water of ONIASI both chemically and biologically.

Table 3.2.7 Water Quality in Ashonman Area

Name	Kind	Test date	Temperature (°C)	Hydrogen ion Concentration (pH)	Electric conductivity (μs/cm) at 20°C	Total iron (ppm)	NH4 (ppm)	Escherichia coli	General bacteria	Others
TEBU(1)	Reservoir	Apr. 27	28.7	-	411	-	-	-	-	Green in color
POKA	Reservoir	Apr. 13	36.4	7.4	181	4	0.6	Totally colored; unsuitable	Totally colored; unsuitable	Slightly brownish
BUKO	Reservoir (for bathing)	Apr. 13	29.7	-	244	-	-	-	-	Green algae have occurred
KONKRON	Reservoir	Apr. 13	29.4	6.4 - 6.6	281	above 5	4.0	Totally colored; unsuitable	75% colored; unsuitable	Opaque due to mud
NMOGBM	Reservoir	Apr. 27	35.4	-	103	-	-	-	-	Yellowish green in color
ONIASI	Surface water from spring	Apr. 27	29.2	7.4	715	0.1	0.1	60% colored; unsuitable	Discolored in a speckled pattern	Transparent with small live fishes

* Escherichia coli and general bacteria qualitatively analyzed with test paper.

(3) Water consumption by inhabitants

For the purpose of grasping the amount of water consumption of the inhabitants n Ashonman area, four families were interviewed.

Interview Survey on the Status of Water Consumption
in Ashonman Area

	Family size	Water consumption	Water consumption per head per day
Family A	17 persons	300 ℓ/day	17.6 ℓ/day
B	10 persons	Drinking: 23.8 ℓ/3 days	13.1 ℓ/day
		Cooking, bathing, etc.: 107 ℓ/day	
C	12 persons	Drinking: 90.9 ℓ/4 days	11.0 ℓ/day
		Cooking, bathing, etc.: 218 ℓ/2 days	
D	4 persons	Drinking and cooking only: 109 ℓ/7 days (Bathing and washing done at the reservoir)	3.9 ℓ/day
		Average for the three families of A, B and C	13.9 ℓ/day

Every household generally separates the water for drinking from the water for cooking and bathing. On the whole, the average amount of water consumption per head per day is presumed to be 13.9 ℓ /day.

(4) State of the use of water

Altogether 12 existing sources of water may be counted in Ashonman area, of which BUKO reservoir, which is nearest to the village, is exclusively used for bathing and washing while the water of the other 11 sources is for drinking and cooling.

Water usage prior to 1983, when the old pump well was still in operation, is described below.

1) During the wet season from May to September or December, the water from the reservoirs in the vicinity of the village was used.

2) When the quantity of water in the reservoirs decreased, the water from the old pump well was used.

3) Surface water from ONIASI was seldom used as it was too far away.

The following lists the different waters in the order of the villagers' preference.

1) Wellwater from the old pump well

2) Surface Water from ONIASI

3) Water from reservoirs

4) Water from the spring of Tenshie

It is clear from the foregoing data obtained by interview survey, that the water sources for bathing and washing are clearly distinguished from those for drinking. However, when the state of use of all household water is reviewed, we see that it is not necessarily in agreement with the preference of the villagers. Their preference and sense of hygienity carry only small weight whereas the weight of labor looms large. In other words, for the women and children of the village the scooping of water and carrying it home, which happens to be their job, is a heavy workload and this seems to have resulted in their preference for the reservoir which requires less work.

3.2.4 Needs for Safer Water Supply Facilities

With 10 reservoirs distributed around the village and surface water (ONIASI) which never dries up being available at a place 1 km away as are the sources of water for the Ashonman area at present, the village is comparatively well endowed insofar as the quantitative aspect of water supply is concerned. However, all these water sources contain much escherichia coli and general bacteria which are proving to be the cause of diarrhoca, an infectious disease communicated through water, so that the water from these sources cannot be claimed to be safe as household water.

The water of the reservoir which is the most frequently utilized by the inhabitants is the rainwater which has been collected from the ground so that it is susceptible to contamination by the bacteria contained in the soil. Furthermore, as the villagers use a bucket or such-like to scoop water from the reservoir while their feet are immersed in the water due to the fact that the reservoir is gently sloping at the bottom, the water source has every chance of becoming contaminated by both bucket and feet. In the case of the surface water of ONIASI, too, it is likely to become contaminated even before it reaches the point of intake which is 500 m away from the spring.

Thus, as far as the water sources, as concerned, it is desirable to develop groundwater which satisfies the requirements of safe water in terms of both quantity and quality. Concerning structure of the water supplying facilities, one which does not open the water source, a structure which severs contact between water source and people and animals is required.

Fortunately, in Ashonman area, there is a well with a jammed pump at a place about 500 m away from the village, and since this well is said to have been supplying water satisfactorily to the inhabitants in terms of both quantity and quality until 1983 when the pump went out of order, it should be able to supply safe water to the villagers if installed with a new pump.

The inhabitants of Ashonman tend to prefer the use of the reservoirs to spare themselves of the labor of pumping, but it is judged that the broken pump ought to be replaced on the condition that the villagers be educated in the hygienic use of water and the use of groundwater at least for drinking.

As a result of negotiations held by UNICEF and GWSC late June, it was decided to include the pump replacement work of the old Pump Well in the Rehabilitation Project of the existing wells being implemented by the UNICEF (Refer to 2.2).

The inspection of the wells and the water quality test, as well as the installation of the hand pumps, will be carried out in an early date under the supervision of the person in charge of the UNICEF project of GWSC-Kumasi, with the expenses borne by UNICEF.

That being so, it is regarded as better to entrust the whole project for supplying potable water in the Ashonman area to the UNICEF project.

CHAPTER 4 WATER SUPPLY FACILITIES PLAN

4.1 Basic Policies for the Project

Upon an overall study of the characteristics of the project areas, national scheme, prevalent state of water use, local hydrogeological conditions and other relevant factors, it has been decided that the water supply scheme in Ashonman area shall be carried out as a UNICEF project.

Should a problem of water quality be solved, the basic policies for the water supply project in the Fete area would be represented as follows.

1) Until the time that distribution of water shall be implemented through pipe, a tentative water source of a quality acceptable to the inhabitants of Fete area shall be secured.

2) The water source shall be ground water and be supplied from shallow wells of 30 m in depth.

3) The wells shall be of the closed type to prevent pollution from external sources, and pumps shall be installed as the water lifting equipment.

4) The pumps shall be of simple and durable design in consideration of cost and ease of operation and maintenance.

5) Maintenance and administration of facilities shall be undertaken by the beneficiaries and GWSC.

6) Construction materials shall be procured locally as a rule, but those which are difficult to procure locally, such as pumps, shall be procured from sources outside of Ghana.

4.2 Design Criteria

(1) Estimated population to be supplied with water

Since the water source is only tentative, the present population of 2,060 persons in Fete area was deemed as the estimated population to be supplied with water.

(2) Estimated quantity of water supply

Because of economic reasons (domestic water must be purchased from the water tank lorry of GWSC), the inhabitants of Fete area consume only about 11 ℓ/day/head of water which is the bare minimum for them.

Although the distance that the inhabitants of Ashonman have to walk to the water platform is only about 500 m, they consume only about 13.9 ℓ/day/head because the work of carrying water is hard on them. Considering that the candidate site for water source development in Fete area is about 1.5 km away from the center of the village, it is judged unlikely that their water consumption will exceed the virtual unit water consumption of the inhabitants of Ashonman area.

GWSC also reports that the actual record of water consumption of the inhabitants in local areas ranges between 13.5 and 22.5 ℓ/day/head.

Under this project, the original intent of which is to secure the minimum amount of safe drinking water for the inhabitants, the quantity of water to be supplied per head per day was determined to be 14 ℓ in consideration of the aforestated conditions.

The daily quantity of water that will be supplied in the Fete area as a whole is therefore 28.84 m^3/day.

(3) Water quality

Ground water in and around the Fete area generally has a high salt concentration and therefore cannot be claimed to be a water source of good quality. Accordingly, the consent of the inhabitants must be obtained prior to developing a water source.

To prevent water pollution, the wells will be closed in construction, but to be doubly sure, disinfectants such as bleaching powder shall be kept on hand.

4.3 Selection of Water Source

(1) Water source development area

Based on the results of hydrogeological survey, the alluvial plain on the right bank of the Osonko River about 1.5 km westnorthwest of Fete Village was determined as the area in which water source should be developed.

(2) Discharge per well and number of wells

The discharge per well was established on the basis of the pumping capacity of hand pump currently adopted by GWSC as follows:

Assuming 10 hours of pump operation a day based on a pumping rate of 800 - 1,000 ℓ/hour, a discharge of at least 8 m^3/day of water can be safely estimated.

In view of the fact that 28.84 m^3/day of water supply is required, four wells will be needed with the average discharge per well being calculated to be 7.21 m^3/day.

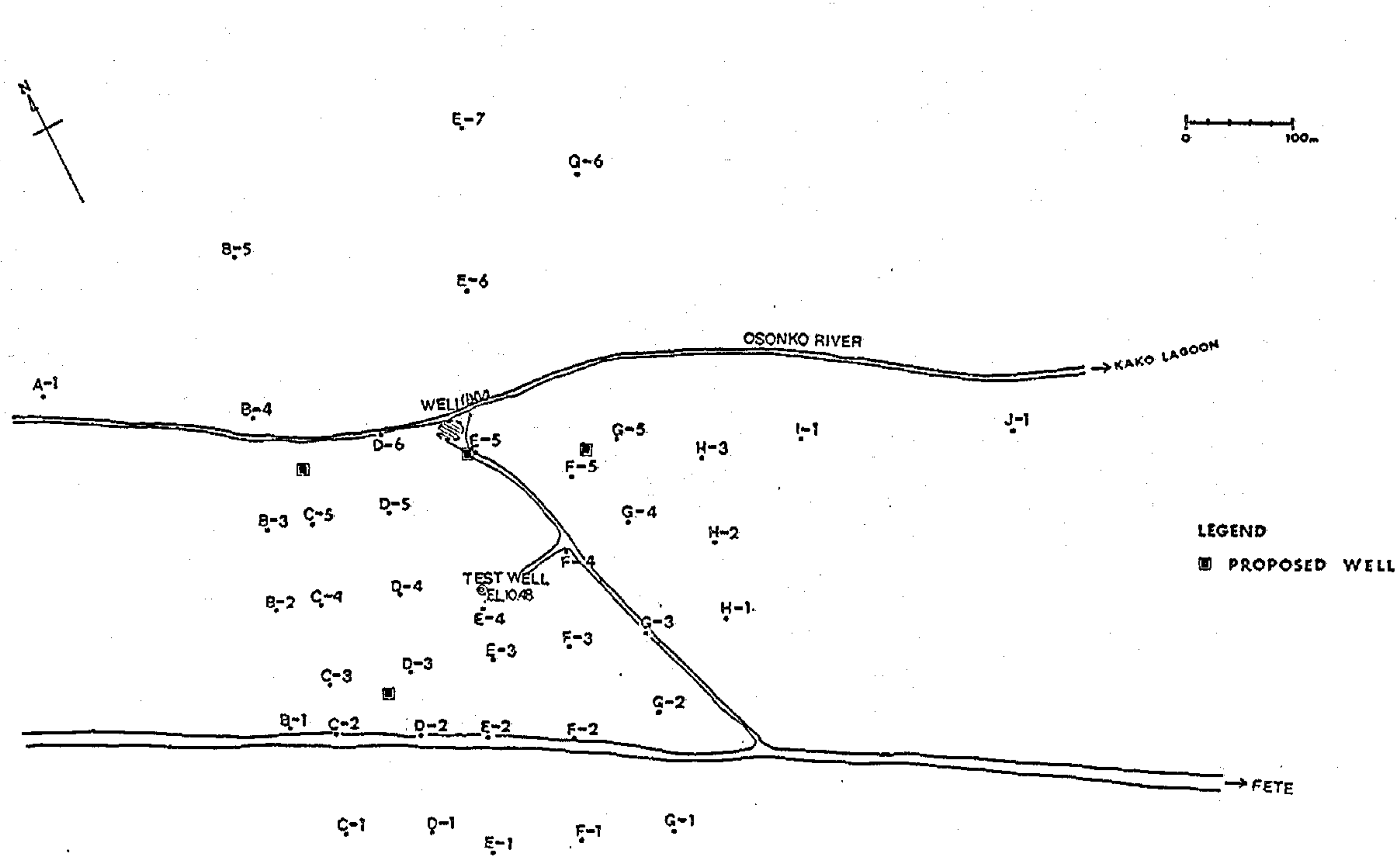
(3) Selection of well sites

Of the four wells, one will be the test well drilled in the current survey. The other three will be newly drilled.

The candidate sites of the new wells were selected as shown in Fig. 4.3.1 with due consideration to the following:

1) that the ground water has not turned into saline water.
2) that aquifer is thickly distributed.
3) that wells shall be arranged so that they do not interfere with each other as to cause abnormal drawdown.
4) that wells are located close to Fete Village.
5) that wells shall be located on the right bank of the Osonko River.

FIG. 4.3.1 LAYOUT OF PROPOSED PRODUCTION WELL



(4) Verification of pumping conditions

The trend of well water level was estimated on the basis of hydraulic constants obtained by pumping test of the test well.

The conditions for estimation are as follows:

Pumping rate $Q = 7.21\ m^3/day$

Coefficient of transmissibility $T = 2.59\ m^2/day$

Coefficient of storage $S = 1.50 \times 10^{-1}$

Radius of well $r = 0.075\ m$

By substituting the above conditions into the Theis' non-equilibrium formula, the following relationships hold:

$$s = \frac{Q}{4\pi T}\ W(u) = 0.222\ W(u) \qquad (1)$$

$$u = \frac{S \cdot r^2}{4 \cdot T \cdot t} = 8.14 \times 10^{-5} \qquad (2)$$

wherein s: drawdown (in m)

W(u): the well function obtained from the relationship with u.

Drawdown of well water after continuous pumping operation of 1 day, 30 days (one month), 180 days (6 months) and 365 days (one year) respectively was estimated on a trial basis from equations (1) and (2) as shown in Table 4.3.1.

Table 4.3.1 Continuous Pumping Operation Time and Drawdown

Continuous pumping operation time t (days)	u	W(u)	Drawdown s (in m)
1	8.14×10^{-5}	8.9	1.98
30	2.71×10^{-6}	12.1	2.69
180	4.52×10^{-7}	13.5	3.00
365	2.23×10^{-7}	14.2	3.15