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regional water supply in Ghana

The planning and execution of a regional water supply project for northern Ghana

INTRODUCTION

As part of Ghana's Upper Region Water Supply Project which commenced in November 1973, a regional rural water supplies development programme was implemented. The Project was jointly financed by the Government of Canada through a loan administered by the Canadian International Development Agency (CIDA) and funds provided by the Government of Ghana. The loan was to be used by Ghana for the purchase of services, materials and equipment not available in Ghana that was required to carry out the Project. Additional financial contribution was made by Canada, under her Commonwealth Africa Assistance Programme, to cover engineering, advisory and other services, and equipment and material requirements for the expansion of the Project.

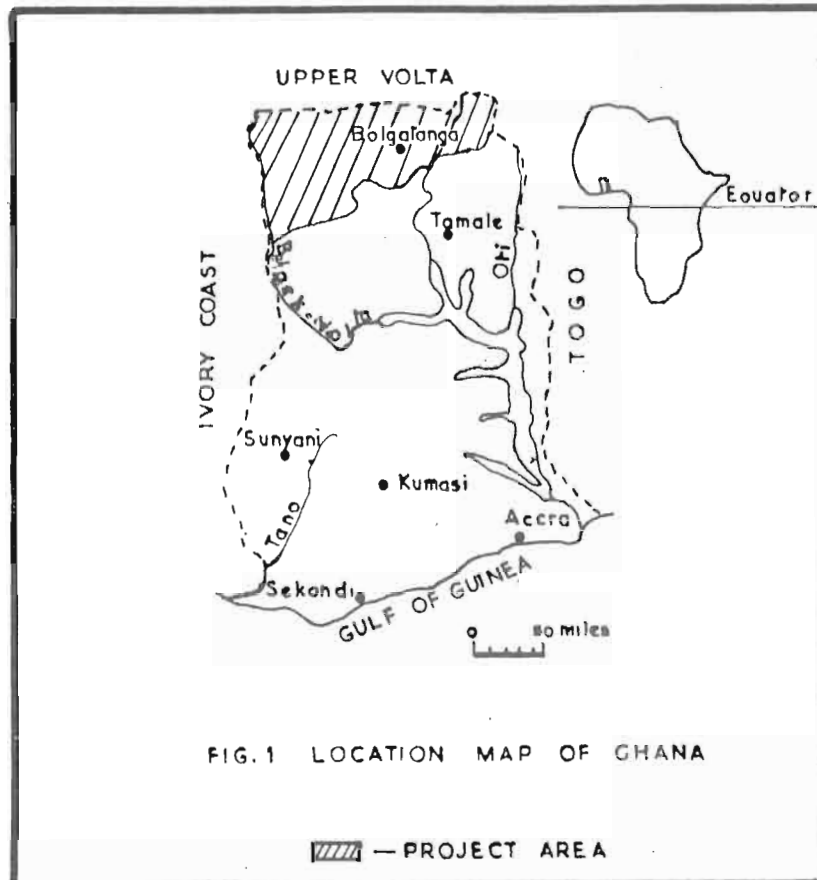
The participants are the Ghana Water and Sewerage Corporation (GWSC) which is the executing agency for the Government of Ghana and the Canadian International Development Agency (CIDA) which contracted the services of a Canadian engineering consulting firm to act as project managers and advisers in the implementation of the project. The cost of services of the Consultant was borne by the Government of Canada through a technical assistance grant.

The objectives of the Project are to:

- construct hand pump wells in the rural areas.
- construct wells for mechanization in specific intermediate size towns.
- rehabilitate some 250 existing wells, in 130 rural communities.
- establish well maintenance facilities and procedures in five district centres and a base centre at Bolgatanga.
- provide training for GWSC staff in all aspects of ground water development and equipment maintenance.

The project area encompasses 11 000 square miles which includes the entire Upper Region of Ghana (figure 1). The physical characteristics of the region are typical of that portion of the pre-Cambrian shield of West Africa lying between the Sahel sub-region to the north and the rain forest to the south. The tropical climate and contrasting long dry and short rainy seasons combined with the geological environment have resulted in a modest groundwater resource.

Figure 1



It was established that the water supply needs of the rural population of the Upper Region could be satisfied by the installation of 2300 new hand pump wells. Rural population in some 33 communities were scheduled to be satisfied by construction of wells suitable for mechanisation wherever sufficient groundwater supplies were identified.

The first phase of the programme was completed in February 1977 by which time 1430 hand pump wells had been installed in over 800 villages throughout the Upper Region. Sixty wells suitable for mechanisation were constructed in six intermediate size towns. In addition some 250 existing wells fitted with hand pumps which were not functional were rehabilitated.

A well maintenance programme was conceived and implemented to assist the long-established GWSC Regional Maintenance Organisation expand its capability to provide long term repair and service for the new water supplies provided by the Project.

District Maintenance Workshops and facilities were established. Ghanaian staff were trained in the repair and maintenance of hand pumps, mechanised water supply systems and other equipment provided on the Project.

The second phase of the Project which is a continuation of the programme commenced in February 1977 and is scheduled for completion at the end of 1979. An additional thousand wells are being installed. Expansion and improvement of routine water supply maintenance to accommodate the additional wells are being carried out.

Comprehensive training has been provided in all aspects of groundwater supply planning, exploration and development, including hydrogeological investigations, well drilling, pump testing, well maintenance and equipment repair and maintenance. Technical and managerial skills of GWSC personnel have been upgraded, so that they have the expertise necessary to utilize the equipment provided by the Project on a continuing basis to develop the much needed groundwater supplies throughout Ghana.

PROJECT MANAGEMENT AND CONSULTANCY SERVICES

The services of a Consultant were provided to the Project under Canadian technical assistance grant. Five Canadian engineering consulting firms, who had been pre-qualified by CIDA, and approved by GWSC, were invited to Ghana, to familiarise themselves with local conditions prior to submission of proposals. Selection of the consultant was made by CIDA and an agreement was signed between CIDA and the consultant which spelt out the consultant's responsibilities and relationship to GWSC.

The Consultant provided technical, advisory and training services to the GWSC to assist them in meeting the overall objectives of the Project. They provided key personnel - comprising a Project Director based in Canada and on-site project manager, drilling superintendent, drillers, hydrogeologists, mechanical superintendent and well maintenance superintendent - who worked with a Ghanaian counterpart manager and other staff appointed by GWSC. The curriculum vitae of all the Consultant's personnel was submitted to GWSC and CIDA for approval to ensure that only personnel with expertise were engaged. Schedules of the various activities including the frequency of joint evaluation of progress were also submitted.

The Consultant was responsible for all aspects of the Project in the first phase, with the Ghanaian staff assuming increasing responsibility. However, as scheduled the Ghanaians who had been trained in the first phase staffed all line management positions for the second phase and took full responsibility for the technical and managerial aspects of the Project with limited Consultant participation.

A joint plan of operation was prepared by the Consultant in conjunction with GWSC which outlined the ways and means to be used to carry out the various elements of the Project.

The Consultant was also appointed as purchasing agent on behalf of GWSC for the procurement and expediting of imported materials and equipment required by the Project and associated Water Supply Maintenance Programme. Purchasing procedures were set up by CIDA and GWSC.

Other responsibilities of the Consultant were to conduct technical studies such as design of well pads and aspects of well and aquifer contamination and to prepare reports on project evaluation through monthly, quarterly and annual reviews of Project activities.

PLANNING CONSIDERATIONS

Population distribution

The total population of the Upper Region is approximately 862 000 and over 90% of this is described as rural, that is living in communities with population less than 5000. The density of the population varies considerably across the Region. The east side is heavily populated; the middle portion lightly populated and the west side moderately. The majority of this rural population is located on individual family-compound farms and in small communities with populations of a few hundred to about 15000.

Rural water supply policy

The distribution of the population is such that pipe-borne water supply facilities are not appropriate to serve the majority of them. It is the rural water supply planning policy, that such scattered rural populations be best served with wells equipped with hand pumps, where each hand pump is to serve a population of 300 to 350 people.

For communities having population of 1500 or more it is the policy to provide pipe-borne water systems. In order to take advantage of the drilling activities in the Region, 60 wells suitable for mechanisation would be constructed in 33 communities. Mechanisation of these wells is, however, excluded from the present Project. Each of the wells would be fitted with a hand pump in the interim. The total population to benefit from this added programme is approximately 64 000.

Before the start of the Project only 30 000 of the rural population were served with pipe-borne supplies; another 60 000 living in 130 small communities had access to adequate supply of potable water for drinking, personal hygiene and other domestic purposes through 250 wells equipped by hand pumps. The rest of the population totalling 772 000 were dependent upon dug-wells, dugouts, small dams, ponds, rivers and other unreliable sources. Based on one well for each 300 people the foregoing population would require a total of 2573 installations. Since the availability of groundwater was not certain in all areas of the Upper Region, provision was made for only 2300 hand pump installations.

Allocation of wells

Consultation was held among various organisations - Project Management, Consultant and the Department of Health, Regional Administration, to establish criteria and guide-lines for the equitable distribution of the wells. The Departments of Rural Development and Social Welfare, the Ghana Highway Authority and the Regional Planning Committee were consulted on accessible roads and routes to the numerous sites during the various seasons.

A strategy for the construction of the wells proposed by the Consultant was reviewed in terms of local (intra-regional) politics. It was decided that the most rational allocation of wells across the region was to base it on population distribution.

The Region was divided into 13 Districts and the rural population in each district was determined. Table 1 shows the relationship between population and wells allocated to each district. A system of priorities showing areas of priority considering water borne diseases, drought and other needs was prepared.

TABLE 1 - UPPER REGION WATER SUPPLY PROJECT SUMMARY OF HAND PUMP WELLS

MAINTENANCE DISTRICT	AREA	RURAL POPULATION (1970 Census)		NO OF WELLS					TOTAL WELLS BY 1980
		Total	Percent of Region	Pre-Project	Phase 1	Phase 2	Total	Percent of Region	
BAWKU	Bawku	53 000	7	7	135	45	187	7½	
	Garu	61 700	8	11	216	1	228	9½	
	Pusiga	38 600	5	6	116	0	122	5	
	Zebilla	44 700	6	10	90	65	165	6½	
	Northern Region Phase I	-	-	-	4	-	4	-	
	District Totals	198 000	26	34	561	111	706	28½	
BOLGATANGA	Bolgatanga	153 000	20	29	282	173	484	19	
	Chiana-Paga	50 900	7	28	83	35	146	5½	
	Navrongo	38 600	5	9	56	31	96	4	
	Sandema	50 100	6	15	61	92	168	6½	
	District Totals	293 100	38	81	482	331	894	35	
TUMU	Tumu Total	38 000	5	21	64	56	141	5½	
LAWRA	Lawra-Jirapa	68 000	9	26	80	89	195	7½	
	Nandom-Lambussia	41 800	5	12	62	79	153	6	
	District Total	109 800	14	38	142	168	348	13½	
WA	Nadawli-Funsi	63 900	8	12	68	115	195	7½	
	Wa	68 700	9	14	91	155	260	10	
	District Total	132 600	17	26	159	270	455	17½	
	REGION TOTALS	772 000	100	200	1408	936	2544	100%	

Topographic maps of 1:30 000 were available for the entire Region. There was also complete coverage with aerial photographs at the same scale. Geological maps at a scale of 1:125 000 were available for the portion of the Region east of Tumu; but for the west side, the geological maps were at a scale of 1:1 000 000. These maps were found invaluable in the location of the communities, the determination of access and the siting of the wells.

A well numbering system was designed and used to identify well drilled by the Project. Pre-project wells were incorporated into the new system.

Lists of all communities that were to benefit from the programme were prepared and approved by the Regional Administration. Their locations were plotted on district maps, which were in turn discussed with the various District Councils for final approval.

The allocation of the proposed wells to a community was based on the following considerations:-

- (a) The total number of wells to be drilled or rehabilitated is 2575 (about one for every 300 people in rural areas).
- (b) Rural population not served by pipe-borne water should be provided with a hand-pump well within a half mile walking distance.
- (c) Each hand-pump well should serve a maximum of 500 people and a minimum of 150 people.

The population figures for the 1970 census were used. For centres not shown on the census lists, population was estimated by referring to number and location of compounds shown on air photos.

Actual field location of proposed wells, of course, varied from siting shown on the planning maps due to:-

- (a) Availability of groundwater.
- (b) Access problems for rigs.
- (c) Field assessment showed different distribution of population.

WELL CONSTRUCTION PROGRAMME

Staffing and organisation

The well construction programme encompassed drilling rig and service rig operations, plus workshop, hydrogeological, electrical and transport services. An organisation of the operational responsibilities was set up for each category. Some equipment and manpower were on site in March 1974; however, the full complement of equipment was assembled in January 1975 and the well construction activity was underway by March 1975.

Briefly the well-drilling equipment consisted of three drilling units each composed of a drilling rig, a water truck, and a truck-mounted air compressor. Support equipment included two service rigs, a mobile drilling camp, camp generator set a prefabricated base workshop, workshop tooling, radio communication equipment, (a fleet of pick-up trucks, a dump truck, fuel truck, transport trucks).

Initially, the drilling operation was under the Consultant's management and supervision with six Consultant's drillers operating the drill and service rigs in the field and Ghanaian crews assisted. However, as time went on GWSC staff acquired progressively higher levels of technical and managerial skills and assumed more responsibility.

By the beginning of the second phase, a full complement of over 190 trained and experienced GWSC staff of various categories were available to carry out the operations. The number of Consultant staff was thus reduced to four with only two of these directly involved in the field drilling operation, the rest providing support services as advisers.

Schedule of operations and well production rates

It was scheduled that the construction of the 2300 wells should be carried out in two phases with installation of 1200 wells in the first phase.

The phasing had a considerable merit, in providing an initial few wells in each community with the intention of returning as part of the second stage operation, to install the remaining wells. The advantages of this were that by the end of the first phase, about one-half of the population spread across the region would have access to some of the well supplies rather than leaving one-half of the region untouched and that areas which would otherwise have had to wait up to five years for the installation of their wells, were partially served by end of the second year.

It was also possible to establish maximum efficiencies and rates of production in the first phase, so that in organising the second stage considerable advantage was taken of the experience gained. Actually the second phase operation proved to be more efficient, because of a better understanding of the hydrogeological conditions.

Taking into account the time which was lost throughout the early stages of the rainy season, the actual shut-down for the peak rains in August-September, the poor production rates during the heat of the day for the two driest months March-April plus normal breakdowns and annual maintenance, about 280 working days were realised each year.

The first 12 months of the programme was allowed core drilling equipment selection, tendering, delivery, transport and initial mobilization, break-in period and training. The number of wells completed by the end of the first, second, third, fourth years of drilling were 508, 1208, 1650, 2006 respectively. (Figure 2 shows the monthly well construction totals). Figure 3 shows the locations of all wells drilled in the Regions.

The actual drilling programme would be completed within 54 months.

Field Operations

The main base of the drilling operation was at Bolgatanga, the Project Headquarters where permanent staff accommodation was provided. Field drilling operations moved across the Region on a planned sequence working from a mobile camp set at 9 locations. All drillers, drill crews and other supporting staff were housed at the camp in mobile trailers. Depending upon the access roads and topographic conditions, the drilling operation worked within 20-30 radius of the work camp (Figure 4).

Areas of easy access for work were reserved for the beginning and end of the rainy seasons (June through September). This allowed for field operations in all months except August and September which were used for annual leave and equipment overhaul.

GHANA UPPER REGION WATER SUPPLY PROJECT HAND PUMP WELLS
& MECHANIZED WELLS

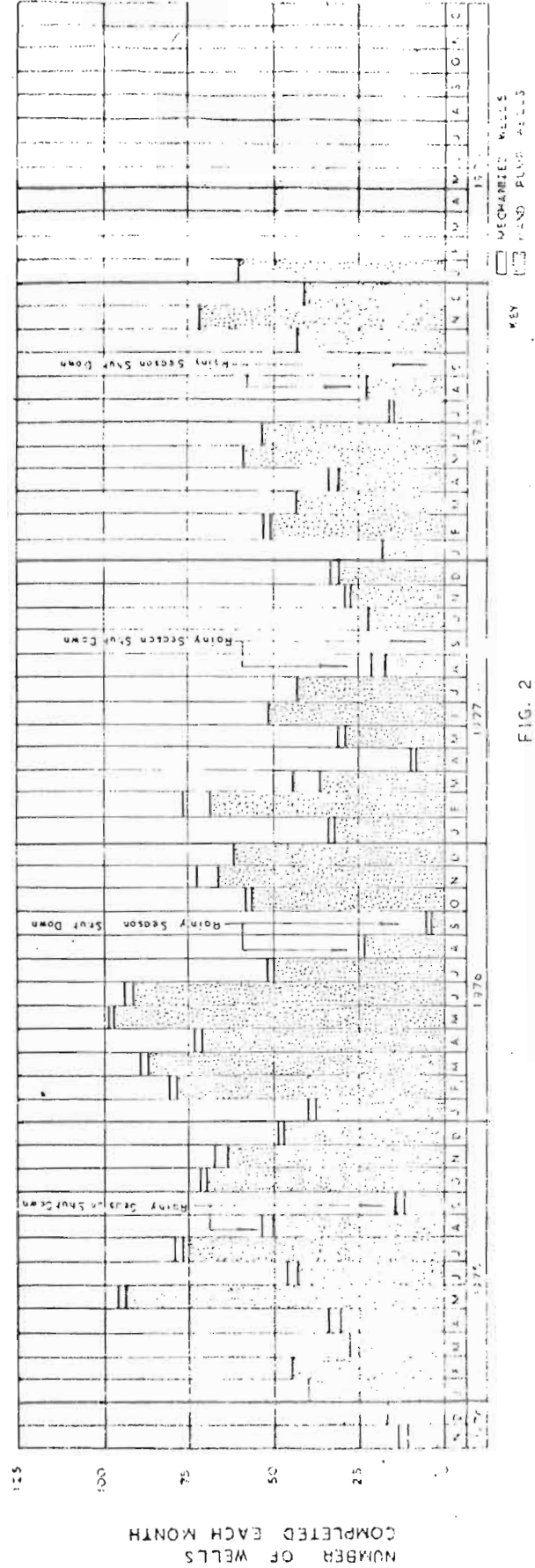
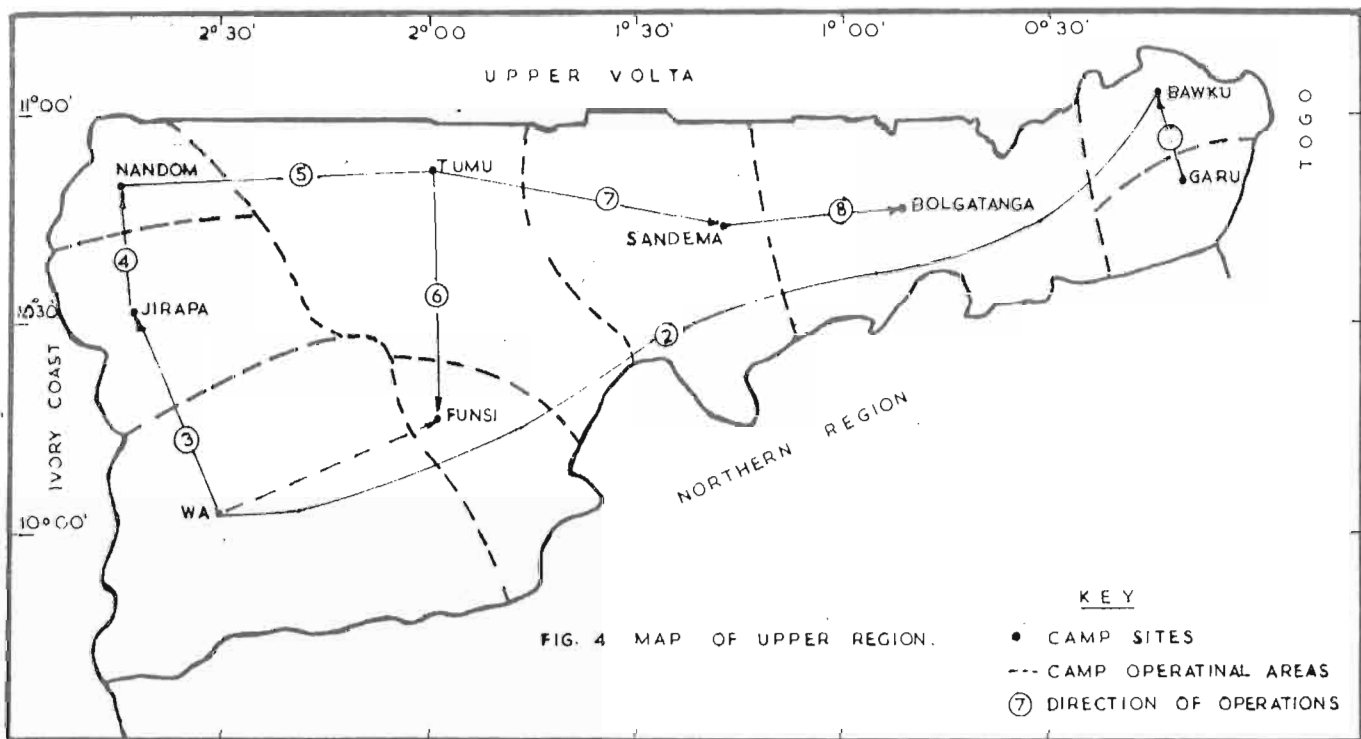
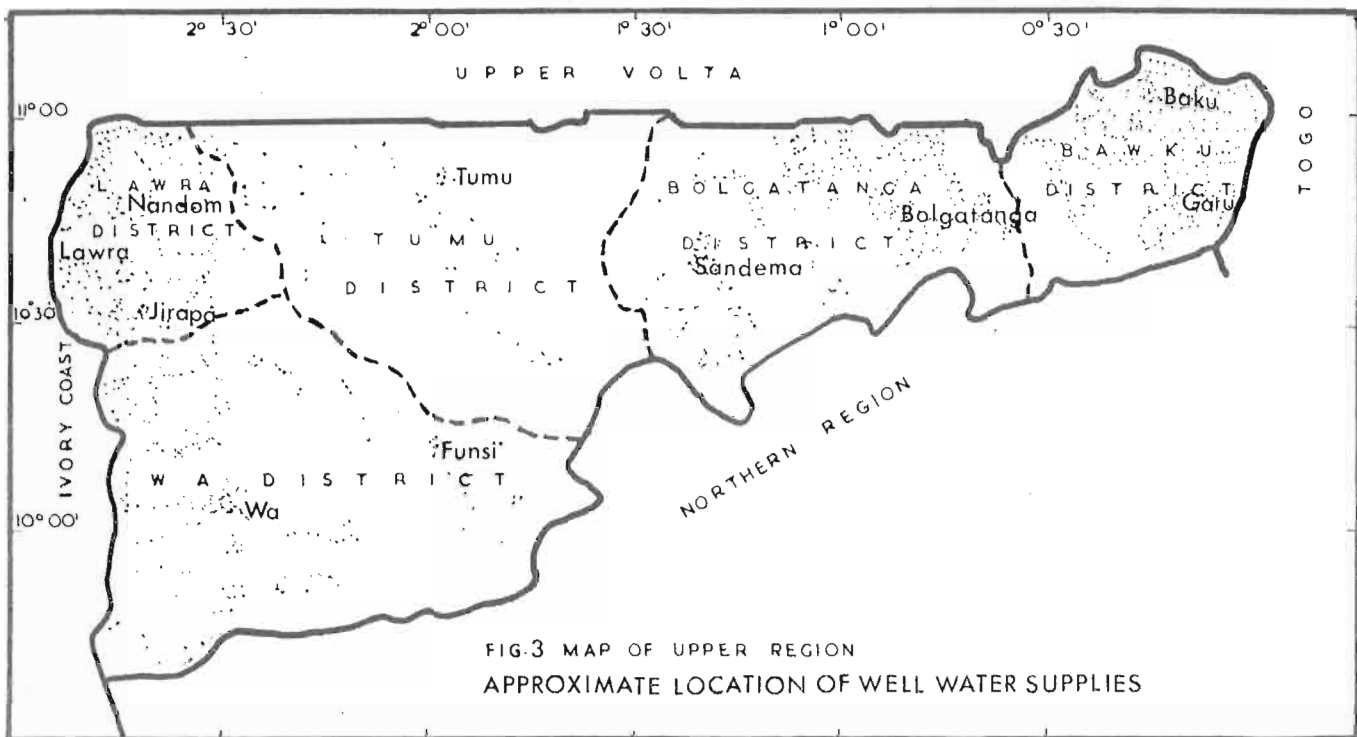


FIG. 2



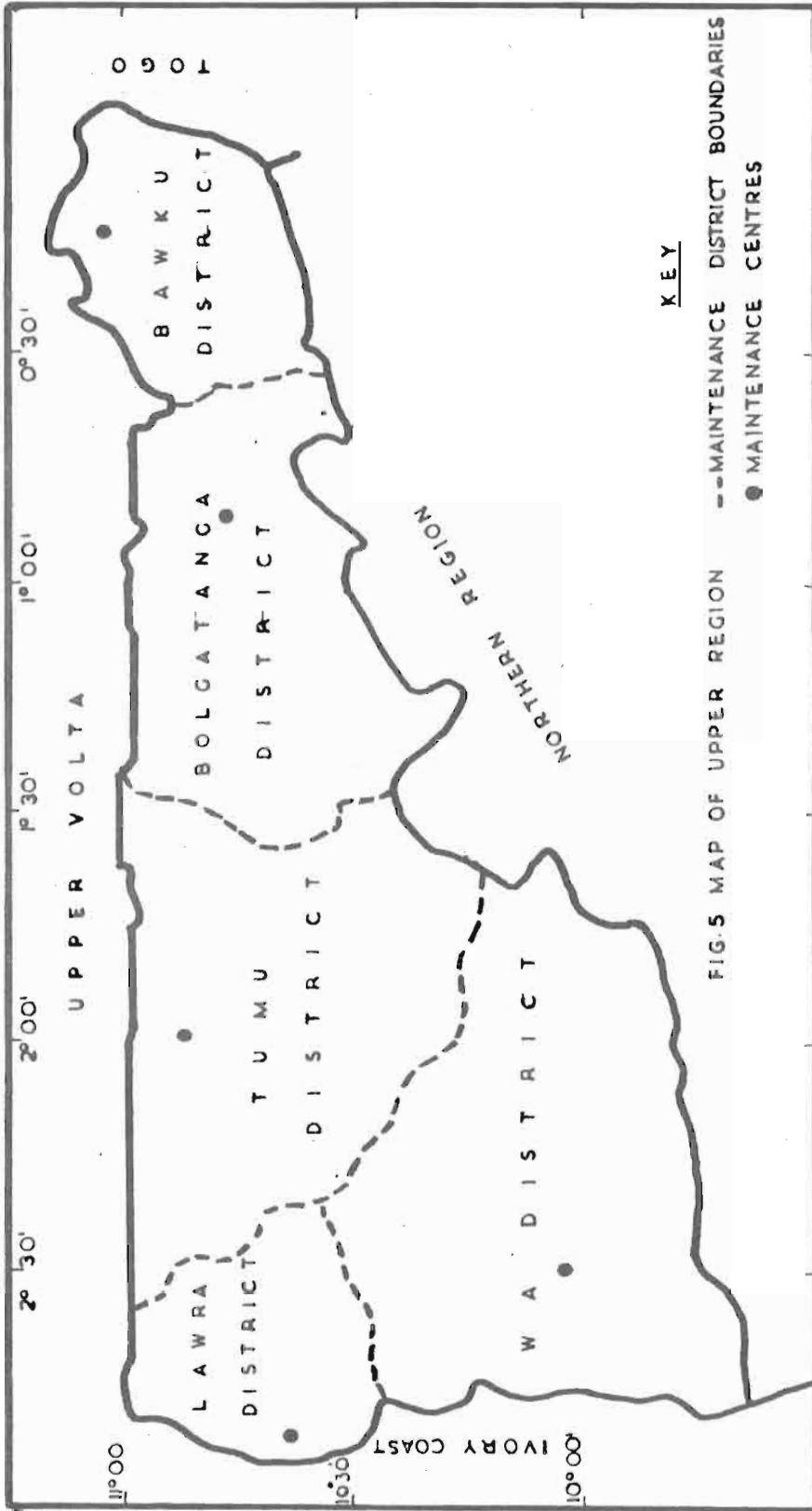


FIG.5 MAP OF UPPER REGION

KEY

- MAINTENANCE DISTRICT BOUNDARIES
- MAINTENANCE CENTRES

Site selection crews from the Hydrogeological Section worked in advance of the drilling operation identifying potential well locations for the hand pump wells. The main well production unit, consisting of three rotary drilling rigs and two service rigs supported by cementing and well-pad construction crews were run on standard contracting principles. To ensure full utilization of equipment each crew worked 21 days in the field and 7 days off. This allowed each crew sufficient time to return to base for rest. The operation was carried out 7 days a week, working 10-12 hours every day. The drill rigs concentrated on drilling holes and the service rigs fulfilled all the subsequent tasks, thereby efficiently accelerating production.

Preventive maintenance and minor repairs were carried out at the drilling sites or at the camp, but major repairs were carried out at the main workshop at Bolgatanga.

Exploration and development techniques

Efficient methods were adopted for the selection of well sites and the construction of the well. The selection of equipment and techniques was based on mobility, flexibility, speed and ease of operation. The use of a simple, quick earth resistivity survey technique for well site selection combined with air-rotary drilling equipment for well construction resulted in a high rate of well completion.

Site selection

The selection of a well site in a particular village began in the office with an examination of the aerial photographs to determine the distribution of family compounds. A tentative selection of the site was made based on locating the well to best serve a group of compounds - normally this meant locating the well so that the distance to the farthest compound was about one-half mile. Then the site selection crew visited the chief of the village to determine the local preference for the well siting. A compromise as to the general location of the well site was reached with the chief. The site selection crew would then examine the preferred site location. Avoiding any outcroppings of rock, a series of earth resistivity readings were taken to identify points near the preferred site location with the best possibility for completing a well successfully. Normally a prime site and one or two alternate sites were chosen in this manner.

Two basic tools were used in the site selection process; aerial photographs and the earth resistivity instrument. Aerial photographs were used primarily to determine population distribution, establish access routes and determine field location. Relatively good success was achieved in using the resistivity technique to locate most of the well sites in decomposed rock at a reasonably low cost. However, in areas where difficulty was encountered in locating suitable well sites deep bedrock fracture systems were identified on the aerial photographs. This technique however required considerable experimentation.

Although the earth resistivity technique was used to identify sites with reasonable confidence, this did not guarantee that a successful well could always be completed. This was particularly so in schist rocks where the determining factor was often the presence of shattered quartz veins whose presence could not be determined by this method. The resistivity survey nevertheless proved a valuable tool in guiding the well drilling operation and reducing the number of dry holes.

Drilling Operations

The air-rotary and mud-rotary drilling techniques were used to complete wells on the Project. The air-rotary technique was used wherever possible primarily because it made the identification of water bearing

zones much easier. However, caving conditions, particularly in schist terrain, sometimes forced the use of the mud-rotary technique.

Three rotary drilling machines were used for the construction, one Gardner Denver 15W rotary table drive and two TH60 Cyclone top drive machines. For pilot holes 4-7/8 inch insert bits were used while for hand pump well completion 6-1/4 inch rock bits were used. Down the hole hammers were used for drilling in the hard rock.

At the outset of the programme, electric logs (resistivity and self potential) were taken in many testholes in order to assess the technique as means of identifying water bearing zones. Although in some cases the E-log provided useful information, normally the E-log was not helpful in selecting water bearing zones. In any case this was not critical since air drilling was the normal method and therefore, identification of water bearing zones was quite easy.

Well Completion

All wells drilled were completed with PVC casing manufactured in Ghana. For hand pump wells PVC casing with an internal diameter of 100 mm was used while for mechanized wells casing with internal diameters of 150 mm and 200 mm were used. A section of slotted casing was placed opposite the water bearing zone. The slotting of the pipe was done by machine at the Project base workshop. Slot sizes ranging from 0.028 inches to 0.060 inches were used.

The slotted casing produced on the Project was found to be quite adequate for the hand pump wells and resulted in a very economical installation as compared to using wire round screen. The use of slotted PVC casing for completion of mechanized wells also proved satisfactory. Step drawdown tests on the mechanized wells indicated no serious loss of efficiency in spite of the open area being less than that for wire wound screens.

A gravel pack stabilizer was placed in the annular space between the screen and the water bearing zone. During the first phase, this stabilizer material was obtained from Tema, the main Port for Ghana, where there was a beach sand quarry operation. Some alluvial sands in the Upper Region were found to be satisfactory for stabilizer material and were used to supplement the supplies obtained from Tema.

Each well was completed with a cement pad, and the upper ten feet of the annular space around the well casing was filled with cement as an integral part of the pad. The cement pad extended one foot above normal ground level. Then the pad was backfilled with coarse aggregate thus providing good drainage away from the well head. Wherever possible the local villagers were relied upon to place the back-filling material.

On completion each well was pump tested. For hand pump wells, one-hour pump tests using the rig pump were conducted, while for mechanised wells pump tests lasted 24 hours using submersible pumps. To eliminate the possibility of contaminating the groundwater during the drilling operation, it was standard practice to chlorinate the drilling water. On completion of the pump test, each well was disinfected with a concentrated chlorine solution. Also when the hand pump was installed in the well all parts were washed with a concentrated chlorine solution. Similarly, whenever the pump was removed from the well for repair or inspection, it was washed with chlorine solution before re-installation. As a further precaution against contamination each well would be chlorinated at least once a year as part of the well maintenance programme.

For the intermediate size towns, extensive test drilling and pumping of test wells was undertaken, to determine groundwater availability and subsequently establish well fields in the most suitable locations.

Selection and installation of hand pumps

It was recognised at the outset that a durable hand pump would be required to meet the conditions in the Upper Region, where the hand pumps will serve as a community pump. The selection of the hand pump was therefore done with the greatest caution and in stages.

Prior to the Project, Ghana has had some experience with two types of hand pumps, about 300 of which had been in use in the Upper Region for some time. Both types of pumps did not give satisfactory performance due to constant failures, so it was decided that a different make of pump should be considered for the Project needs.

Search for hand pumps

The experiences of some international organisations on hand pumps were solicited and extensive literature review was made. Contacts were made with known hand pump manufacturers. Two types of pumps were identified as possibly meeting the requirements of the Upper Region and these were evaluated over a six-month period through field and shop tests. As there was still some uncertainty about the long term performance of both types of pumps, one type which at that time was much preferred was selected and an order was placed for only 500 units.

Sometime after the installation of these pumps, a number of deficiencies and failures were identified. Through the Well Maintenance Programme which was already in place, extensive modifications were made, some of which involved the manufacturer and the problems were alleviated to a large degree. Various design changes intended to overcome the deficiencies were incorporated into the order of the next lot of pumps.

Field testing of pumps

In spite of the respectable service performance which was achieved there was the need for a higher order of durability in future pumps. Efforts were continued to identify a hand pump suited to use as a community pump in the rural conditions of the Upper Region. It became clear that the only means of selecting a type of pump, was through a field test evaluation programme of hand pumps available on the world market. Fifty hand pumps from 15 different manufacturers from 10 different countries were subjected to test under normal use conditions in the Upper Region. The hand pump evaluation programme was run for two years. Recommendation was made for the selection of two types of pumps to be installed in the Upper Region using the following criteria: (i) Test performance of pump (ii) long-term cost of pump (iii) suitability of pump to eventually being partially maintained at the village level as a means of minimising the long-term maintenance cost.

Hand pump installation

The hand pumps were installed by separate crews using service rigs. The hand pump base plates were set in concrete as part of the drilling operation thus facilitating the installation of the pumps later.

ESTABLISHMENT OF WELL MAINTENANCE PROGRAMME

With the large number of well water supplies being installed in the Upper Region, it was evident from the outset that a comprehensive well maintenance programme should be established.

The objective was to assist the existing GWSC Regional Maintenance Organisation expand its capability to provide long-term repair and service for the new water supplies provided by the Project. The support provided was in the form of plant, equipment and technical assistance.

The programme was implemented by establishing five maintenance districts at Wa, Bawku, Tumu, Lawra and Bolgatanga. In each district, a system of motorcycle inspectors, service trucks crews and workshops was provided.

The GWSC Regional Manager is responsible for the programme and provides general direction. The Regional Engineer assisted by maintenance engineer and field supervisors are responsible for its continuous function. A total of 250 GWSC workshop and field staff with a core of trained and experienced technicians and supervisors were assigned to maintenance. Two Consultant advisers also participated in the programme.

Field operation

Each of the district organisations operate independently under the general direction of the Regional Office represented by the Maintenance Engineer and Field Supervisor. The District Officer is responsible for the repair, servicing and maintenance of wells in his district. Records are compiled to monitor the performance of each hand pump and each mechanised pump. These records are based on field reports completed by the motorcycle inspectors at the time of each inspection, and by the service truck crews at the time any repair or maintenance work is performed on a pump.

Due to the poor access to the pumps occasioned by the limited road network, and due to the ever-increasing cost of fuel, it was decided to utilize lightweight trail motorcycles for routine inspections of the hand pumps. The inspection is along designated routes, providing a site visit every two to three months on the average.

Eight motorcycle inspectors based at the five district centres carry out oiling of the pumps, provide preventive maintenance as well as make minor repairs and report pump failures. Through the inspector's site visit a rapport is established with the villagers, educating them on pump usage, water conservation and well-head sanitation. Approximately 80% of the total hand pumps in the Region are inspected each month.

Eight specially equipped service vehicles also based in the districts carry out major repairs on the hand pumps which cannot be completed by the inspector. These units do not make routine inspections, but respond only to reports from the inspectors or the villagers of hand pump failures. The service vehicle crews undertake also maintenance and repair of mechanised well pumps and periodic chlorination of the wells and pumps.

Normally a reported breakdown of hand pumps is scheduled into the work programme of the service vehicles. A response time of pump repair is at least 3-4 days after a failure is reported.

The workshop services include repair of the maintenance vehicles and motorcycles; repair of pumps and storage and control of supplies tools and equipment.

Radio communication has been established between the districts to facilitate the regional maintenance functions.

The objective of the Well Maintenance Programme is to maintain a performance level of 95% of the hand pumps in operation at any point in time. However, since July 1976, a continuous serviceability of 90% of the hand pumps has been maintained and this is considered an acceptable pump performance. With the staff and equipment now in place and through a continuous training in technical skills and communication with the villagers, it is expected that a higher level of service will be maintained in the long term.

CONCLUSION

By the end of the Project, the main objective of providing safe water for domestic purposes to the majority of the rural population of the Upper Region should be met. The maintenance programme which has been set up will aim at ultimately involving the villagers in the servicing and repair of the hand pumps, and in maintaining sanitary conditions at the well sites. These will be done through an educational campaign.

A number of Ghanaians have acquired expertise, that it is hoped, they will be able to carry out a similar operation in other parts of the country on their own.

The Collaboration which was achieved between Project Management and equipment and other material suppliers on one hand and with various government and international organisations on the other, during the Project has provided an intercourse between the various bodies and has proved invaluable in fostering better relations between Ghana and Canada.