Problems Of Rural Water Supplies In A Developing Economy: Case Studies Of Anambra and Imo States of Nigeria

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ABSTRACT

Over 75% of the population of Anambra and Imo States live in rural communities and this is projected to remain so until the end of the century. Most of these rural communities do not have modern water facilities. They depend on traditional sources that are generally of questionable quality, insufficient quantity and often liable to seasonal failures. Waterborne diseases, sometimes in an acute form, are therefore endemic in many of the rural areas. In order to solve this problem, a reliable and consistent low cost water supply scheme based on the available water resources in the communities must be designed and constructed. In this study three types of such schemes are developed. The first uses rainwater, the second, surface water, and the third relies on ground water. Areas where each of these schemes may be developed have been indicated. Comparative cost analysis indicates that schemes using ground water have a cost advantage over those using rainwater or surface water. It also shows that boreholes equipped with handpumps or improved/sanitary wells are more economic than those with motorized pumps for rural populations of less than 2,000 inhabitants.

INTRODUCTION

The bulk of the population of Anambra and Imo States, comprising most of the rural communities, depends on supplies of water sources that may be far or near, of questionable quality, insufficient quantity and that may often be liable to seasonal failures. Waterborne diseases, sometimes in an acute form, are therefore endemic in many of the rural areas.

These disturbing factors of poor and inadequate water supplies and other features of underdevelopment have attracted the attention of successive governments. The present state and federal governments lay strong emphasis on rural development. Hence, rural development ranks high in national planning and development programmes. A Directorate of Rural Development has been created to design and construct development projects at the rural level. This Directorate is supposed to take over some of the functions of the River Basin Authorities which performed these duties in the past. However, although rural roads and electricity projects have been initiated and pursued with vigour by national and state governments as well as private agencies, one has yet to see a consistent rural water scheme or any organized and long-term planned water resources programme. The emphasis so far is on programmes for urban areas.

Rural development ranks high in national planning and development programmes.

This paper critically assesses the alternative water supply schemes that could be embarked upon in rural areas, and discusses the relative social and economic advantage of each of these schemes. The primary objective is to aid water resources planners in developing a basic framework from which to select appropriate and consistent water schemes for the rural communities in Imo and Anambra states in particular and Nigeria in general.

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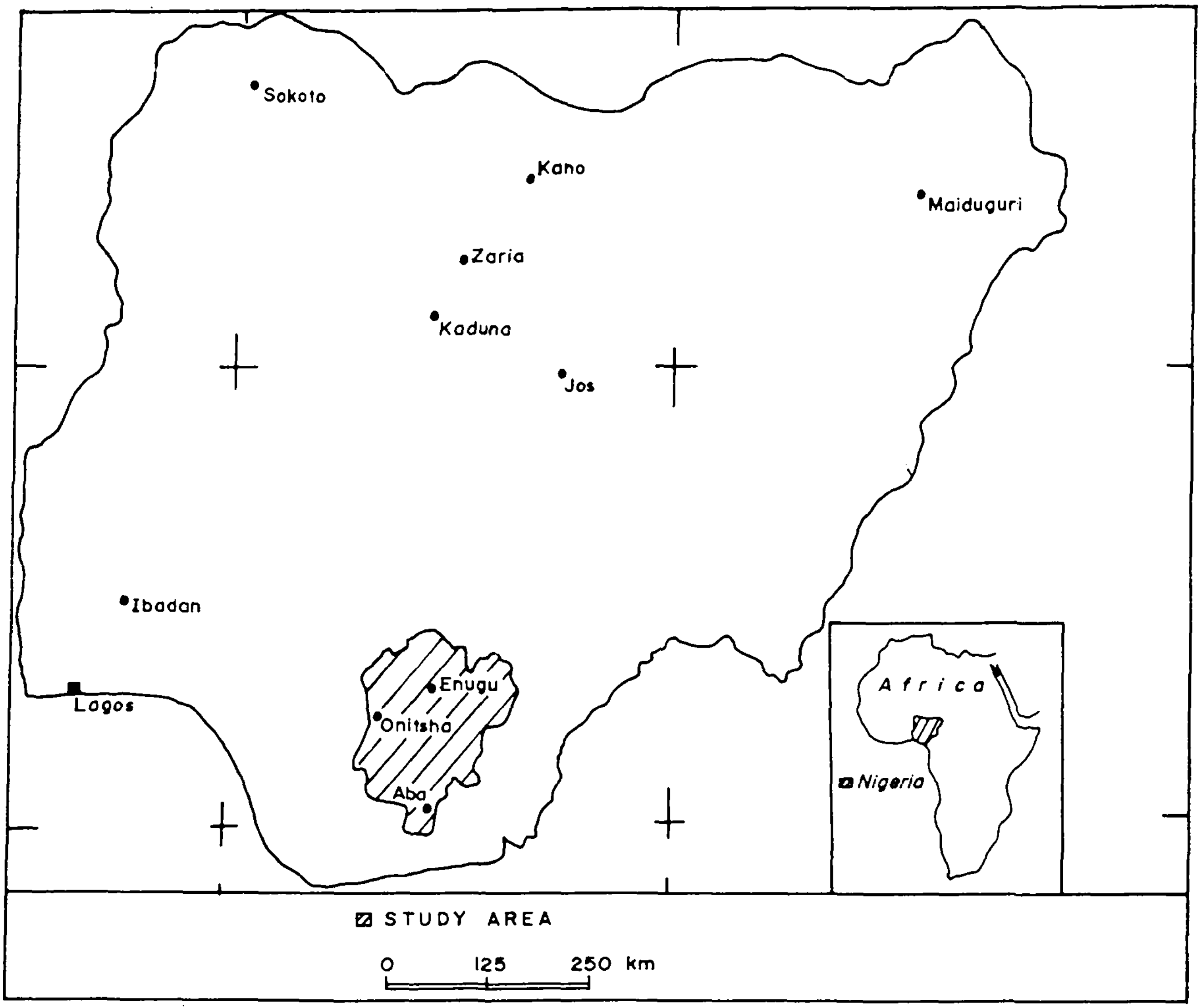

Figure 1. Location map of studied area (insert shows the location of Nigeria in the African Continent).

DEFINITION AND DISTRIBUTION OF RURAL COMMUNITIES IN ANAMBRA AND IMO STATES

The definition of rural communities varies from country to country. In some developing countries what constitutes a rural community often varies from one government to the other. Generally, the principal factors considered are the economic activities and population of the communities. According to a United Nations demographic Year book for 1970, rural communities have population ranging from less than 500 to about 30,000. The predominant economic activities in these communities are production of food and raw materials. In this study, rural communities have been taken as those with populations less than 20,000 and whose inhabitants are mostly peasant farmers and fishermen. Such people are usually not expected to support social services on an economically viable basis.

There are more than 2,000 rural villages scattered throughout Anambra and Imo States. Figure 1 shows the location of these states in Nigeria and the African Continent and Fig. 2 shows the approximate areal distribution of the more populous rural communities ($\geq$ 5,000 inhabitants) in Imo and Anambra states. The smaller ones could not be located due to the scale of the map used. The population of the communities in Imo State is given in Table 1. The figures are based on the 1963 census and an annual growth rate of 2.5%. For immediate planning purposes, projections for the year 1990 are of greatest importance. The table shows that over 85% of the Imo State population of about 5.6 millions live in rural communities and this is pro-

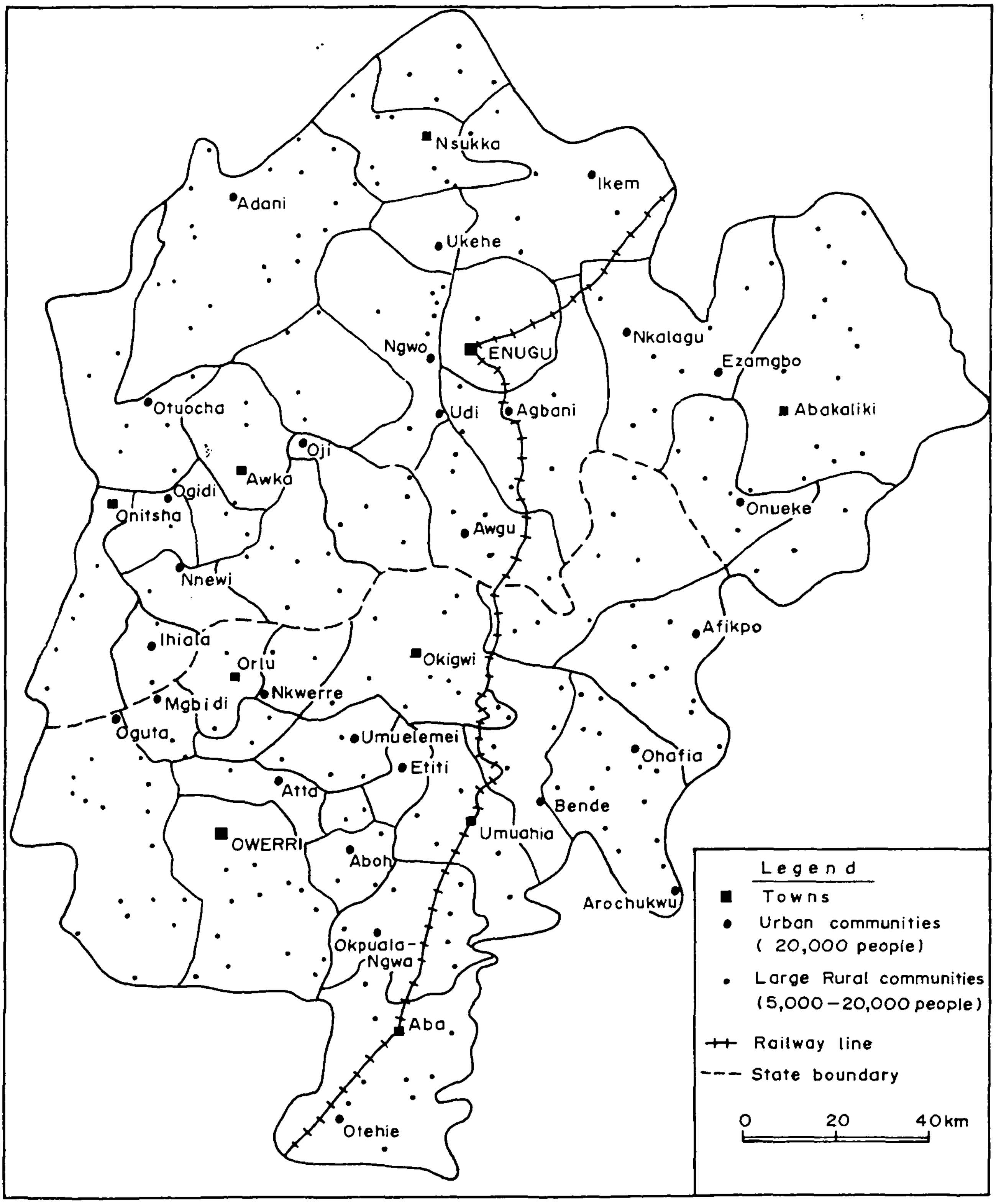

Figure 2. Distribution of rural and urban communities in Anambra and Imo States.

jected to remain approximately so till the end of the century. Population for Anambra State is similar to that of Imo State.

Table 1: Community population in Imo State

Community Population	Number of Communities		Total Population	
	1985	1990	1985	1990
20,000 (Percentage)	39 (3.45)	45 (3.98)	830,000 (14.72)	957,600 (15.0)
10,000-20,000 (Percentage)	148 (13.07)	155 (13.69)	1,650,000 (29.26)	1,955,000 (30.64)
2,000-10,000 (Percentage)	385 (34.01)	391 (34.54)	2,452,800 (43.49)	2,773,000 (43.46)
2,000 (Percentage)	560 (49.47)	541 (47.79)	707,200 (12.54)	695,542 (10.91)
Total	1,132	1,132	5,640,000	6,381,142

PHYSIOGRAPHY AND GEOLOGY

Two major cuestas characterise the regional relief of Imo and Anambra States. The first is the N-S trending Ukehe-Enugu Okigwe-Arochukwu cuesta while the second is the more subdued NW-SE trending Abagana-Okigwe cuesta. The two cuestas intersect at Okigwe and generally rise to about 330m above sea level and 150 to 200m above the surrounding plains. The terrain between these major relief features comprises dissected ridges and isolated hills. Generally the landscape rises gradually from the south (Aba) toward the north (Nsukka).

The two major relief features outlined above control the drainage in the two states. Three main river systems, the Niger, to the west, Cross River to the east and Imo River to the south, drain the area. The watershed between these river systems is an inverted Y-shaped figure corresponding to the crests of the two intersecting cuestas. The drainage in the area contained in the obtuse angle between the stem and the western arm of the inverted Y goes to the Niger while that within the obtuse angle to the east is to the Cross River. The area between the intersecting arms encloses the drainage basin of the Imo River [1].

Anambra and Imo States are underlain by a sequence of sedimentary rocks intruded in some parts by dolerite and more basic rocks. Figure 3 shows the surface distribution of the geologic formations in the area. The rock formations generally fall into 2 groups; the Cretaceous and Tertiary formations. The Cretaceous formations comprise the Asu River Group (Albian and the oldest sedimentary formation in the area), Eze-Aku Formation (Turonian), Awgu Shale (L. Senonian), Nkporo Formation (Cenomanian), Mamu Formation (L. Maestrichtian), Ajali Sandstone (M. Maestrichtian) and Nsukka Formation (Upper Maestrichtian). These formations are composed mostly of shales, argillaceous sandstones, limestones and thin coal seams. The Asu River Group and Eze-Aku Formation are intruded into by dolerite sills and dykes and this has given rise to intense fracturing of rock units of these formations especially in the vicinity of the intrusions. The Ajali Sandstone is the only dominant sandy formation within the Cretaceous group and has been extensively tapped by water wells.

The Tertiary formations include the Imo shale (Paleocene), Ameki Formation (Eocene), Ogwashi/-Asaba Formation (Oligocene to Miocene) and the Benin Formation (Miocene to Recent). The Imo Shale is dominantly argillaceous, the Ameki Formation is made up of intercalations of shale and argillaceous sandstones while the Ogwashi/Asaba and Benin Formations are dominantly sandy sometimes with more than 80% of sandstone units. The outcop of areas of the Ogwashi/Asaba and Benin Formations are intensively penetrated by water wells.

RURAL WATER SCHEMES

Rural Water Supply Schemes are those that are designed to supply water to the rural communities. There are three main types of water supply schemes that may be developed for any community whether urban or rural. These are rainwater interception scheme, surface water scheme and ground-water schemes. The selection of any of these schemes for a particular area depends on the type of water resources available in that area and the relative cost of developing the resources (i.e. the unit cost per user of water).

Rainwater interception scheme involves the interception and storage of rainwater for use during the dry months. This scheme may be economic for individual households but the design and construction of interceptor networks that can serve small communities is rigorous and costly. Even where individual households are provided with storage tanks, it may be difficult to operate the rainfall scheme at a sufficient sanitary level.

The surface water scheme involves the impoundment of streams and rivers or direct extraction of water from big rivers, freshwater lakes and oceans and the treatment of the water to remove objectionable constituents. The marked difference in the initial costs of developing large surface water schemes relative to ground water (as would be established later) makes the scheme unattractive for rural communities. Sometimes it is possible to persuade communities to use local labour to construct relatively cheap impoundment structures on small permanent streams at close proximity to the communities. This could make such surface schemes attractive economically. Also the availability of the surface water resource is known at all times

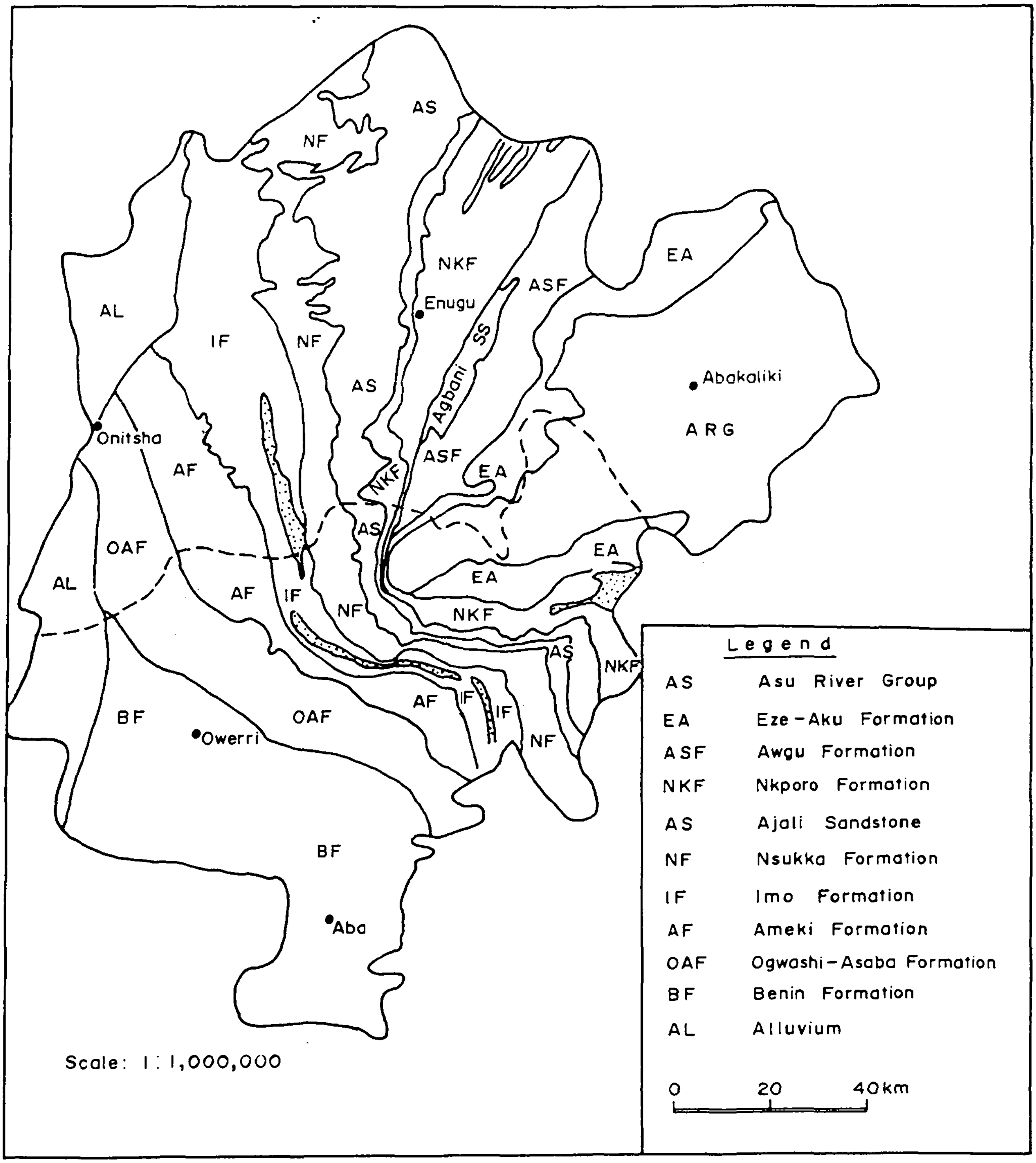

Figure 3. Geologic map of Anambra and Imo States.

and its handling is almost permanently under control. These advantages often outweigh the cost disadvantage especially for large s le water supplies to urban areas or for irrigation purposes.

The ground-water scheme comprises schemes in which the supply source is ground water. It may be divided into pipe-borne system and non-pipe-borne system. The pipe-borne system uses a distribution network of pipes to reach the individual users whereas the non-pipe-borne system supplies directly to the users without any distribution network.

Pipe-borne water supply systems based on ground water are developed either for individual communities or for a number of communities under one supply area. Such a system comprises one or more boreholes (8 to 10 inches diameter) with electric submersible pumps or diesel driven reciprocating pump and an appropriate distribution network that serves the community through public standpipes. There may however be a few households which would have direct connections. The practice of connecting households directly from the central network is good for public health considerations and it also facilitates water revenue collection.

The U.N.O. recommended minimum amount of water necessary to maintain life is about 200 liters per capita per day. However for the rural communities in Nigeria, 100 liters is enough to cover the needs of an individual, including the requirements of the small animals raised by the household. Depending on the characteristics of the target aquifer, a borehole with motorized pump can yield $20m^3hr^{-1}$ to over $100m^3hr^{-1}$ in Anambra and Imo States. Assuming a borehole is operated for 8 hours daily (8 hours is the daily working period in Nigeria) a borehole can thus supply water to at least 1600 people. Communities of this size or more should therefore be the target for the pipe-borne schemes based on ground water.

There are three main types of non-pipe-borne systems that characterize ground-water development. The first consists of boreholes equipped with hand operated pumps or windmills. These boreholes are preferably located in close vicinity to the villages and it is desirable to provide at least one borehole for every 300 persons to avoid overcrowding at each water point. Such boreholes are particularly appropriate for the small villages with populations less than 2,000 which are spread over large areas of Anambra and Imo States. Since the boreholes are drilled essentially for handpump operation, their diameter is restricted to 15cm (6 inches) and they usually only partially penetrate the full thickness of the aquifer. The average yield of hand pumps is only about 0.5 to $1.5m^3hr^{-1}$ and mostly depends on the depth to the ground-water level. Thus low permeable materials such as clayey sands, sandy clays, sand/shale intercalations as well as high permeable materials may be used as aquifers. The drawdown associated with hand pumps is also low because of the low and discontinuous yield. The only hydraulic requirement is that the static water level in the wells should not be more than 70m [2] to allow easy lifting of water to the surface.

It is desirable to provide at least one borehole for every 300 persons

The second type of non-pipe-borne system is the hand-dug well [3]. This type of well is traditional and has been used in various parts of Nigeria for many years. It is constructed with hand tools and may be lined with concrete tubes. Such wells are generally shallower than boreholes and are sometimes covered and equipped with small pumps. More usually, they are left open and a bucket is used to raise water to the surface. They therefore present a pollution hazard. Owing to their shallow depths and the fact that they only partially penetrate the aquifer, they are affected by seasonal fluctuations of the water table and hence may dry up in the long dry season. The sanitary level of hand-dug wells can be improved by lining them with concrete rings. Shallow pumps with suction lifts may be used to lift the water. Such suction-lift pumps are located on the surface and are therefore easy to operate and maintain and would also avoid the subsequent pollution of the water resource.

They are left open and . . . therefore present a pollution hazard.

The third type of non-pipe supply is developed on springs by constructing a head box and storage tank. Most springs are perennial and the water is clear, requiring no treatment. The supply is by gravity flow. Such systems are the most economical to run because operational and maintenance costs are minimal.

The water supply schemes discussed above constitute the modern water supply schemes. Before the introduction of these systems, communities got their water by fetching directly from nearby streams, springs and ponds or by storing rainwater. These earlier methods constitute the traditional water supply systems.

WATER RESOURCES POTENTIALS OF ANAMBRA AND IMO STATES

The types of water supply schemes that may be developed for rural communities have been outlined in the preceeding section. The selection of any of these schemes depends on the type of water resources available in an area and in places where more than one resource is available, on the relative unit cost of developing each resource. This section establishes the water resources of the study area and outlines the available resources for each area.

In terms of water resources, Anambra and Imo States may be divided into 5 Zones as shown in Fig. 4. Zone 1 extends from Abakaliki westwards to Enugu and from Ikem (Anambra) Southwards to Nguzu Edda (Imo). The zone is underlain by middle Cretaceous sandstones, fractured shales, limestones and scattered pyroclastics and intrusives. Generally the sandstone units are thin (less than 20m), fairly well compacted and have low permeability except at some localities where fracture porosity occurs. Location of prolific aquifers in this zone would involve elaborate geophysical investigations and is costly. The chances of success are also slim. However the near surface sandstones and fractured shales yield sufficient water to hand-dug wells and shallow boreholes with handpump as evidenced by the high success rate of the UNICEF rural water supply schemes in parts of the Zone using Indian Mark II handpumps. Only a few permanent springs occur in this zone and most of the streams have very low dry season flow. In addition the streams are frequently located at places very far (sometimes 5km or more) from the users or are under inaccessible conditions such as at the toes of steep hills. Although the streams could be impounded cheaply using direct labour, the water from them will reach the users only after long trekking to the supply point. The only practicable surface water scheme is stored flood water. This is expensive for small rural communities. The only possible water supply schemes to the rural communities in this zone are rainfall interception, shallow handpumped boreholes and improved/sanitary hand-dug wells.

Zone 2 is underlain by the Ajali Formation and extends from Nsukka (Anambra) to Arochukwu (Imo). The zone contains very prolific aquifers. The average yield of boreholes is over $50m^3\ hr^{-1}$ and the hydraulic conductivity ranges from $0.36m\ hr^{-1}$ to $36.0m\ hr^{-1}$. Extensive well fields with motorized pumps can be developed. However the average depth to the ground water is more than 60m below the surface and schemes using shallow boreholes with handpumps or improved hand-dug wells may not be successful. Springs are rare but where they occur, they are usually perennial. Developable streams or rivers are also rare. The only practicable water supply schemes are those that use deep boreholes with motorized pumps. The small rural communities in this zone should therefore be combined to form a supply area or be connected to the distribution grid of nearby urban areas.

Zone 3 comprises areas underlain by the Nsukka and Ameki Formations and sandstone members of the Imo Formation. Promising confined aquifer systems occur at depths ranging from 60m to 20m below the surface. The yield of boreholes is variable with an average of about $30m^3\ hr^{-1}$ and hydraulic conductivities range from $0.1m\ hr^{-1}$ to about $7.0m\ hr^{-1}$. Numerous isolated unconfined aquifers occur at the outcrop of the several sandy units of the formations. The depth to the water table in these aquifers is generally less than 20m below the surface. However, the saturated thicknesses of the unconfined aquifers are variable and many rope wells completed in this zone are seasonal. Numerous springs occur and many of them are perennial.

Almost all the schemes using rainwater, surface water and ground water may be developed for communities in Zone 3. However, more detailed hydrologic and hydrogeologic investigations are needed to establish the specific relative abundance of the resources in each community. This would enable more appropriate and reliable schemes to be selected for each of the communities in this zone.

Zone 4 is underlain by the Imo Formation. The formation is made up of thick clay-shale units, sandy clays and minor clayey sand units. Borehole records indicate a high failure rate of boreholes completed in this zone. However at some localities, high yielding artesian aquifers have been encountered at depths below 200m of the surface. A number of perennial streams and some seasonal springs also occur in this zone. Water supply schemes using deep boreholes with motorized pumps may be costly to drill, operate and maintain. Shallow boreholes with handpumps or improved rope wells may not work in this zone. The only economic schemes are those using rainwater or stream sources.

Zone 5 coveres the extreme West and South of the States. It comprises areas underlain by the Ogwashi/Asaba and Benin Fromation and the Quaternary alluvium of the River Niger Plains. Deep unconfined aquifers generally occur in this zone and the water table is everywhere less than 50m below the surface. The average well yield is over $50m^3\ hr^{-1}$, but the hydraulic conductivity values vary extensively, especially within the areas underlain by the alluvium. The springs and streams are mostly perennial and suffer little fluctuation in discharge throughout the year. Water supply schemes using rainwater, surface water or ground water may be developed for any rural community in this zone. The choice of an appropriate scheme is, however, dependent on the unit cost of developing each of the schemes. The next section outlines the

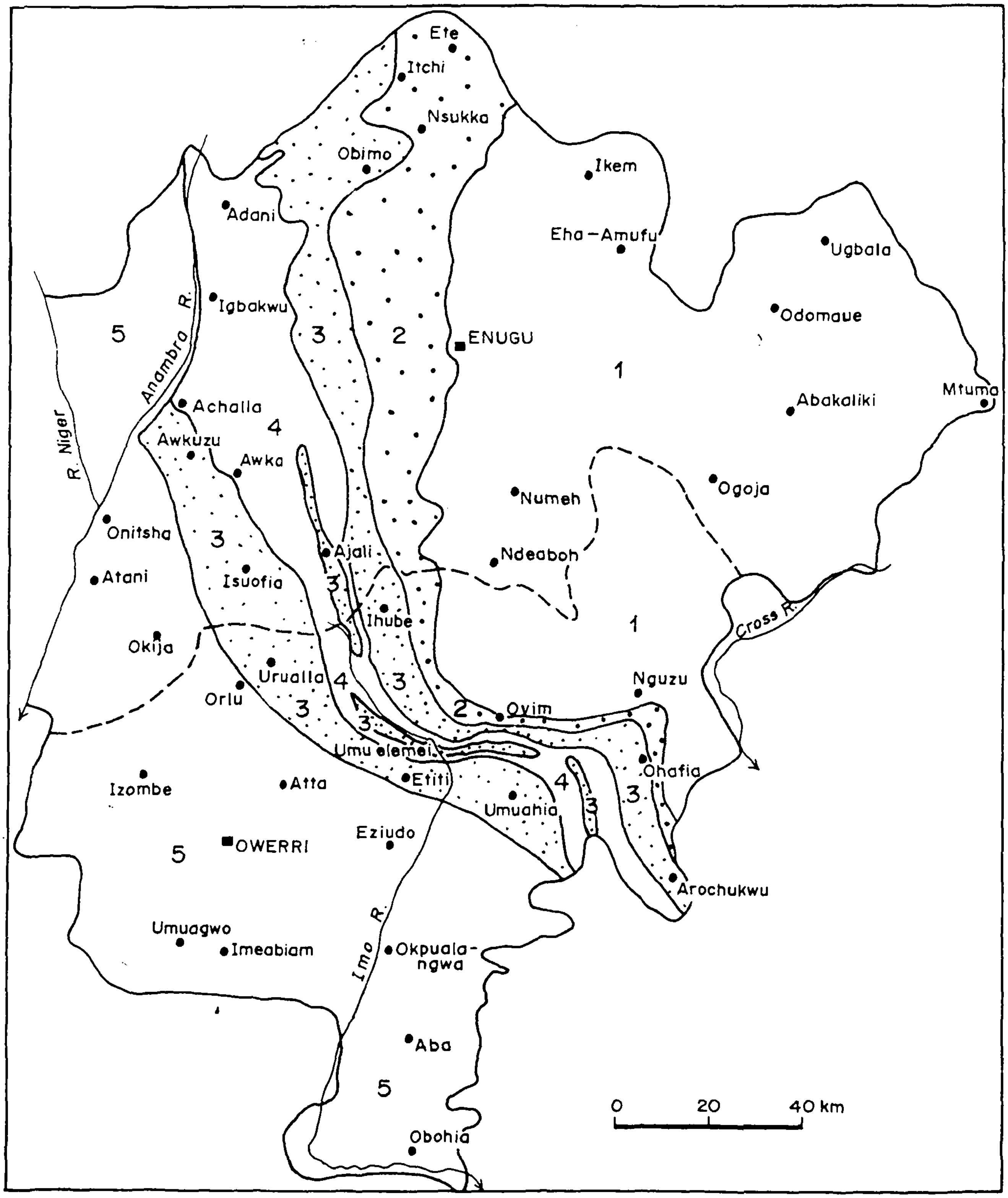

Figure 4. Water resources potential map of Anambra and Imo States.

comparative cost of developing ground-water and surface water resources and established a scale of preference in the choice of an optimal water supply scheme for any rural area.

COMPARATIVE ADVANTAGE OF GROUND-WATER AND SURFACE WATER SCHEMES

Studies have shown that ground water has several advantages over surface water. It is usually less expensive to develop than surface water and can be easily expanded at a future date by the addition of new boreholes. Ground water is also generally physically and chemically pure and is more likely to be free of pathogenic bacteria. Frequently, ground water has been supplied directly to users without any form of treatment. Where the quality of ground water is objectionable, the cost of treatment is usually low compared to the corresponding surface water treatment.

Ground water has several advantages over surface water.

Table 2: Comparative cost of developing surface water and ground water to a community of 20,000 people at 200 liters per capita per day (as of 31 Dec. 1982).

	Item		Rate (₦)	Cost (₦)
A.	**SURFACE WATER**			
i.	*Intake structure		100.000-200.000	150.000
ii.	**Treatment work		130 per m³	520.000
iii.	Reservoir	same as for Ground water		
iv.	Power			
v.	Pipelines			
vi.	Pumping House			
			Total	670.000
B.	**GROUND WATER**			
i.	+Drilling, casing Screening, Development and Pumping test		60.000 per 150m deep borehole	240.000
ii.	+Installation of pump, riser, mains, outlet elbow etc.		25.000	100.000
iii.	Reservoir	Same as for surface water		
iv.	Power source			
v.	Pipelines			
vi.	Pumping House			
			Total	₦340.000

*Figure from Enplan 4
**Figure from Balasha-Jalon 5
+Figures from Federal Department of Water Resources, Enugu.

Table 2 gives the comparative cost estimate of developing surface water and ground water to a rural community of about 20,000. The water requirement of the community is taken as the U.N.O. recommended value of 200 liters per capita per day and the total water needed is thus 4,000m^3 day^{-1} (4 million litres day^{-1}). It is assumed that this volume of water shall be abstracted either from a river or from four boreholes producing at an average rate of 45m^3 hr^{-1}. Estimates of the unit cost were taken from the reports of 2 consulting engineers [4, 5] to Imo State Water Corporation and 1982 borehole drilling reports of contractors to the Federal Department of Water Resources, Enugu, Nigeria. It can be observed from the table, that although the estimates for the surface water source were made at least two years before those for ground water, the cost of developing the 4,000m^3 day^{-1} of water from surface sources is about twice that from ground-water source. The cost difference arises mainly from surface water treatment work. However the unit cost of treatment usually decreases with increase in the treatment plant capacity and it is likely that at greater water demand, the cost difference for the two sources will diminish. The cost estimates given in Table 2 does not include variable costs such as pumping and maintenance costs. The current average cost of pumping water from a borehole is about twenty Naira (₦20.00) per hour and for 4 boreholes operated at about 24 hours daily, the total cost is ₦192.00. The major maintenance work needed to keep a borehole working in Nigeria is the repair of the submersible pumps which sometimes fall into the borehole. Such repairs are commonly done twice a year per borehole at a cost of about ₦500. This gives ₦4000.00 for the four boreholes annually. These variable costs when added to the initial cost of developing ground water would certainly make a lot of difference. However the major economic defect of the surface scheme is the high initial cost needed to develop it (as demonstrated in Table 2). This makes it unattractive for rural communities especially those that are less than 5,000 in population. For urban water schemes (involving more than 20,000 people) the surface water scheme is often a better alternative.

Studies made in Ghana [6] for the various types of supplies, namely boreholes with handpumps, mechanized boreholes, and surface water systems are given in Figure 5. The study was made in 1975 (eleven years ago) and the absolute costs now would certainly have changed. However, it is reasonable to expect that the relative costs would have the same trend. The figure shows that for communities less than 20,000, the unit cost for a surface water scheme is more than twice that for a ground-water scheme. In addition, it also shows that boreholes equipped with handpumps have a cost advantage over mechanised borehole systems within the lower population range (less than 2,000).

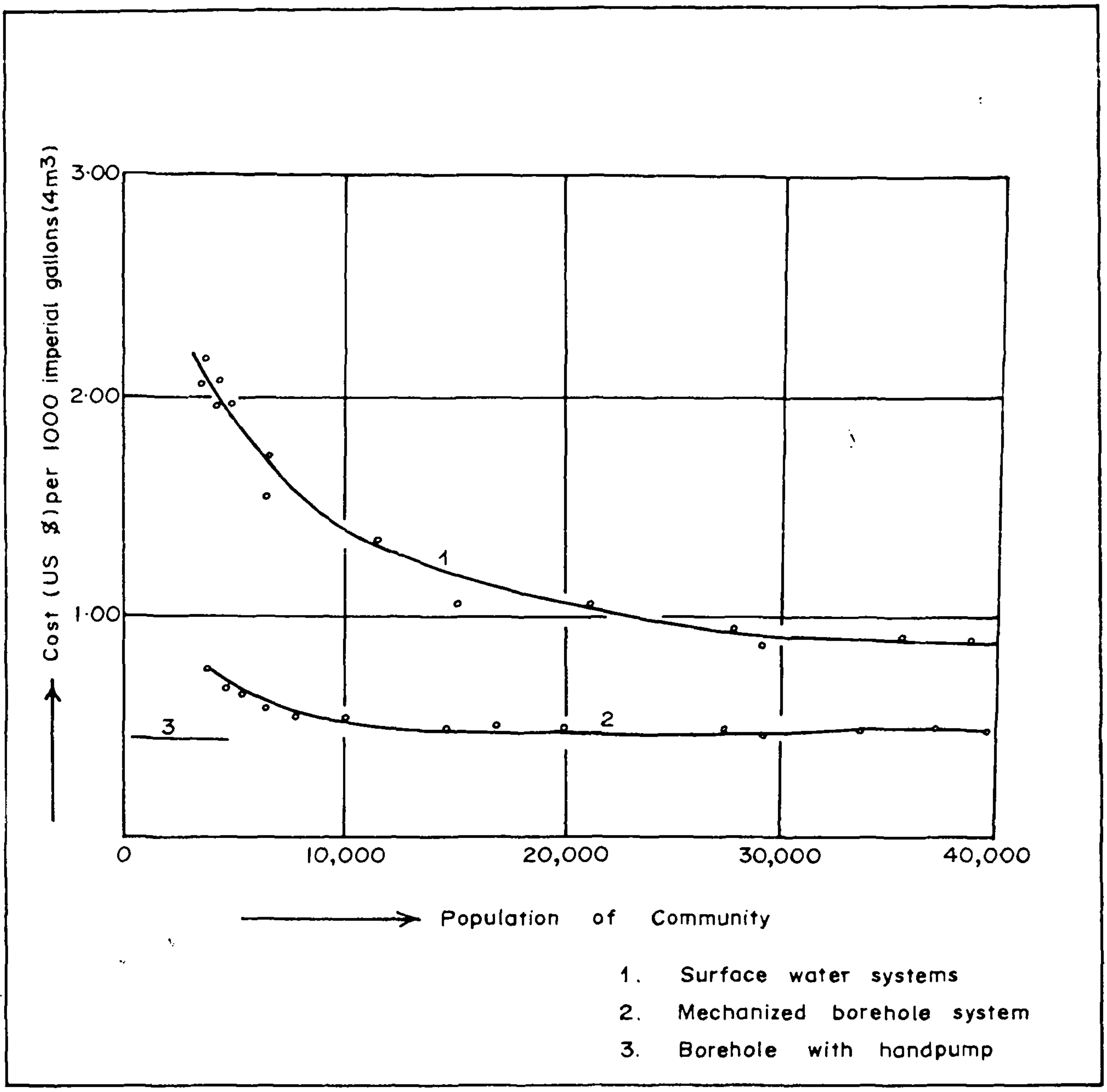

Figure 5. Comparative cost of developing surface water mechanised borehole and borehole with handpump [6].

In addition, boreholes can be drilled close to the towns they serve, whereas the intake structures for surface water treatment are, on the average, about 3km from the sites of the treatment plants. The cost of transporting the raw water may sometimes amount to thousands of Naira or even fractions of a million Naira. For example at the current cost of about ₦65.00 per meter of the relatively cheap asbestos cement pipeline (8 inches diameter), a 2km long pipe will cost about ₦130.000. This transportation cost may be enough to develop new well fields. The marked difference in the initial costs of the alternative systems proves the economy of the ground-water source and supply. It is clear therefore that a ground-water scheme should be preferred for rural communities wherever ground water can be found in sufficient quantities and with acceptable quality.

EXISTING WATER SUPPLY SCHEMES

Table 3 shows the distribution of existing water supply schemes in the rural communities of Anambra and Imo States based on inventories taken by Uma [7]. Almost all the communities with populations more than 20,000 (urban communities) have water schemes in Imo State. The corresponding percentage for Anambra State is 52.0. For communities with populations between 2,000 and 10,000, about 27% of them in Imo and 37 in Anambra have water supply schemes. Almost all communities with population less than 2,000 in Anambra State do not have any water scheme. In Imo State where the UNICEF rural water scheme exists, about 24% of the small communities (less than 2,000 inhabitants) have water schemes. On the average only about 30% of communities in Anambra and 38% of communities in Imo State have water supply facilities while the rest do not.

Table 3: Distribution of Existing Water Supply Facilities In Rural Communities of Anambra and Imo States (Data from Inventory Taken by Uma [7]).

Community Population	No. of Communities		No. of Communities with Water		Percentages of Communities with Water	
	Anambra State	Imo State	Anambra State	Imo State	Anambra State	Imo State
20,000	28	39	25	34	89.3	87.2
10,000-20,000 (Rural)	98	148	51	92	52.0	62.2
2,000-10,000	253	385	93	102	36.8	26.5
2,000 (Rural)	827	560	20	137	2.4	24.5

Average percentage of Rural Communities with water 30.4 37.7

The water supply schemes for the more populous communities is through boreholes with motorised pumps. The smaller villages are either connected to the grid of the nearby bigger communities or are combined to form a supply area. Communities under the UNICEF rural water scheme have boreholes with handpumps. A small number of schemes using spring sources exist in some communities. Inventories on such schemes were not taken and they are not included in the table. Comparing Table 3 and the community population distributions, in Table 1, it is clear that most of the rural communities do not have modern water supply facilities. They therefore depend solely on the traditional systems which are insufficient both in quantity and quality.

DISCUSSION AND CONCLUSIONS

It is apparent from the foregoing sections that two types of water supply problems exist in the rural areas.

Most of the rural communities do not have modern water supply facilities. They . . . depend solely on the traditional systems

The first concerns the reliability and/or adequacy of the existing systems and the second is the absence of any supply scheme in most of the small scattered villages.

An inventory taken in 1983 [7] indicated that of the more than 250 boreholes drilled in Imo and Anambra States only 42 percent are in use; 38 percent are either abandoned or in disuse while the rest are not yet commissioned. Table 4 gives a clearer impression of the actual situation in some of the rural and urban water well fields. In some of the well fields, the number of boreholes in disuse outnumbers the number in use. Generally the most frequent mode of failure is the collapse of the pumping units and the burning of the pump motor. These are as a result of poor well design and poor maintenance. Although prolific aquifers occur, most of the wells partially penetrate the aquifers and in some, the screened sections of the wells are less than 25 percent of the saturated aquifer thickness. Drawdowns are thus high for relative small pumping rate and time, especially in the vicinity of the pump-

Table 4: Operational condition of some well fields in Anambra and Imo States (As of Dec., 1983).

Borehole	State	No. of boreholes drilled	Operational Condition: Commissioned		Not Commissioned
			In-Use	Abandoned	
*Nine Mile Corner	Anambra	5	4	1	—
(Old pumping station)		5	4	1	—
*Nsukka Urban	"	10	4	6	—
UNN (Nsukka)	"	5	2	3	—
Ohodo	"	3	1	1	—
*Onitsha	"	11	6	5	—
*Nnewi	"	5	2	3	—
Nnobi	"	2	1	1	—
Eke-Nguru	Imo	3	1	1	1
Enyieogugu-Mbaise	"	4	—	2	2
*Umuna-Orlu	"	6	2	4	—
Eziama-Nkwere	"	4	1	2	1
Umuahia	"	9	4	5	—
Ohafia	"	4	1	2	1
Arochukwu	"	3	1	2	—
Mbutu	"	4	1	3	—
Nenu	"	3	2	1	—
Orie-Mbieri	"	4	1	2	1

*Urban Scheme

ing wells. Because the wells were not properly tested before production started, and also because the water levels in the pumping wells are not monitored, critical drawdowns can not be forecasted and prevented. Frequently, therefore, the water levels go below the submerged pumps and the motor burns off. The well designs should follow standard procedures and completed wells should be properly tested to estimate optimum production. Provisions for such tests are incorporated in most existing job orders given to contractors and would be carried at no additional cost to the water agencies. The major problem is the lack of effective supervision to ensure that the activities listed in the job orders are performed to specifications.

Hydrochemical analysis of some ground-water samples [8, 9] indicate moderate to high acidity (pH = 6.5 to 4.9), high free carbon dioxide (CO_2) and thus corrosion hazards. The boreholes in such areas should be regularly maintained and the frequency of maintenance should depend on the production history of the boreholes. This has not been the case in the states studied; rather rehabilitation is carried out only after failure has occurred.

An additional problem is insufficient and inconsistent energy supplies to the rural pumping stations. Fuel is supplied from a central point located at the state headquarters. While stations close to the headquarters may receive their allocations in timely fashion, others farther away may have to wait for days and sometimes weeks, especially where the (communicating) roads are poor and seasonal. This results in inconsistent pumping and thus inconsistent water supplies. Further, the fuel allocated to pumping stations may not be sufficient to run the electric generating sets for periods long enough for water to reach every user. In most rural pumping stations, water is pumped only for three hours daily and sometimes for four days in a week. Water supply to communities under such a situation cannot be adequate. Fuel shortage is an administrative problem and may be solved by having a more effective fuel distributing system. Instead of a central distributing system, local governments should be responsible for the fuel used in their areas of authority. The local communities may even fuel the engines directly. A more lasting solution would be to connect all water pumping stations to the National Electricity grid (NEPA).

The small rural communities should not be ignored in the design of state water supply schemes, as is currently the practice. These communities constitute more than 30% of the state populations and must be considered in the water supply design especially now that the government is encouraging rural resettlement. The general water resources potentials of these areas have already been established. What needs to be done is to establish the water resources of each specific community and select an appropriate scheme for the community. Already it has been shown that schemes using shallow wells with hand pump or hand-dug wells with surface pump are suitable for such small rural communities in terms of economy and adequacy. Such hand pumps must be sturdy, corrosion and weather resistant and easy to operate and to maintain. The handpump — Indian Mark II — which has been developed under UNICEF sponsorship meets most of these requirements. It also facilitates the lifting of water by hand from depths of up to 70m. The success of the UNICEF rural water scheme using this type of technology should be a good case study. The main problem of the scheme is that the pump requires servicing about once a year. The annual maintenance cost per borehole is less than a hundred Naira and can be funded by the communities if effectively organised and supervised. It is even likely that the general operation of the borehole would be more satisfactory if the wells are owned by the communities as they will have a vested and vital interest in their proper functioning.

The success of the UNICEF rural water scheme using this type of technology should be a good case study.

It should be remembered always that the existing traditional water supply systems in the communities will compete with the newly devloped systems. Such traditional systems may not be sanitary or adequate but once they have been traditionally accepted, it is usually difficult to ignore them. Sometimes more prejudice against the earthy taste of ground water or a malfunctioning handpump can switch a whole community opinion against the new system. For the rural population to accept the newly developed ground-water supply, the following criteria must be satisfied [6]:

1. The population must be convinced through education that the new supply is free from all diseases and is potable;
2. The new supply must be adequate both in quantity and quality;
3. It must be suitably located and distributed. For example, it should be closer to the community than the traditional source; and
4. The new supply must be dependable, hence at the start, the borehole should be properly constructed and the handpump sturdily built to withstand any possible abuse. Both borehole and pump must be maintained regularly.

If these conditions are not satisfied, the population invariably drifts back to the traditional source.

The decision by the Directorate on Rural Development to supply water to all rural communities through boreholes equipped with hand pumps is a wise decision in the right direction. However as established in this paper the hand pumped borehole project is not viable in all the rural communities in Nigeria. Hydrogeologic and hydraulic conditions at the subsurface may render the project unworkable. A better approach may be to accurately establish the nature of the water resources for each community and select the most appropriate scheme based on cost analysis of the alternative schemes. The guidelines given in this paper may form a basic framework for such a comprehensive approach.

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CALENDAR OF FUTURE MEETINGS INVOLVING IWRA

Mar. 14-18, 1988	International Conference on Computer Methods and Water Resources. Rabat, Morocco.
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May 29-June 3, 1988	VIth World Congress on Water Resources — Water for World Development. Ottawa, Ontario, Canada.
June 5-9, 1988	Short courses offered following the VIth World Congress on Water Resources, University of Ottawa, Ottawa, Ontario, Canada.
June 27-July 1, 1988	International Workshop on Water Related Problems in Societal Planning and Decision Making. Stockholm, Sweden.
Nov. 7-12, 1988	State of the Art of Hydrology and Hydrogeology of Arid and Semi-arid Regions of Africa. Ouagadongou, Burkina Faso, Africa.
Nov. 10-12, 1988	International Seminar on Hydrology of Extremes (Floods and Low Flows). Roorkee, India.
Nov. 16-19, 1988	International Water Resources Conference on Water Resources Planning and Management in a Developing Economy. Benin City, Nigeria.
Dec. 15-17, 1988	International Seminar on Water Resources Education and Training. New Delhi, India.
June 5-10, 1989	40th International Commission on Irrigation and Drainage Executive Council Meeting. Ottawa, Canada.
June 19-23, 1989	International Symposium on Integrated Approaches to Water Pollution Problems. Lisbon, Portugal.

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