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Country Report: The Gambia

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PREFACE

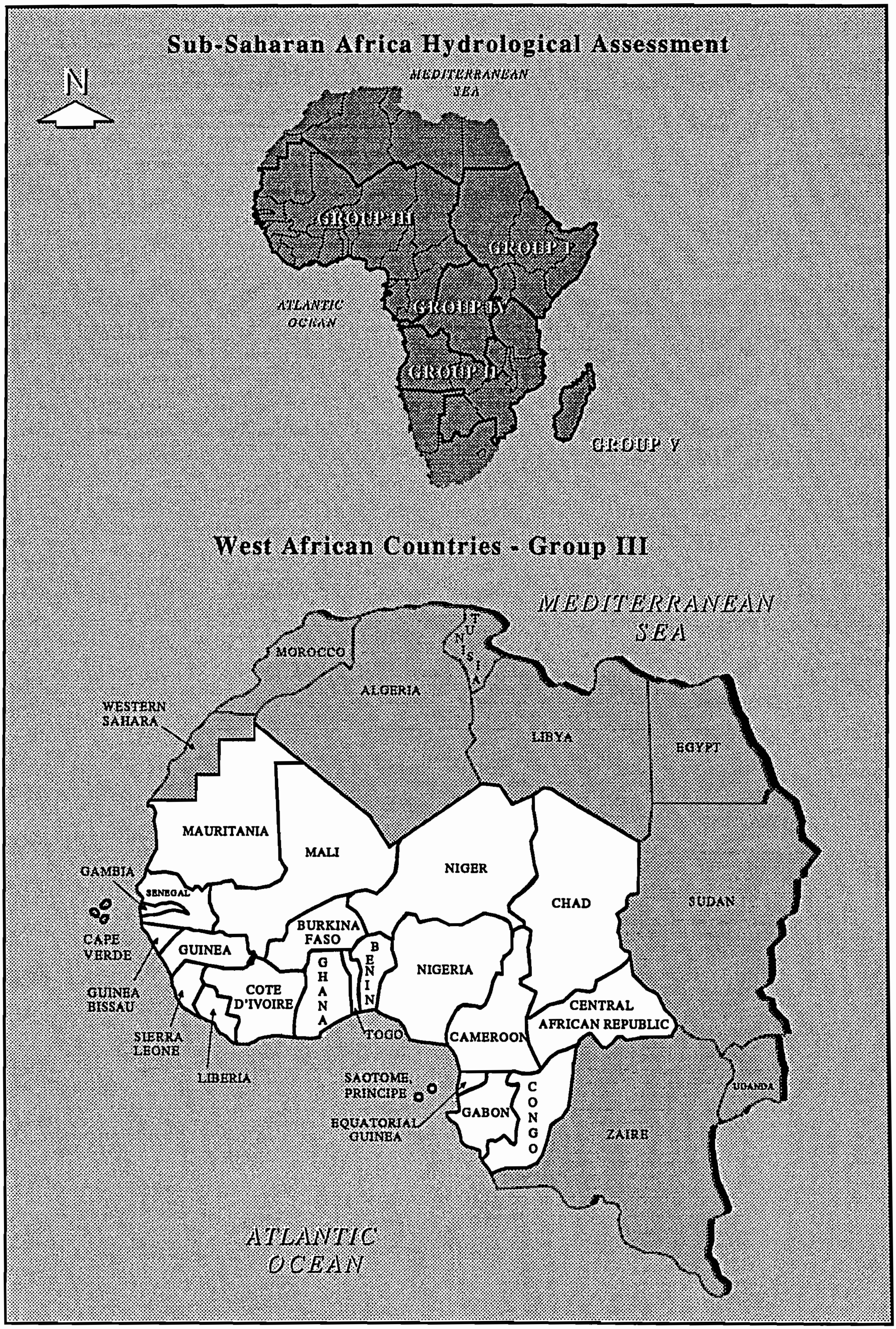
This study is the third tranche of a regional hydrological assessment for sub-Saharan Africa funded by UNDP (Project Nr RAF/87/030), the African Development Bank, and the French Fund for Aid and Co-operation. The study covered twenty three countries in West Africa and started in September 1990. The countries were visited by members of the study team between November 1990 and November 1991. The total time allocation for each country averaged six weeks, of which half was spent in the Consultants home office. In 17 countries the Consultants were assisted by CIEH. The organisation of the study was such that the assessments have been carried out by staff from Mott MacDonald International, BCEOM, SOGREAH, ORSTOM, and a number of local consultants from the region. Every effort was made from the outset to ensure consistency of approach and homogeneity of assessment.

The purpose of the project was to evaluate the status of all existing hydrological data collection systems and to make recommendations to enhance the performance of these systems, the ultimate aim being to assist the countries in the establishment or improvement of a sound hydrological database for the purposes of planning and evaluating water resource development programmes and projects. The goal was to identify those areas where international support would be required, and to develop these recommendations into project proposals in a format suitable for donor financing.

The national assessments, recommendations, and identified project proposals have been published in individual country reports. In addition there is a 'regional' report which supplements the country reports by covering aspects of the study which require assessment at a regional or basin level. It also summarises the common features of the country assessments, and includes a number of project proposals for activities which cover all or part of the region.

This report is based on information obtained and documents collected during a mission to The Gambia during the period 11-28th June 1991. The mission was undertaken by staff from Mott MacDonald International.

We wish to place on record our appreciation of the help of the many people, too numerous to mention, who assisted us during the visit.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ABBREVIATIONS

International

AGRHYMET	Regional project of CILSS/WMO/UNDP
CILSS	Comité Inter-états de Lutte contre la Sécheresse dans le Sahel, Niamey, Niger
DARE	Data Aquisition and Rescue Project, International Data Co-ordination Centre, Brussels, Belgium
EDF	European Development Fund
IMF	International Monetary Fund
KfW	Kreditanstallt fur Wiederaufbau, German aid
NGO	Non Government Organisation
NORAID	Norwegian aid
OMVG	Organisation de Mise en Valeur du fleuve Gambie, Dakar, Senegal
ORSTOM	Institut Français de Recherche Scientifique pour le Developpement en Coopération
UNDP	United Nations Development Programme
UNDTCD	United Nations Department for Technical Cooperation and Development
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations Childrens Fund
UNSO	United Nations Sudano-Sahelian Office
USAID	United States Agency for International Development, American aid
WHO	World Health Organisation
WMO	World Meteorological Organisation

National

DWR	Department of Water Resources, Ministry of Natural Resources and the Environment
GUC	Gambia Utilities Corporation
MEPID	Ministry of Economic Planning and Industrial Development
MFC	Mixed Farming Centres, Ministry of Agriculture

Technical

BOD	Biological Oxygen demand
COD	Chemical Oxygen demand
EC	Electrical conductivity
GNP	Gross national product
GSD	Gambia Survey datum
TDS	Total dissolved solids
UPS	Uninterruptable power supply
VGA	Video graphics adaptor
1°/oo	One part per million, definition of saline water

UN Rate of Exchange (June 1991) US$ = Dalasis 8.60

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SUMMARY

The Gambia's unique geography has an important bearing on the hydrological assessment. The small size of the country, its low elevation and lack of relief results in an unusual uniformity of climate across the territory. Even rainfall, which varies from 1 100 mm in the coastal south-west to 700 mm in the interior north-east, changes smoothly across the country. The rainy season from June to October provides all but 1 to 2% of the annual total. Rainfall records display the regional trend towards lower rainfall in the past two decades.

The country is bisected by the Gambia River which rises in Guinea and passes through Senegal before flowing the length of The Gambia. The Gambia River through The Gambia has a gentle gradient and tidal influence is still apparent as far upstream as the Senegal border. As with rainfall, runoff is highly seasonal and freshwater flow in the Gambian tributaries to the main river is perennial. As a result of this seasonality in river flow the salt/freshwater boundary (taken as the 1‰ salinity) shifts from a maximum penetration of 250 km in the dry season to 100 km in the wet season. The position of the boundary is also dependent on the depth at which the measurements are taken since dense seawater may underlie freshwater. The presence of saline water so far inland has important consequences for the population. Most drinking water is obtained from groundwater which is found at shallow depth and of good quality over practically the whole country. The potential for irrigation using surface water is dependent on the position of the salt interface. Proposals have been made for a combined tidal barrage/bridge to fix the position of the saline/freshwater interface but this is unlikely to proceed as it is at present considered uneconomic.

Water resources and climatic monitoring in The Gambia are the responsibility of the Department of Water Resources, Ministry of Natural Resources and the Environment. Within the Department there are divisions for meteorology and hydrology, groundwater is the responsibility of the Rural Water Supply Division.

Meteorological data is primarily required for improving agricultural production. The network is well maintained and equipped, largely by the CILSS/WMO/UNDP AGRHYMET project. Regular 10-day bulletins are published as part of AGRHYMET and these are regarded as very useful. The continued support of AGRHYMET appears assured. The Meteorology Division presently has staffing and logistic problems. There are two main staff problems: a lack of professional staff, and a high turnover of trained observers. The former is a national problem affecting all the activities of the Department of Water Resources and is discussed further below. The latter should be capable of resolution particularly if the logistical problems can be dealt with. Logistical problems are dominated by the lack of transport; there is a single 4-WD vehicle shared with the Hydrology Division and therefore it is not currently possible to increase the number of stations visited.

The calculation of fluvial flows in the Gambia River is extremely difficult because of tidal influences. In the dry season the fluvial flow may be only 1 to 2% of the total flow and a specially designed campaign of measurement is required lasting from a minimum of two tidal cycles up to periods of a lunar month or more. There are at present no stations in The Gambia with full range, up

to date, rating curves. The Hydrology Division lacks the necessary equipment to carry out the required current meter measurements. It is recommended that automatic water level recorders should be installed to monitor tributary catchments where the rainfall-runoff response is rapid and twice daily staff gauge readings are inadequate to record the hydrograph accurately.

The Hydrology Division is below complement and suffers from the same shortage of professional staff as the Meteorology Division.

Groundwater is a major resource of The Gambia, which already supplies most of the rural and urban potable supplies. It is well documented with several good regional and country-wide reports, issued with the assistance of United Nations agencies and international consulting organisations. A further country-wide hydrogeological study, financed by EDF, is about to be started in mid-1991.

The groundwater monitoring network recently reactivated under the UN groundwater project comprises 155 wells, 120 measured quarterly and 25 measured monthly. It is evident that networks of this size cannot be sustained beyond the life of the instituting assistance project, they require greater staff and logistical inputs than the Department of Water Resources can make available long term. It has been recommended that it would be better to concentrate resources on a smaller network (of say 20 to 30 sites) and to take measurements more frequently, preferably daily but at least weekly. A network of this size would leave sufficient resources to introduce regular water quality monitoring. Upgrading of the water quality laboratory facilities is also a pressing need.

Whilst training of junior staff and observers is well handled by the Department's training school the build up of a cadre of professionals in the fields of water resources is beyond the country's resources and overseas training will remain the only answer in the foreseeable future. There are well established training centres in neighbouring countries which could be used to provide much of the required training. This subject is addressed in a regional project proposal.

Four project proposals have been formulated for The Gambia. They cover the strengthening of the Meteorology and Hydrology Divisions, particularly addressing some of the logistical problems which constrain these services at present. As groundwater is presently benefitting from a major assistance project we have identified the upgrading of the laboratory facilities as being a suitable project for future consideration.

CHAPTER 1

GENERAL BACKGROUND

1.1 Geography

The Gambia, one of the smallest countries in Africa, lies on an east-west axis on the banks of the Gambia River. It lies between longitudes 16° 50'W and 13° 45'W and latitudes 13° 00'N and 13° 50'N. The country is 480 km long and nowhere is it more than 50 km wide. Its total surface area is 11 000 km^2 (some sources give it as 10 400 km^2). Most of the country is low lying with only a few points above 50 m elevation.

The main topographical feature is the River Gambia which runs through the country for almost 500 km. The river is tidal for the whole of its length in the country. The interface between salt water, taken as a concentration of 1‰, is 100 km from the sea in the rainy season and 250 km in the dry season.

To the west the country faces the Atlantic Ocean along a 50 km coastline but on all other sides it is surrounded by Senegal.

The country is divided administratively into five units: Western Division, Lower River Division, North Bank Division, MacCarthy Island Division, and Upper River Division. These are shown on Figure 1.1.

1.2 Climate

The rainfall in the country varies from 1 100 mm in the south-west to 700 mm in the north and east. The rainfall is highly seasonal with all but 1 or 2% falling in the period June to October. The small size of the country and the lack of relief means that there is little variation in the climate over the country, other than the difference in rainfall. An isohyetal map is shown on Figure 1.2. This map was specially prepared for this report and used rainfall for the period 1961 to 1990. As with many countries in the Sahel there has been a steady reduction in apparent annual rainfall. For example the isohyetal lines on Figure 1.2 are some 100 to 200 mm less than the equivalent lines on a similar map for the Gambia River basin produced by ORSTOM but using data for the period 1951 to 1980. This point is further discussed in Appendix D.

1.3 Water Resources

As far as drinking water is concerned all the piped water supplies in urban centres rely on groundwater. In the case of the capital city, Banjul, three different borehole fields are in use. For rural drinking water, again the use of groundwater predominates. This is in part due to the availability of groundwater in all parts of the country but also the fact that the River Gambia is saline for much of its length within the country and freshwater flow in the tributary rivers is insignificant in the dry season.

Most of the agriculture in the country is rain-fed and there is relatively little pumped irrigation. One small pilot scheme exists. The essential difficulty related to increasing the area irrigated is that the Gambia River is saline for much of its length and any additional abstractions from the river for irrigation would move the saline/fresh water interface further upstream thereby depriving low-lying areas, at present able to get irrigation water at high tide, of fresh water. The dry season flow of the Gambia River can not be determined with any great precision as the relatively large tidal flux dominates any small flow in the river. It is estimated to be not larger than 3 m^3/s. There are a few horticultural areas which use groundwater but these are mostly small scale using wells with manual methods of lifting the water.

Groundwater

The Gambia is underlain by Mesozoic and Cainozoic sedimentary sequences, some members of which are water bearing. Groundwater quality in these aquifers is normally good and they constitute the most important water resource of the country; practically the whole of the population relies on wells and boreholes for potable supplies.

Two main aquifer systems have been identified in The Gambia: - the upper, Miocene to Pleistocene (Continental Terminal) coarse detrital sediments and the lower, Maestrichtian to Palaeocene sandstone. The upper system comprises two units, termed the phreatic and semi-confined aquifers, separated mainly by silts; these sands are normally encountered at 10 to 120 m depths. The lower aquifer occurs at 250 to 450 m depth and comprises loosely cemented calcareous sandstone, interbedded with marl, silt, clay and thin limestone bands.

Groundwater quality in the upper aquifer is good, except where influenced by sea or estuarine surface water. In the lower aquifer, salinity increases from east to west and potable groundwater probably occurs only to the east of Kau-ur.

The overall recharge to the shallow aquifer has been computed as about 600 million m^3/annum on average (Ceesay and Howard Humphreys, 1987). Most of this is from direct infiltration of rainfall on Gambian territory. The deep sandstone aquifer is recharged on its outcrop in Senegal but some of the throughflow reaches The Gambia; under present conditions this throughflow is estimated at about 1.75 million m^3/annum.

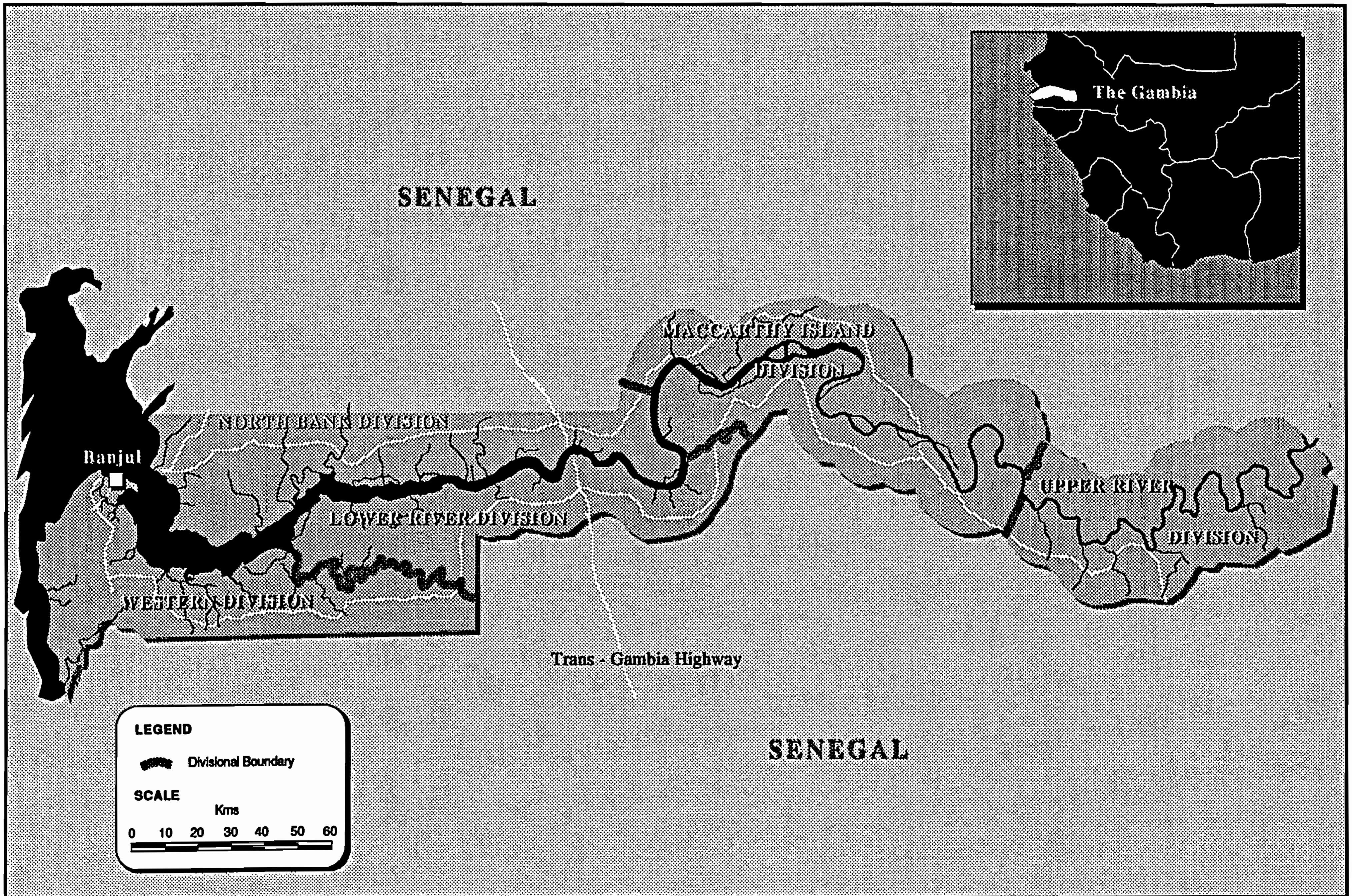


Figure 1.1
Administrative Divisions

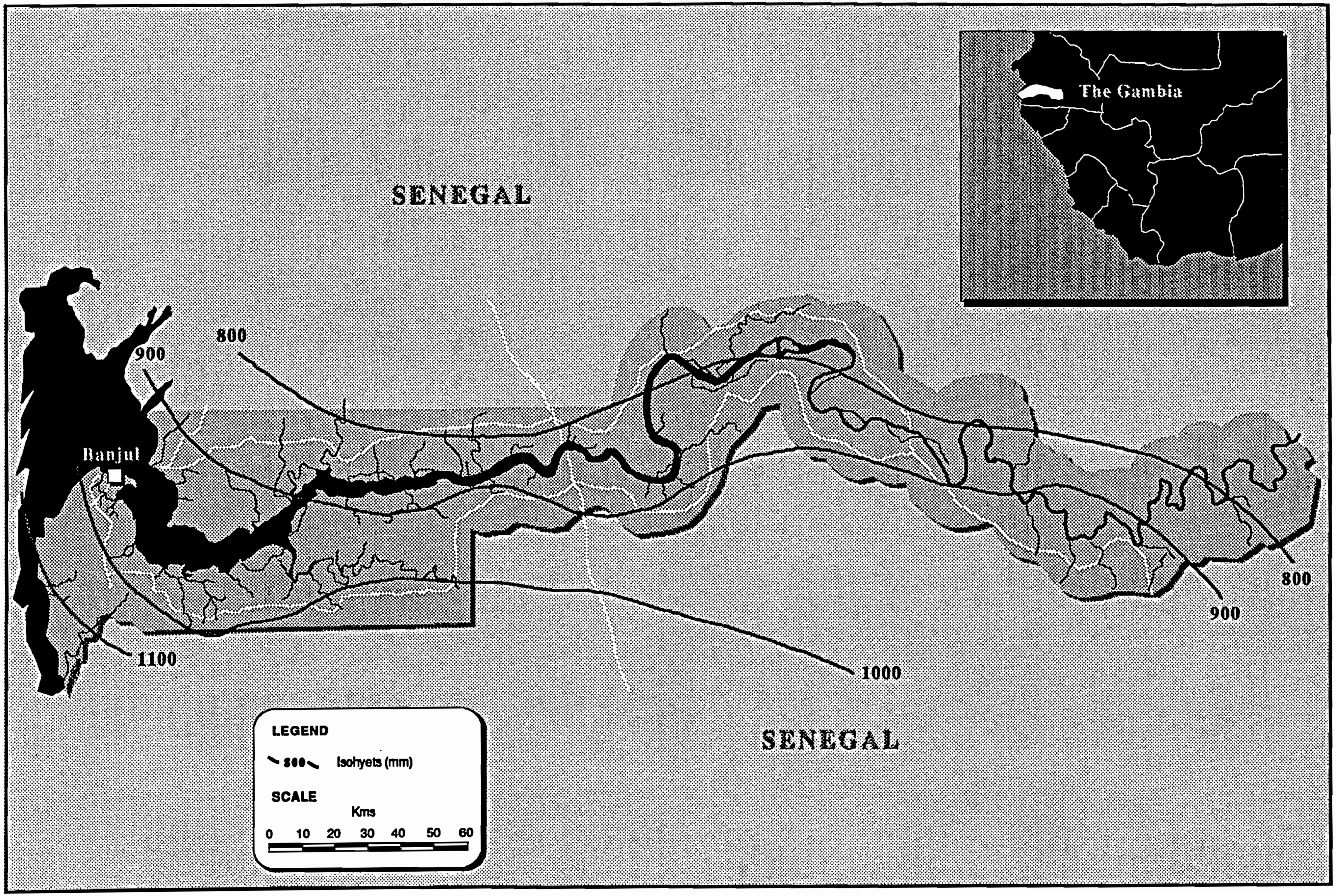


Figure 1.2
Isohyetal Map

Groundwater abstractions are by dug wells and shallow boreholes for rural water supply and deeper boreholes for urban supplies. Modern village sources are equipped with hand pumps. Provincial town supplies are pumped with electric submersible deep well turbines to header tanks for distribution by standpipes. The capital area (Banjul and North Kombo) is served by wellfields connected to treatment works and a full piped distribution system. Total groundwater abstractions in The Gambia are estimated as approximately 15 million m^3/annum (UNCDF, 1988).

1.4 Population

The first census of The Gambia, in 1901, gave a population of less than 100 000. By 1921 this had grown to just over 200 000. The population then grew relatively slowly reaching 310 000 in 1963. At the time of the last census (1983) the total population was 688 000 and is now, in 1991, estimated as 900 000 (the 1983 figure increased at the growth rate of 3.4% per annum indicated by that census). The birth rate has remained almost constant at 50 per thousand population over the last 20 years but the death rate has dropped from 30 to 20 per thousand. The total fertility rate (births per female) is 6.5.

The main urban centre is Banjul, the capital, with a population (1983 census) of 44 200. There is however a largely urban area surrounding Banjul and the population of this 'greater' Banjul, including the city itself, was 179 100. Outside of this conurbation the main centres classed as urban are:

Brikama	- 20 300 (on the southern edge of greater Banjul)
Farafeni	- 10 000
Basse	- 5 700
Bansang	- 4 100
Georgetown	- 3 300
Kerewan	- 3 100
Kau-ur	- 2 700
Kuntaur	- 2 100

The population of these centres accounts for one-third of the population - the remainder are classed as rural. These figures are taken from the 1983 census and it would be difficult to estimate the present population of these centres as that census demonstrated that there had been large migration from rural to urban areas leading to a higher than average growth in the towns. To what extent this trend has continued can only be known after the next census.

There are at least eight ethnic groups represented in The Gambia - each with its own language, traditions and cultural habits. The three most populous groups are the Mandinka (42%), the Fula (16%), and the Wollof (16%). There is, however, a harmonious relationship between the groups with frequent intermarriage and many people are able to speak the language of more than one group.

1.5 Health

The life expectancy at birth is 43 years (estimate for 1986-88) up from 33 years in 1973. As in many African countries the low life expectation is to a large extent a result of a high infant mortality rate which in The Gambia is 167 per 1 000 live births. Of the under fives 48% of the deaths occurred in the first year, 23.6% in the second year and 15.5% in the third. Of the deaths in the first year almost half are classed as perinatal. Many of the perinatal deaths occur as a result of lack of facilities to deal with difficult deliveries and septicaemia due to poor hygiene. The main causes of infant mortality are acute respiratory infections (17% of deaths), malnutrition/diarrhoea (16%) and malaria (14%).

1.6 Education

In 1985 the adult (15 plus) illiteracy rate was estimated as 77.4%, down from 89% in 1970. The proportion of school age children enrolled in school is 57%, the number of children in school having more than doubled in the ten years from 1976. In 1983/4, the country had 179 primary schools, 16 secondary technical schools, and 8 high schools. Apart from a teacher training college there are no further education institutions in the country. This is a severe constraint on the development of technical services as even for a first degree foreign study is necessary before further specialised training to master level in hydrology or hydrogeology can be contemplated.

1.7 The Economy

The country's Gross National Product (GNP), at market prices, in 1988/89 was 1 489.5 million Dalasis (US$1 = 8.33 Dalasis in March 1989). The per capita GNP was $270. The main components of the GNP are Agriculture (34.1%), Industry (10.3%) and Services (55.6%). The total contribution of groundnuts, the country's main export crop, was 10.0% (of which 2.2% was trade in groundnuts). This was down from 33.5% (of which 14.3% was due to trade) in 1974/5. Groundnuts and groundnut products earned $17.3 million in export earnings in 1988/89, with tourism accounting for $41.5 million and the re-export trade estimated as $78.5 million. The figures for the re-export trade are approximate as some two-thirds of it is not officially recorded.

Over much of the last ten years the country has been applying an Economic Recovery Programme. This has involved a freeing of the currency exchange rate and attempts to reduce government spending. Many of the objectives of the programme have been achieved, including a growth rate which has averaged 4% over the last five years, but there still problems in income distribution resulting from the changes. It is also becoming apparent that the use of a floating exchange rate has adversely affected the profitability of the re-export trade which may lead to it making a less important contribution to exports in the future.

CHAPTER 2

WATER RESOURCES

2.1 Surface Water Resources

Surface water is relatively little used in The Gambia. Firstly, the flat nature of the country's terrain means that not only is the River Gambia itself saline for much of its length in the country but many of its tributaries are also saline for several tens of kilometres upstream of the confluence. Secondly, whilst in the past some of the tributaries are reported as having had perennial flow, none of the tributaries now flow all the year round.

The River Gambia is tidal for the whole of its length in the country and a tidal variation of 100 mm has been recorded at Gouloumbo in Senegal more than 500 km from the mouth of the river. The tidal length is such that when high tide is recorded at Banjul, at the mouth of the river, the previous high tide has just reached Bansang, 315 km from the mouth, and the one before that would have reached Gouloumbo, 526 km from the sea, only a few hours before.

The flow in the Gambia River is highly seasonal. The maximum occurs at the end of rainy season in late September or October. The maximum recorded at Gouloumbo, in Senegal just upstream of the national boundary, was 2 100 m^3/s on 15 September 1961. In recent years the maximum has been lower and since 1967 the maximum has always been less than 1 500 m^3/s. The lowest flow gauged at Gouloumbo was 4.48 m^3/s on 26 January 1984. This figure is likely to be higher than the lowest flow in the river as flows will decline until the end of the dry season which occurs in June. Unfortunately no gaugings have been made at this time of year and the rating curve is very unreliable for low flows owing to the tidal effects of the river. There have been a number of attempts to assess the flow of the river within the tidal reach. One of these was conducted by Howard Humphreys as part of its study of the river and another was carried out by the British Hydraulic Research Station. These studies are discussed in more detail in Section 4.2.2. What they demonstrate is that there are variations in both level and flow with a periodicity of 13 hours (a single tidal cycle) and 28 days (a lunar cycle) which mask the variations in level due to freshwater inflow.

One effect of the variation in flow is that there is a marked variation in the position of the interface between fresh and salt water. In the dry season the interface, defined as the point at which the salinity is 1 ‰, is 250 km from the sea. In the rainy season the increasing river flow pushes the interface downstream until by October it is only 150 km from the sea.

The Gambia River catchment is shared between the Republic of Guinea, Senegal, Guinea Bissau and The Gambia and since 1978 plans for the development of the resources of the river have been co-ordinated by an international body widely known by its French title the Organisation de Mise en Valeur du fleuve Gambie (OMVG) - Gambia River Basin Development Organisation.

There are no existing reservoirs on the Gambia River. There are however a number of proposals both for reservoirs and for a barrage. In the case of reservoirs the proposals are for dams to be built in Senegal or Guinea. These would be both for irrigation and for hydro-power. The proposed barrage would be built on the River Gambia within the country some 130 km from the mouth of the river. What is planned is to have a barrage with the dual function of preventing salt water from moving upstream of the barrage and also providing a road crossing of the river. At the moment it is unlikely that either the reservoirs or the barrage will be built in the foreseeable future. That is because neither the reservoirs nor the barrage are economically attractive and the barrage would also have severe negative environmental consequences. This point is covered in more detail in Section 2.3.6.

A major study of The Gambia, funded by UNDP, was published by Howard Humphreys in 1974. This study, entitled 'Hydrological and Topographical Studies of The Gambia', looked in great detail at the flows of the river, including flow measurements, establishing rating curves, preliminary frequency analysis, and some sediment measurements; but the assessment of water resources opportunities was carried out on the basis of published maps only. Other studies have looked in more detail at specific options such as the dams and the barrage. Under funding of USAID, and working with the Gambia River Basin Development Organisation, a long term study of the whole river basin has been carried out. The studies, carried out by the University of Michigan and Harza Engineering, were published in 1985 as one volume summarising the studies, four volumes looking at specific aspects and, over a period of several years, 70 specialised papers.

The river is navigable throughout the year and ocean going craft of up to 5.5 m draft (3 000 tons) can reach Kaur 201 km up river.

2.2 Groundwater Resources

2.2.1 Background

The Gambia is well endowed with groundwater resources. Water of good quality in reasonably productive aquifers is found at shallow depth over practically the whole country. In the absence of year-round availability of fresh water from surface sources, wells have probably been used for potable supplies for hundreds of years. However, technical literature on local hydrogeology and groundwater development is all very recent (mainly from the last 20 years).

Because of the nature of its geology, which is not very promising for occurrences of valuable minerals, The Gambia lacks the strong geological base, provided by the colonial administrations in other British ex-colonies in West Africa. Apparently in the mid-1920s, a member of the Gold Coast Geological Survey undertook a short appraisal and produced a geological map of The Gambia followed by a report (Cooper, 1927) describing his findings; although he identified the main features of surface geology as well as some heavy mineral concentrations of possible commercial value, it was not until the 1950s that a British mining company (Gambia Minerals Ltd) carried out further surveys and actually exploited titanium ore from a sandy deposit near the coast.

In the meantime, also in the 1950s, relevant work was undertaken in the adjacent Francophone countries. Michel, working on the geomorphology of Senegal, included The Gambia in his publications issued in 1960 and 1973. Tenaille et al (1960) reported on the subsurface conditions in the region, based on petroleum exploration. At the same time, prospecting for oil in The Gambia confirmed the occurrence of aquifers in the upper strata (BP-BRP Exploration (Gambia) Ltd, 1960 and 1961) and the first drilled water well, penetrating into the deep sandstone aquifer, was installed in Banjul.

In the late 1960s and 1970s the pace of geological work related to mineral exploration increased, following UN sponsored studies of The Gambia by Veltheim (1969 and 1971). In particular Matthew Hall Ortech Ltd (1976a, 1976b and 1977) investigated titaniferous sands, whilst the UN assisted the evaluation of other deposits of economic potential (kaolin and brick clay). However it was not until 1988 that a comprehensive treatment of the country's geology was published (Whyte and Russell, 1988); this included 1 : 250 000 scale geological mapping based on fieldwork and photogeology (using 1 : 25 000 scale aerial photographs); all previous work was incorporated in this treatment, including subsurface data from oil exploration and drilled water wells.

Systematic technical work on groundwater in The Gambia started in the 1970s. The first appraisal of the country's hydrogeology was included in Howard Humphreys' 'Hydrological and Topographical Studies of The Gambia River Basin', issued in 1974. During the late 1970s the same organisation carried out more detailed work concerned with borehole construction for Banjul water supply (Howard Humphreys, 1978a) and with evaluation of groundwater resources of the Kombo Peninsula (Howard Humphreys, 1978b).

Simultaneously various UN agencies undertook groundwater work in the country, mainly concerned with rural water supply and institution strengthening. Notable UN assisted projects include:

- Rural Water Supply GAM/74/007; UNDP financed, UNDTCD executed.

- Water Well Drilling in The Gambia UNSO/CILSS/GAM/204; UNSO financed, used consultant (PHZ Polservice).

- Rural Water Supply and Groundwater Development GAM/82/088; UNDP and UNICEF financed, UNDTCD executed.

- Rural Water Supply GAM/80/C04; UNCDF assisted.

- Preliminary Investigations of Groundwater and Experimentation of Pumping Systems GAM/82/T01; UNDP and UNIFSTD financed, UNDTCD executed.

- National Strategy for the Environmentally Sound Management of Groundwater Resources in The Gambia UNSO/DEC/GAM/82/X04; UNSO financed, used consultants.

- Groundwater Resources Planning and Development GAM/87/002; UNDP financed.

- Well Construction in Rural Areas GAM/86/C02; UNDP assisted.

- Solar Powered Equipment in Rural Areas GAM/86/C01; UNCDF financed.

Only short appraisal reports are available for most of these projects. As far as can be ascertained the major accomplishments of the UN efforts have been the installation of about 500 modern dug wells, some two thirds of them equipped with hand pumps, and of 28 boreholes equipped with small electrical turbines and generators. Of special interest has been project GAM/82/T01, which installed two wind powered and one solar pump; a full report of these activities was issued in 1986.

In addition, in 1983, UNDP/UNDTCD assisted the Ministry of Water Resources and the Environment to prepare the most comprehensive evaluation of groundwater resources to that date, under the title of 'Groundwater Resources of The Gambia, Preliminary Report'. However, in 1987 this was superseded by what remains the fullest treatment of The Gambia's hydrogeology, namely 'Groundwater Survey Studies of The Gambia' (Ceesay and Howard Humphreys, 1987); this includes hydrogeological maps of the whole country at the scale of 1 : 125 000 and discusses in some detail both the shallow and the deep sandstone aquifers.

Lastly, two bilateral aid projects undertaken during the UN Water Supply and Sanitation Decade, deserve mention. The KfW (German aid) project implemented by GITEC, has not only constructed over 300 fully equipped dug wells but also produced a whole series of excellent reports on subjects varying from feasibility study of rural water supply, through computerised database for well records, to maintenance systems for hand pumps; the project started in 1980 and is still continuing. The other is the Saudi Sahelian Programme, executed by German consultants, which installed 120 dug wells and 68 boreholes, all equipped with hand pumps, as well as 8 boreholes with electric pumps and generators.

2.2.2 Geology

The Gambia is located on one of the major sedimentary basins of Africa, usually referred to as the Mauritania/Senegal Basin. Its formation was associated with the break-up of the ancient continent of Pangea during the early Mesozoic into what are now West Africa and North America. The floor of the basin is probably down-faulted by a series of step faults, so that the thickness of the sediments increases westwards, towards the Atlantic; at the coast the basement is known to plunge steeply under the continental shelf. As a result of this, the country is underlain by a series of almost horizontal Mesozoic and Cainozoic strata, comprising mainly limestones, marls, shales and sandstones. The uppermost succession, relevant to groundwater occurrence, is given in Table 2.1.

TABLE 2.1

Geological Succession Underlying The Gambia

ERA/System	Stage/Formation	Lithology
CAINOZOIC		
Recent		Aeolian and alluvial deposits
Pleistocene - Pliocene	Continental Terminal	Fine to medium sands, silts, clays with laterites and occasional limestones
Miocene		Shales and marly fine sands with subordinate limestones
	Unconformity	
Oligocene		Marly limestone
	Unconformity	
Eocene		Shales and marly limestones with band of chert near base
Palaeocene		Chalky and white marly limestones with intercalations of black shale; sandy facies at the extreme east and west
MESOZOIC		
Cretaceous	Maestrichtain	Fine to coarse sandstone with grey to black shales, phosphatic nodules and lignite bands
	Campanian	Grey clays and marls with calcareous sandstones, dolomitic limestones and lignites

Source: Cessay & Howard Humphreys, 1987 and Whyte and Russell, 1988

Because of the flat topography of The Gambia and the dominating influence of a great river on the country's geomorphology, surface geology is dominated by recent superficial deposits with some identifiable outcrops of the 'Continental Terminal'. The rest of the succession has been established on the basis of outcrops in adjacent countries and confirmed by drilling of water supply boreholes and exploratory oil wells within The Gambia.

2.2.3 The Aquifers

Two major aquifers occur in the succession underlying The Gambia, namely the Miocene to Pleistocene (Continental Terminal) sands and the Maestrichtian to Palaeocene sandstone. The former constitute the upper or shallow aquifer, which occurs under the whole country and provides most of its potable supplies. The latter forms the lower or deep sandstone aquifer; its occurrence is also countrywide but is as yet unexploited in The Gambia, though it is an important source of water in Senegal.

The Continental Terminal is highly variable lithologically and the proportions of sand and impermeable lithologies vary from place to place. Nevertheless, some saturated sandy layers are usually found at depths of 10 to 120 m everywhere. It is normally subdivided into two units, the upper phreatic and lower semi-confined, separated by mainly silty beds of variable thickness. It is of significance that there have been a few drillings, sometimes over 100 m deep, which failed to find sufficient thickness of aquifer to justify completion of production boreholes at these sites (Dipl-ing H R Prack, 1989).

The phreatic aquifer is mainly tapped by dug wells and if saturated, is reported to always yield enough water for a hand pump from a thickness of 3 m to 6 m. Groundwater levels are mainly in the range of 10 m to 30 m below ground level.

Production boreholes tap mainly the semi-confined aquifer, though some are screened in the phreatic unit as well; both are reported to have the same watertable. The boreholes vary in depth from about 30 m to more than 100 m and produce yields of less than 1 l/s (some are equipped with hand pumps) to more than 20 l/s. Specific capacities of tested boreholes range from 0.02 to 5.5 l/s per metre and estimated aquifer transmissivities are from abut 20 m^2/d to almost 4 000 m^2/d; converted to permeability these give a range of 1 to 50 m/d, but most of the results are between 10 and 40 m/d. It is possible that these ranges may not be strictly representative of the aquifer's productivity as variable penetration and vastly different borehole designs may have influenced the calculated values. The storativity of the shallow aquifer has not been credibly estimated from the pumping tests, but on the basis of its lithology is likely to be of the order of 10%.

Despite its variability, the Continental Terminal forms a productive aquifer of regional extent, capable of sustaining small yields (say 1 l/s) to dug wells and boreholes practically everywhere in The Gambia, and of much greater yields of up to 20 l/s in most areas (particularly in the west), to properly designed and constructed drilled wells.

The Maestrichtian-Palaeocene (deep sandstone) aquifer is much more poorly documented. Its presence under the whole country has been inferred from outcrop and borehole evidence in Senegal, and confirmed by oil and groundwater exploration boreholes in The Gambia, where it occurs at depths of approximately 250 m to 450 m; the whole of the formation may be up to 450 m thick, but the sandstone fraction is much thinner. The three boreholes completed in that aquifer within The Gambia tapped between 20 m and 75 m of the sandstone; each well was capable of production of 20 l/s or more. The calculated transmissivities and permeabilities (Ceesay and Howard Humphreys, 1987) are as follows:

Location of borehole	Depth (m)	Transmissivity (m^2/d)	Permeability (m/d)
Half Die (Banjul)	351	211	3
Sankwia	440	1 750	20
Garowal	345	510	6

However, since the specific capacities of the three wells were practically identical (about 1 l/s per metre), these values are suspect.

In Senegal the ranges of transmissivity and permeability are reported as 29 to 3 542 m^2/d and 1 to 118 m/d respectively. The storage coefficient of the deep aquifer is of the order of 10^{-4}, typical of strongly confined conditions.

2.2.4 Groundwater Quality

Groundwater quality of the shallow aquifer is generally good with most of the measured hydrochemical parameters within the WHO (1984) desirable limits for potable supplies. The exceptions are groundwaters influenced by the immediate proximity of sea and estuarine water.

Away from these influences, the only problems identified, are low pH, common throughout The Gambia, and high iron and nitrate in some areas. Neither the low pH nor the relatively high iron are a threat to the health of the consumers. The former makes the water corrosive to unprotected steel (and many other base metals), whereas the latter makes the water unpleasant to drink, particularly after it has been exposed to air; aeration raises the pH causing the iron to precipitate, imparting a reddish colour to the water and leaving an unpleasant scum at the surface. The permissible concentration of nitrate is normally taken as 50 mg/l (as NO_3) in most developed countries or 100 mg/l (WHO permissible limit); though most of the shallow groundwaters in The Gambia are within the WHO limit, there are records of a few samples (particularly at Gambissara) with much higher nitrate (up to 360 mg/l); this suggests that nitrate should be measured in all sources used for potable supplies as it may constitute a health hazard.

Nevertheless, there is sufficient evidence to show that the chemical quality of most of the groundwater sources used for potable supplies is good. In the case of urban supplies some treatment is provided to ensure that the water is bacteriologically safe and to make it more palatable (pH adjustment and chlorination).

In the case of rural supplies there may be a problem with biological contamination. A study by GITEC (1981) identified the occurrence of E coli and Salmonella sp in many dug wells. However, this is considered to be a problem of well protection rather than one of the resource.

The hydrochemistry of the deep sandstone aquifer varies from east to west, with the overall groundwater mineralisation increasing in that direction, which is the main direction of flow. Some of the measured parameters from the three boreholes within The Gambia are listed below:

Location of borehole	pH	EC @25°C (µS/cm)	TDS* (mg/l)	Fluoride (mg/l)
Half Die	7.5 - 8.0	2 550	1 766	5.0
Sankwia	8.0	1 450	955	2.0
Garowal	7.0	440	322	<0.5

Note: * TDS - total dissolved solids

Only the Garowal borehole produced water suitable for drinking. It is likely that water of such quality is present in the deep aquifer under the whole of the eastern half of The Gambia.

2.2.5 Recharge

The recharge conditions for the shallow aquifer appear advantageous. The main source of the recharge is probably direct infiltration of rainfall, which greatly exceeds potential evapotranspiration during the wet season (July, August and September); the land slopes are generally low, limiting runoff, and the soils are often coarse with high potential infiltration intake. The main natural groundwater discharge mechanisms are probably outflow into the river system feeding the base flow, and evapotranspiration by phreatophytes, particularly near the main river, where the watertable is high.

Ceesay and Howard Humphreys (1987) estimated average annual recharge on the basis of rainfall statistics and infiltration properties of the soils, as well as aquifer properties, groundwater gradients and watertable oscillations. Their results are shown in Table 2.2.

TABLE 2.2

Estimates of Average Annual Recharge (Shallow Aquifer)

Division	Recharge from infiltration (million m^3)	Subsurface inflow from Senegal (million m^3)	Total recharge (million m^3)
Western	315	10	325
Lower River	90	7	97
North Bank	64	-	64
MacCarthy Island	26	12	38
Upper River	81	20	101
The Gambia	576	49	625

Source: Ceesay and Howard Humphreys, 1987.

Another estimate of recharge was made by UNDP/UNDTCD in 1983 on the basis of river hydrographs. Groundwater discharge into the Gambia River was deduced to have the pattern shown in Table 2.3. Though the calculated groundwater discharge and consequently recharge, is considerably larger than the Ceesay and Howard Humphreys estimate, the availability of the resource is probably no greater as groundwater recession is very fast, with more than half of the discharge taking place in the first month (November) after the end of the rainy season. Nevertheless, the large difference between the two estimates needs reconciling and is to be given careful attention during Phase II of the Groundwater Study, about to be started in late 1991.

The deep sandstone aquifer is probably not recharged within The Gambia at all, but carries some subsurface flow from Senegal. Such flow is slow as witnessed by the high mineralisation of the groundwater in the west of the country and by its great age (about 35 000 years at Banjul), as determined by radio-carbon dating. Ceesay and Howard Humphreys (1987) computed that subsurface inflow from average transmissibility and hydraulic gradient based on data from The Gambia and Senegal; their estimate of 1.75 million m^3/annum seems credible.

TABLE 2.3

Groundwater Discharge to the Gambia River
(median year - 1969/70)

Month	Surface runoff (million m^3)	Groundwater discharge (million m^3)	Total monthly discharge (million m^3)
May	0	49.2	49.2
June	85.4	0	85.4
July	656.7	0	656.6
August	2 796.5	0	2 796.5
September	3 699.8	0	3 699.8
October	2 361.6	0	2 361.6
November	0	1 490.9	1 490.9
December	0	515.5	515.5
January	0	198.5	198.5
February	0	39.8	39.8
March	0	59.3	59.3
April	0	46.8	46.8
Year	9 600.0	2 400.0	12 000.0

Source: UNDP/UNDTCD, 1983

2.3 Water Demand

2.3.1 General

Groundwater sources provide practically all of The Gambia's domestic supplies (urban and rural), most of its livestock water requirements and appreciable amounts of its irrigation, particularly of village gardens, where small family allotments are irrigated by hand from open wells. Total estimated abstractions given in different publications are not completely consistent, but the figures given in Table 2.4 are probably approximately correct.

These abstractions are implemented by about 40 boreholes with electrical pumps, approximately 1 000 dug wells and boreholes with hand pumps, and some 10 000 traditional open wells from which water is drawn by bucket and rope.

TABLE 2.4

Estimated Groundwater Abstractions - 1990

Water use	Annual abstractions (million m^3)
Urban and tourist (Banjul area)	7.67
Urban (townships)	0.10
Rural - traditional wells (potable, livestock and irrigation)	3.65
Rural - modern wells (potable and livestock)	2.48
Modern irrigation	1.00
Total	14.90

Source: UNCDF 1988, DWR 1991 and GUC 1991.

The abstractions listed in Table 2.4 are already inadequate to meet the demand; moreover the latter is expected to grow rapidly in the future, as indicated in Table 2.5.

TABLE 2.5

Present and Future Demand for Groundwater

Water use	1990			2000
	Abstraction (million m^3/ annum)	Demand (million m^3/ annum)	Shortfall (million m^3/ annum)	Demand (million m^3/ annum)
Urban and tourism	7.67[1]	9.13[1]	1.46	15.3[2]
Rural and township (potable)	2.37[1]	6.57[1]	4.20	13.1[1]
Livestock	1.57[1]	2.19[1]	0.62	7.7[1]
Irrigation	3.29[1]	4.40[1]	1.11	11.0[1]
Industrial	-	negligible	-	3.7[1]
Total	14.9	22.29	7.39	50.8

Notes: [1] Derived from estimates by DWR, UNCDF and GUC.

[2] Calculated using DWR estimates of daily demands of 30 000 m^3/d during the wet season (4 months) and 48 000 m^3/d during the dry season (eight months).

Source: UNCDF 1988, DWR 1991 and GUC 1991.

Though all the demand figures should be taken as indicative only, it is clear that there is already a considerable shortfall of water supply with respect to demand and that the latter is expected to grow rapidly over the next 10 years. Consequently, a major effort in groundwater development will be required if serious shortages are to be avoided in the future.

2.3.2 Irrigation and Agriculture

Groundwater is used extensively by the agricultural sector for livestock watering and for irrigated horticulture. The livestock includes free range herds and domestic animals in villages. Groundwater irrigation includes a few commercial farms in the Kombo area and village allotments watered by bucket from traditional open wells.

Though considerable growth of demand for livestock is predicted (Table 2.5), this would to some extent, replace the use of the river for this purpose and generally provide watering points of clean water at more convenient places, resulting in an improvement in animal health.

Groundwater irrigation potential in The Gambia seems enormous and it is sure that demand for irrigated agriculture (particularly horticulture) will increase in the future. At present the irrigated village allotments produce vegetables for individual families, with perhaps a small surplus sold at local markets. The few modern commercial farms grow horticultural produce for export and the urban markets of the Banjul area.

Apparently, the tourist industry imports most of its requirements; clearly this is a market which should be attacked by local producers. The key to success would be the achievement of high and uniform quality of the local produce.

The predicted expansion of groundwater irrigation is from the present of less than 200 ha to more than 1 000 ha by the year 2000. This is an ambitious target but not unrealistic, provided that markets for the produce can be established.

There is reported to be some 2 000 ha of irrigated rice in the country. The most important scheme is the Jahally-Patchar scheme which consist of 560 ha of pump irrigated rice and 816 ha of improved rain-fed rice. The scheme was originally developed as a pilot study of the benefits of a possible anti-salinity barrage in the river. The site is situated 275 km upstream of the mouth at a point where the river is never saline. The area was previously used for rice and in addition to a pumping station the improvements include:

- levees and interceptor drains to control upland runoff at low tide to prevent uncontrolled flooding from the river;
- combined flap and sluice gates to control drainage to the river at low tide and water intake at high tide;
- bunding to conserve rainfall;

- deepening and cleaning of natural stream channels to improve drainage;
- causeways for better access.

The pumping station has a dual function in that it pumps fresh water in to the project area and also extracts drainage water. The arrangement of intakes and channels is such that the drainage water is recirculated.

There is at present no possibility of introducing other such schemes as further abstractions from the river would reduce the fresh water flow further downstream and the salt water interface would move further upstream, thereby rendering unusable land at present used for 'tidal' irrigation.

Other schemes have been developed to improve the effectiveness of rain-fed and 'tidal' rice production. These include the use of dikes to improve water retention and reduce salinity and also the construction of bridges, causeways and footpaths to improve access to rice growing areas.

In addition to the rice there are also 200 ha of irrigated horticultural gardens. Some of these are for urban and hotel markets. One problem affecting extension of such areas is that some hotels prefer to use imported vegetables rather than locally grown ones. On the other hand some of the horticultural schemes are able to export vegetables to Europe. The larger schemes use motorised pumps but there are also a number of smaller schemes which use traditional wells from which the water is drawn by hand. Experiments are also being carried out on the use of solar and wind powered pumps. One of these financed by NORAID irrigated 15 ha.

2.3.3 Domestic and Municipal Water Supply

Groundwater sources supply the whole of the domestic and municipal sector, with the minor exception of small communities in the MacCarthy Island and Upper River Divisions, which draw their water directly from the Gambia River.

Despite a considerable success of the UN Water Supply and Sanitation Decade in The Gambia, most of the rural population still relies on traditional open wells (with no sanitary protection) for their drinking water. During the last 10 years about 1 000 modern lined dug wells have been constructed, most of them with hand pumps. It is planned to double the number of such wells in the next few years, but this will still leave most of the rural population without access to modern water supply facilities.

The main urban area is that of Banjul and adjacent regions (particularly the tourist facilities in the Kombo Peninsula); its water supply is from three wellfields, but is already overstretched and rapid growth of demand is predicted (Table 2.5). GUC is currently planning the installation of additional boreholes and the associated treatment and conveyance works, but if the predictions of growth in demand are correct, water shortages can be expected for the rest of this century. The brunt of these shortages is and will continue to be carried by the local population, as priority has always been given to supplying the tourist industry.

In addition to the Capital Area, some of the provincial townships and even large villages have been provided with piped supplies based on boreholes with electrical pumps. Currently, DWR with EDF assistance, is experimenting with borehole/solar pump systems for such townships. Whatever the pumping arrangements, the demand for provincial piped water supply is sure to continue and increase.

2.3.4 Hydropower

At present the country makes no use of hydro-electricity. Given the lack of relief it is apparent that no hydropower can be developed within the country. However there are possibilities for hydropower development further up the Gambia basin and these developments would have an impact on flow within the lower reaches of the river. This is more fully discussed in Section 2.3.6.

2.3.5 Other Uses of Water

At present, industrial demand for water is negligible, but it is expected to become significant by the end of the century. Groundwater would be the most convenient source of water for industrial developments and groundwater abstractions for this purpose are expected to amount to about 10 000 m^3/d by the year 2000.

2.3.6 Development of the Gambia River

Further irrigation on a large scale will require the construction of a reservoir and/or barrage. In its 1974 report Howard Humphreys proposed five possible sites for a reservoir. Two of these were at Sambangalou, two at Mako and one at Kekreti. The largest of these was at Kekreti in Senegal and this is the one which has been retained for further studies. The reservoir would be used for both irrigation and hydro-electricity. A 1977 study for a barrage in The Gambia proposed that this should be constructed at Yelitende, 134 km upstream of the mouth (Coode and Partners). Later studies have suggested that a better site would be further downstream at Balingho. The advantage of this site relative to Yelitende is that part of the barrage could be constructed on dry land, thereby easing the cost and difficulty of construction.

In recent years the economic viability of Kekreti Reservoir has become less attractive. The changes which have brought this about include:

- major developments which were previously expected to use a lot of hydro-electricity (the Felime iron mine and the Mali cement factory in Guinea) are unlikely to proceed;
- lower oil prices have reduced the cost of electricity from other sources;
- there is a lower projected demand for electricity in Senegal;
- the world market prices for agricultural products such as maize and rice have reduced.

In addition there are other more attractive options for electricity generation within the region which include:

- the installation of hydropower turbines at the Manantali Dam on the Senegal River which has already been constructed;
- the Felime falls downstream of Manantali, which already regulates the water flow;
- at Gouima on the Senegal River in Mali.

In addition these alternative schemes could make use of the same transmission lines to the main centres of use.

The original report on the proposed barrage site at Yelitende concluded that the barrage could satisfy three objectives:

- stop salt water movement upstream of the barrage;
- create a fresh water reservoir for pumped irrigation in the dry season;
- allow vehicles to cross the river.

It was calculated that 24 000 ha of rice could be irrigated.

A later report on the barrage to the EDF (NEDECO, 1981) concluded that it should be built at Balingho, slightly downstream of the original site, and that the best option would cost US$86 million. This would have consisted of 80 bays 2.5 m wide capable of passing the 1-in-100 year flood of 2 725 m^3/s.The water level upstream of the barrage would be raised for fresh water but provision was also made to allow some water to flow upstream, partly to maintain levels and partly to produce a simulated tidal effect for rice growing. The barrage would also have allowed vehicles to use the barrage as a bridge except when vessels were passing. One slightly cheaper alternative would have replaced the two-gate lock with a single gate. This would have allowed vessels to pass during two brief periods of each 13-hour tidal cycle when levels upstream and downstream of the barrage were the same.

Later reports on the environmental aspects of the barrage have, however, been generally negative (Rhein Ruhr Ingenieur, 1983). Among the environmental dangers are:

- danger of drainage of sulphidic soils giving rise to the formation of acid sulphate soils with negative effects on farming, forestry and water pollution;
- damming of waters upstream would reduce the catch of the types of fish presently taken but this might be compensated by an increase in the numbers of other fish caught. These alternative fish species are already present but not caught as they are not the preferred choice of the riparian population;
- some 24 000 ha of mangrove forest would be lost;
- there would be an increase in diseases such as bilharzia and malaria.

The most comprehensive study of the combined dam/barrage option was that produced for the OMVG by the University of Michigan and Harza Engineering (1985). This led to the production of a report entitled 'Water Resources Management and Gambia River Basin Development', which was a synthesis of four other volumes and over 70 technical papers.

The report indicated that there were no grounds for the construction of Balingho barrage. Their conclusions on the environmental effects were similar to those of the report quoted above. They calculated that the initial construction of the dam would lead to a loss of 18 000 tons of rice production per annum. The gains from extra irrigated areas would barely compensate for this. The area of the reservoir upstream of the barrage would be 726 km^2 making it, if constructed, the fifth largest in Africa in terms of area. However the water in the reservoir would be very shallow with a large evaporation loss, and even with releases from a reservoir at Kekreti it is not certain that it would be possible to maintain water levels during the dry season. Downstream of Balingho very little water would be released and the simulation studies showed that on average water would be released for only 25 days each year - with no release at all being possible in very dry years. It would also be necessary to resettle some 15 000 people from the flooded areas.

It appeared that Kekreti on its own would be a better option. This is because it could generate hydropower and by making releases to the river during the dry flow the salt water interface could be held further downstream thereby increasing the length of river from which irrigation water could be drawn.

The OMVG figures give an internal rate of return for Balingho of 1.5%, for Kekreti on its own of 9.2% and for the two operated conjunctively of 4.8%. On the basis of a 10% discount rate and 50 year planning period, the net present value of Balingho alone was -$80 million, of Kekreti alone it was -$7 million and of the two together it was -$95 million. These figures ignored the cost of resettlement, and also appeared to ignore the benefits of the use of Balingho barrage as a bridge. To put the costs in perspective it is interesting to note that the likely cost of Balingho is roughly equivalent to one year's GNP of The Gambia.

Plans have also been put forward for a bridge without a barrage.

CHAPTER 3

CLIMATE

3.1 Organisation and Management

3.1.1 The Meteorological Service

The Meteorological Division is one of the divisions of the Department of Water Resources (DWR). It is divided into three sections: Forecasting, Climatology and Agrometeorology. The first of these sections is based at Yundum International Airport and the others in the DWR offices in Banjul.

3.1.2 Other Organisations

The Ministry of Agriculture maintains a number of rainguages at the Mixed Farming Centres, these gauges are referenced with MFC after their name.

3.1.3 Staff and Training

The staff in the Meteorological Division are detailed in Table 3.1. Most of the senior staff are based at the DWR office in Banjul, with other staff, including forecasters, at the meteorological station at Yundum International Airport. The breakdown of the divisions where the staff work is shown in Table 3.2. Other staff are employed as permanent observers at the climate stations operated by the meteorological service.

The Department operates a training school for observers near to the airport at Yundum. This training school has specially built classrooms and a meteorological station for training purposes. The course lasts eight months. Lectures to the courses are provided by the head of the training school, staff of the DWR, and international experts stationed in the country. The courses cover background material such as physics, chemistry, and mathematics as well as more specific material. Much of the course covers subjects common to hydrology and meteorology. There is a normal intake of twelve trainees, of these, in a typical year, eight might be for the meteorological service and the remainder for the hydrological service.

There are no facilities for training beyond high school level in The Gambia and for first degree or higher level studies it is necessary for staff to receive a scholarship and to travel overseas.

There is currently a UN volunteer agro-meteorologist working with the division in the context of the AGRHYMET project. He has an MSc degree from the United States.

TABLE 3.1

Staffing of the Meteorological Division

Post	Nr	Remarks
Principal Meteorologist	1	Head of Division
Senior Meteorologist	1	
Meteorologists	2	
Meteorological Assistant	8	Forecasters
Senior Meteorological Superintendent	1	
Meteorological Superintendent	1	
Meteorological Assistant - I	12	WMO Class III
Meteorological Assistant - II	11	WMO Class IV
Meteorological Assistant - III	19	WMO Class IV
Meteorological Trainees	7	

TABLE 3.2

Location of Staff - Meteorological Division

Location	Division	WMO Class			
		I	II	III	IV
Banjul	Agrometeorology	1	1	2	2
	Climate	0	1	0	4
Yundum	Forecasting	1	5	2	21
Outposted		0	0	0	11

3.1.4 Budget

The total budget for the whole of the DWR for 1990/91 was Dalasis 3.165 million. However, no breakdown of this budget between the different divisions was available.

At present the AGRHYMET project has a budget for spare parts for the meteorological service. Were this project to cease operation, and not be replaced by an equivalent project, then it is understood that the Meterological Division would have difficulty in obtaining spare parts.

3.2 Climatological Data

3.2.1 Climatological Network

There are at present 11 climatological stations operating. All the stations are designated as 'synoptic' stations. The data measured at these stations are: rainfall, evaporation (pan), dry and wet bulb temperature, maximum and minimum temperature, wind speed and direction, and hours of sunshine. The one exception to the above is Banjul where sunshine is not measured. The stations also measure ground minimum temperature, soil temperature at 10, 20, 30 and 50 centimetres and earth temperature at 1 foot and 4 feet. Table 3.3 lists all the climate stations and their period of operation. Figure 3.1 shows the locations of the stations. All the stations have a thermograph, and Yundum and Basse also have a radiation sensor. Three stations, Yundum, Basse and Georgetown have barometers. Table 3.4 gives typical temperature, evaporation and rainfall data for three stations. The data on temperature and evaporation are for the period 1977-86 and the rainfall for 1971-85. The evaporation is based on Piche and/or Class A pan measurements. The data are taken from a report entitled 'Study on Improvement of Irrigated Farming in The Gambia' produced by the national team of the AGRHYMET project.

All the sites are manned by trained operators. Most stations have two observers who record the measurements every 3 hours from 0600 hours to 1800 hours. Yundum and Basse record data every hour for 24 hours a day. These stations are important as Yundum is at the international airport and Basse is the most easterly station in the country and during the wet season rain moves from east to west.

In addition to the climatological network there is also a network of 16 phenological stations. These stations are at representative sites used to note the progress of crops within the country and used as input to a 10-daily agrometeorological bulletin. The locations of these sites is shown on Figure 3.2.

As with other countries in the AGRHYMET programme The Gambia publishes a 10-daily bulletin throughout the rainy season. This records the rainfall in the preceding ten days, the cumulative rainfall in the year and the values of other climatological parameters. The aim of the report is to identify the progress of the growing season and the likely outcome of the harvest. People met during the Consultant's visit, such as representatives of USAID, commented that they find this a very valuable document as it gives them early warning of any food deficits which may be developing.

TABLE 3.3

Climatological Stations

Name	Location		Period of operation	Remarks
	North	West		
Kaur Met.	13° 42'	15° 20'	1984-91	
Basse Met.	13° 19'	14° 13'	1949-91	Met station under DWR from 1972
Banjul Halfdie	13° 27'	16° 34'	1943-91	Moved 1 km in 1984
Kerewan Met.	13° 30'	16° 06'	1979-91	
Georgetown Met.	13° 32'	14° 46'	1949-91	Pruning of nearby trees in 1977
Jenoi Met.	13° 28'	15° 34'	1974-91	Moved 200 m in 1978
Yundum Intl Airport	13° 21'	16° 38'	1945-91	Moved in 1977 and 1979
Sibanor Met.	13° 13'	16° 12'	1986-91	
Sapu Met.	13° 33'	14° 54'	1956-91	DWR since 1976
Fatoto Met.	13° 24'	13° 53'	1976-91	Moved from Fatoto Dispensary in 1978
Kuntaur Met.	13° 40'	14° 53'	1986-91	

3.2.2 Equipment

All of the equipment is made by Cassella. It all appears to be of the same type and therefore corresponds to British norms.

At the sites visited the equipment seemed generally to be in good working order, the charts had been recently changed and the wet bulb thermometer had clean water and a clean wick.

Through the AGRHYMET project it had been possible to buy spare instruments. The one problem area was maximum and minimum thermometers which because of the need to shake them led to there being frequent breakages. This had resulted in the stock of spares becoming depleted.

A further problem of equipment is that of transport. Only one four-wheel drive vehicle is available and this has to be shared with the Hydrology Division. Its most important task is the round trip undertaken every ten days for the agro-meteorological bulletin. This is necessary as because of telecommunication problems there is no other way of getting data to Banjul in time for rapid publication of the 10-daily bulletin. The use of the vehicle by hydrology at other times means the vehicle is almost constantly is use. It was reported that the vehicle is unlikely to last beyond this year.

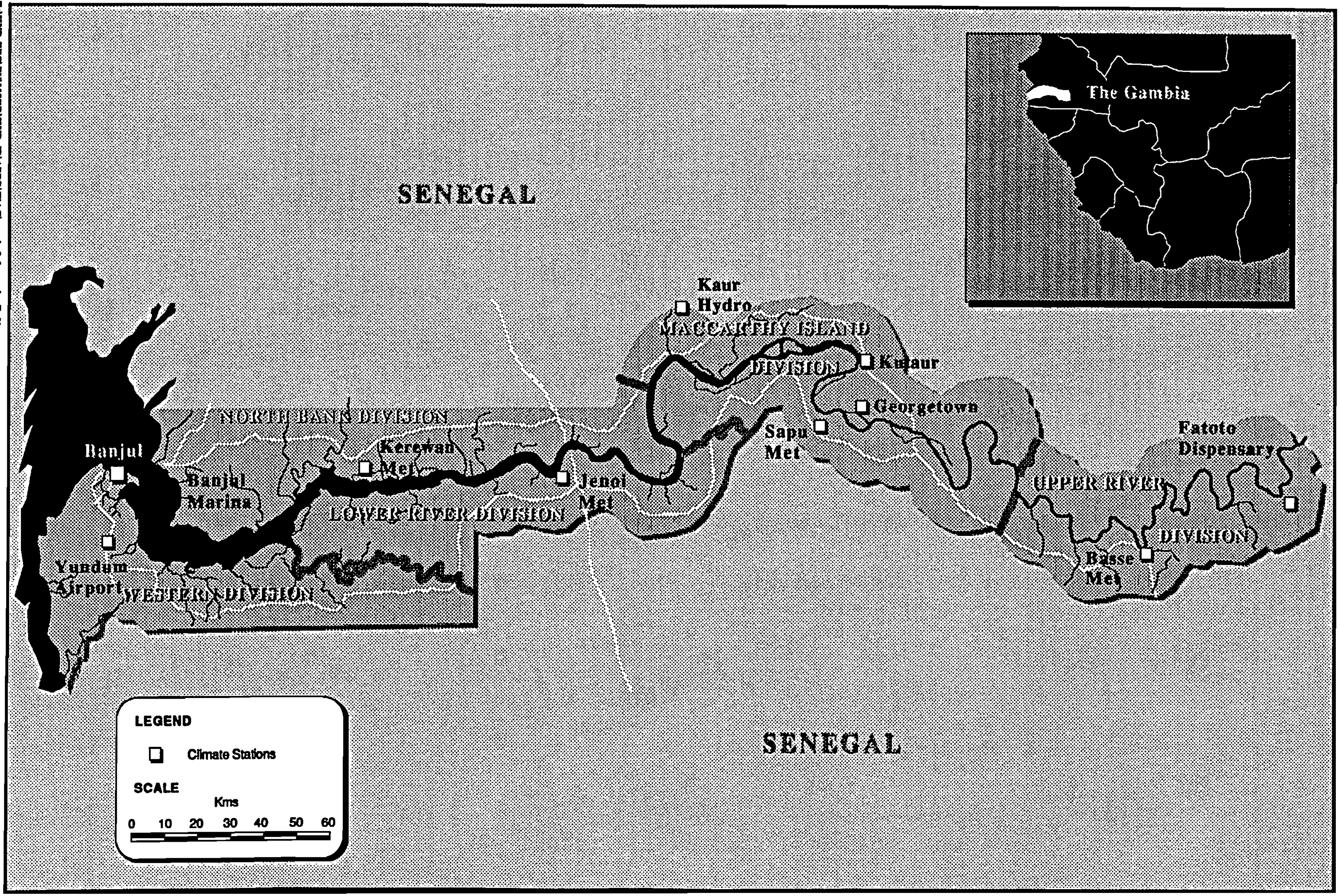


Figure 3.1
Climate Stations

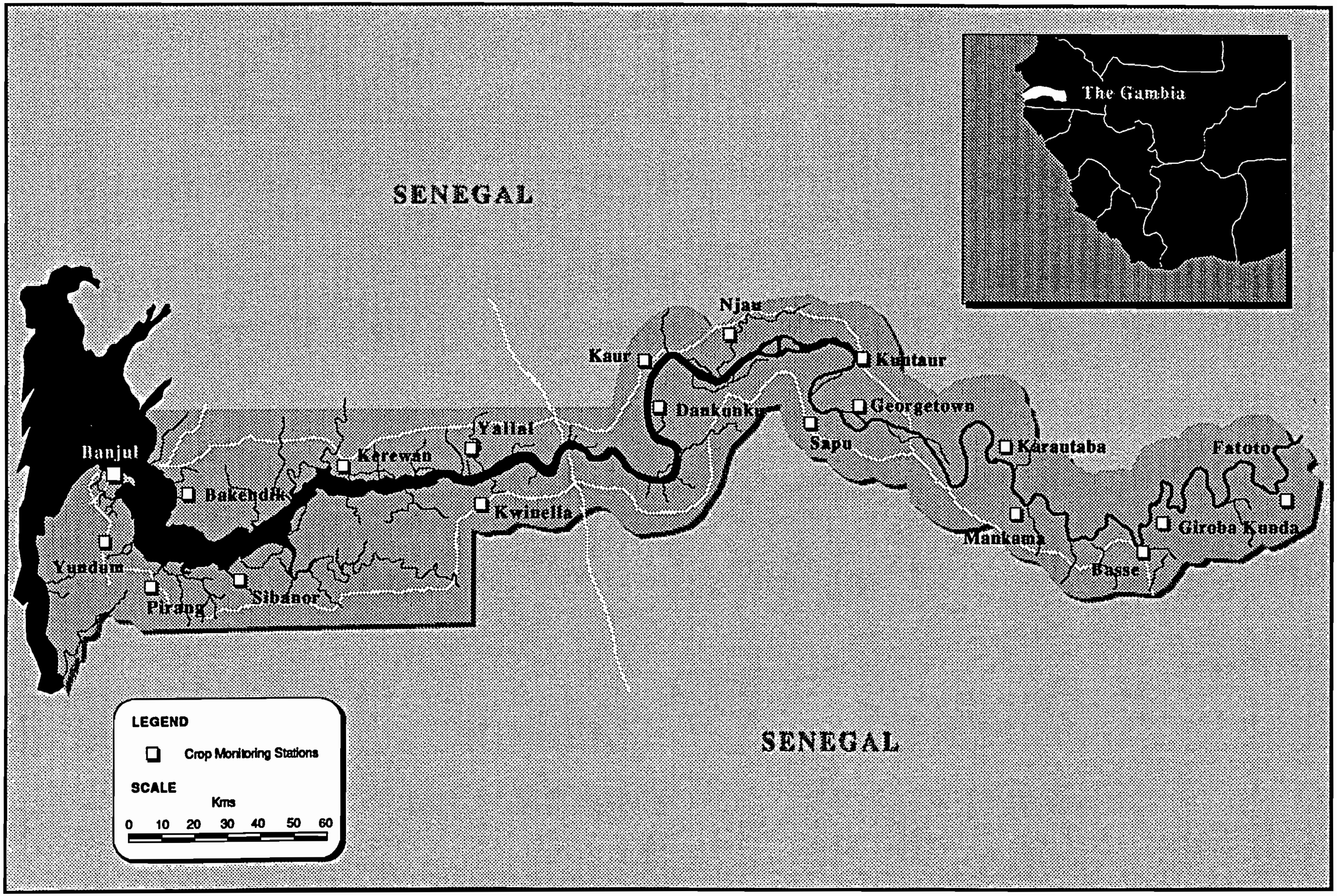


Figure 3.2
Crop Monitoring Network

TABLE 3.4

Main Climatological Data at Selected Stations (1977-1986)

Site	Parameter	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yundum	Mean Temp	°C	23.9	25.2	26.1	26.3	26.4	27.7	27.5	26.9	26.9	27.3	25.9	24.4
	Mean Max Temp	°C	31.6	33.5	34.0	33.2	32.0	32.1	31.3	30.8	31.3	32.4	33.1	31.8
	Mean Min Temp	°C	16.2	16.8	16.8	19.7	20.9	23.3	23.6	23.0	22.5	22.1	18.7	16.7
	Evaporation	mm	157	158	193	187	178	154	145	135	126	139	131	138
	Rainfall	mm	1	0	0	0	1	62	214	293	216	60	4	2
Jenoi	Mean Temp	°C	24.4	26.2	28.6	30.4	30.8	30.1	28.3	27.6	27.7	28.4	26.8	24.0
	Mean Max Temp	°C	33.4	36.1	38.0	39.3	38.2	35.8	33.1	32.0	32.4	33.9	35.1	33.4
	Mean Min Temp	°C	15.4	16.3	19.2	21.5	23.4	24.4	23.5	23.2	23.0	22.9	18.5	14.6
	Evaporation	mm	163	169	211	219	215	180	161	150	140	151	143	145
	Rainfall	mm	0	0	0	0	7	62	194	208	186	46	6	2
Basse	Mean Temp	°C	24.6	26.8	29.8	28.3	32.8	30.9	28.2	27.4	27.5	28.4	27.0	23.9
	Mean Max Temp	°C	34.1	36.6	38.6	39.8	39.1	36.0	32.9	31.6	32.2	34.0	35.6	33.7
	Mean Min Temp	°C	15.1	16.8	18.8	24.0	25.5	25.0	23.6	23.2	22.7	22.8	18.1	14.0
	Evaporation	mm	139	150	142	207	224	179	181	141	135	143	130	123
	Rainfall	mm	0	1	0	2	32	92	203	227	209	60	2	1

3.2.3 Maintenance and Field Support

The limitations on vehicles means that apart from the visits for the 10-daily bulletins other maintenance visits are not possible. On the other hand since each site is thus visited once every ten days it could argued that no further special visits are really needed.

3.2.4 Data Processing

Eight of the stations (all except Kuntaur, Sibanor and Fatoto) are equipped with single side-band radios for transmitting the data. As few of these sites have regular electricity supplies they were all equipped with generators. At present only the raidos at Banjul and Sapu are operational; all the other sites have problems with generators. Indeed at one site visited the generator was missing from the generator building.

The data at the climate sites is therefore collected during the visits for the 10-daily bulletin.

All data up to and including 1984 was micro-filmed by the data rescue project (DARE) of the Royal Belgian Meteorological Service. The micro-film reader provided under this project is currently broken down so the Meteorological Division has no means of accessing this data. The data up to 1984 was also put on the removable hard disk of a PDP 11/34 computer provided in the context of the AGRHYMET programme. This computer is now obsolete and is no longer in service. The disk from the computer had been sent to the AGRHYMET centre in Niamey, Niger, to, if possible, recover the data in PC compatible computer format, but so far the re-formatted data has not been returned to Banjul. All the data from 1985 onwards had been entered into a PC-compatible computer system using the CLICOM programs. The only data entered so far is monthly data and daily data has not yet been entered. Although the staff using this system appeared to have a good grasp of the commands there was a problem relating to the data for 1990 which they had entered but could not retrieve.

The computer equipment, shared with the Hydrology Division, consists of four PC AT compatible computers with VGA graphics and a 5.25" diskette drive. Two of the computers have 20 Mb hard disks and two have 40 Mb hard disks. There are also three Okidata Microline 391 printers and one Hewlett Packard HP 7475A plotter. The computers are operated in a special room which is air conditioned and well kept. The computers all have uninterrupted power supply (UPS) systems. These are necessary as power cuts appeared to be frequent and sometimes of several hours duration.

The CLICOM climate data processing software is available. Even on an AT compatible computer the menus appeared to written to screen slowly compared to standard professional packages. One of the menus in the CLICOM package appeared in French - possibly a left over from customising the system for other AGRHYMET countries who use French.

3.2.5 Data Availability

A list of all the rainfall and climate stations which have ever operated in the country was produced using the CLICOM data package. Within the program it is possible to get information on individual stations such as duration of record, periods with missing data and other comments such as dates when a station was moved. This was not up to date for all stations and from discussion with staff at the climate station visited it was apparent that there was a lot of information on the history of the stations which had not been entered to the system.

It proved to be quite difficult to get data for all the stations. This point is discussed in more detail in the section on rainfall.

3.3 Rainfall Data

3.3.1 Rainfall Network

A total of 64 raingauges have operated in The Gambia at some time. Currently 33 are in operation. All of these are read at least daily in the wet season, but those at the climate stations are read more frequently. Only the station at Yundum has a recording raingauge. Table 3.5 lists all these stations and Figure 3.3 shows the development of the rainfall measurement network. Before 1930 three stations were in use: Banjul Marina (from 1886 to 1965), Georgetown (from 1908 to 1933 and from 1947 to 1990) and Wouli (from 1926 to 1954). Figure 3.4 shows the current operational network, including the synoptic stations. Appendix D presents an analysis of the long rainfall records to estimate the tendency in the average rainfall.

3.3.2 Equipment

The raingauges, as with the climate station equipment, are all manufactured by Cassella. They conform to British standards. Relatively few gauges were visited, but the one at the offices of the DWR was not well sited having a number of trees rather close.

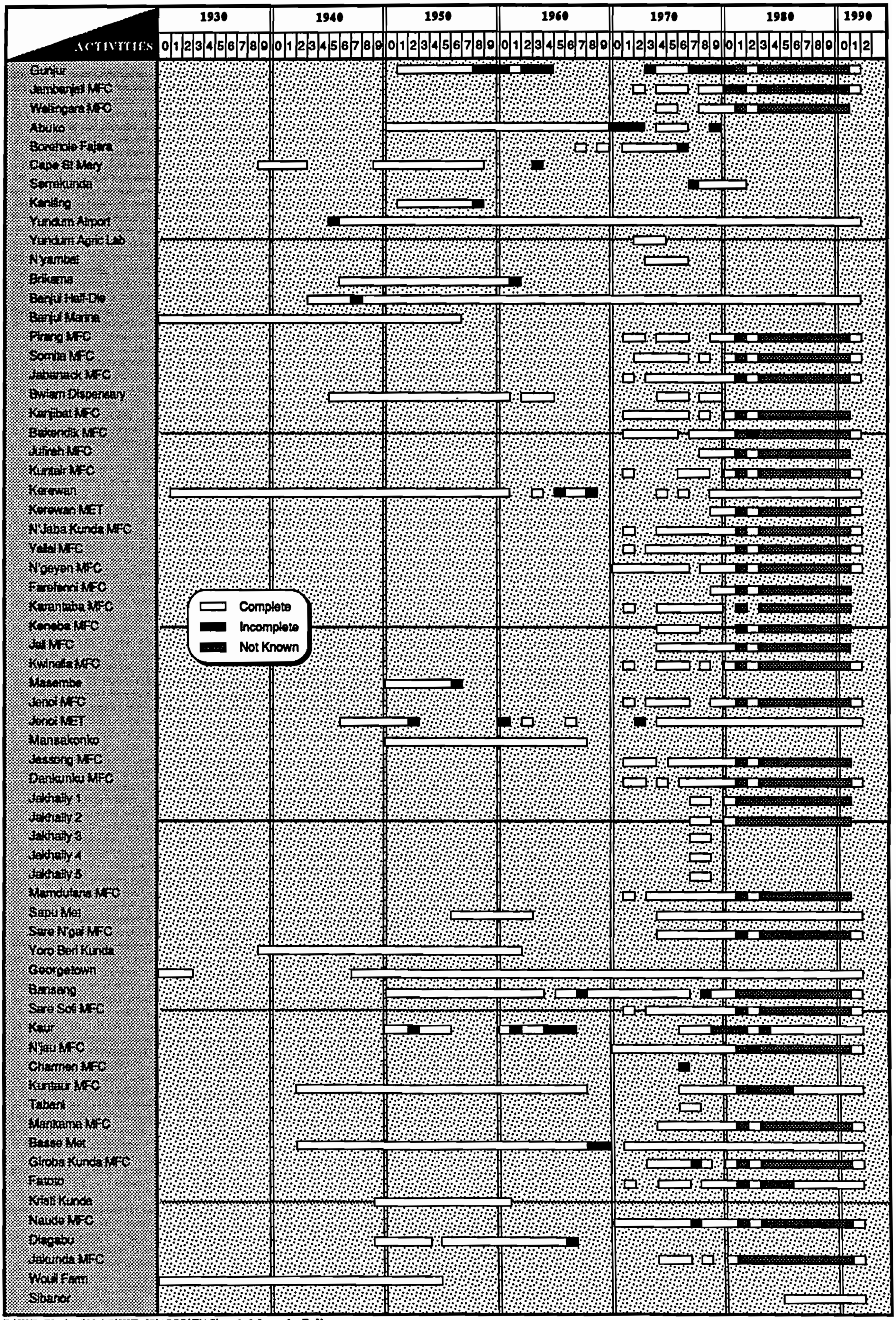
TABLE 3.5

Rainfall Stations

Name	Location		Remarks
	North	West	
Gunjur	13° 11'	16° 45'	Not whole season since 1987
Janmbajali MFC	13° 17'	16° 44'	
Wellingara MFC	13° 24'	16° 40'	
Abuko	13° 24'	16° 39'	
Borehole Fajara	13° 28'	16° 41'	
Cape St Mary	13° 29'	16° 40'	Re-opened 1984
Serrekunda	13° 26'	16° 39'	
Kanifing	13° 27'	16° 40'	
Yundum Airport	13° 21'	16° 38'	Moved in 1977 and 1979
Yundum Agric Lab	13° 22'	16° 41'	
N'yambai Forest	13° 18'	16° 39'	
Brikama	13° 16'	16° 39'	
Banjul Halfdie	13° 27'	16° 34	Moved to DWR in 1984
Banjul Marina	13° 27'	16° 34'	
Pirang MFC	13° 16'	16° 32'	
Somita MFC	13° 12'	16° 18'	
Jibanack	13° 13'	16° 11'	
Bwiam Dispensary	13° 14'	16° 04'	
Kanjibat MFC	13° 13'	15° 58'	
Bakendik MFC	13° 27'	16° 27'	
Jufureh MFC	13° 20'	16° 23'	Non-operational since 1986
Kuntair MFC	13° 32'	16° 13'	Moved to MFC in 1987
Kerewan	13° 30'	16° 06'	
Kerewan Met	13° 30'	16° 05'	Opened 1 mile from Kerewan
N'Jaba Kunda MFC	13° 33'	15° 55'	
Yallal MFC	13° 33'	15° 43'	
N'Geyen MFC	13° 36'	15° 26'	
Farafenni MFC	13° 35'	15° 38'	
Karantaba MFC	13° 21'	16° 09'	
Keneba MFC	13° 20'	16° 01'	
Jali MFC	13° 21'	15° 58'	
Kwinella MFC	13° 24'	15° 48'	
Massembe	13° 25'	15° 39'	
Jenoi MFC	13° 29'	15° 34'	3 km south of Jenoi Met
Jenoi Met	13° 29'	15° 34'	DWR since 1974. Moved 1978
Mansakonko	13° 27'	15° 32'	
Jassong MFC	13° 24'	15° 18'	
Dankunku	13° 34'	15° 18'	
Mamudfana MFC	13° 36'	15° 07'	
Jakhally 1	13° 34'	14° 57'	
Jakhally 2	13° 35'	14° 57'	
Jakhally 3	13° 34'	14° 58'	
Jakhally 4	13° 35'	14° 58'	
Jakhally 5	13° 35'	14° 58'	
Sapu Met	13° 33'	14° 54°	Reopened 1974. DWR since 1976
Sare N'gai MFC	13° 29'	14° 50'	
Yoro Beri Kunda	13° 30'	14° 45'	
Georgetown	13° 32'	14° 46	
Bansang	13° 26'	14° 40'	Moved in 1976. DWR since 1978
Sare Sofi MFC	13° 25'	14° 31'	
Kaur Hydro	13° 43'	15° 21'	
N'Jau MFC	13° 45'	15° 12'	
Charmen MFC	13° 42'	15° 10'	
Kuntaur MFC	13° 40'	14° 53'	
Tabanani MFC	13° 38'	14° 35'	
Mankama MFC	13° 20'	14° 26'	
Basse Met	13° 19'	14° 13'	Reopened by DWR 1972
Giroba Kunda MFC	13° 18'	14° 11'	
Fatoto Disp/MFC	13° 24'	13° 54'	Moved to MFC in 1978
Kristi Kunda	13° 25'	13° 52'	
Naude MFC	13° 28'	14° 27'	
Diabugu	13° 23'	14° 24'	
Jakunda MFC	13° 29'	14° 11'	
Wouli Farm	13° 25'	13° 51'	

Figure 3.3

Operating Periods Of Raingauges - The Gambia



F:\HYD-TEC\EN\MSTR\HYD-JB\ABRD\WAC\gamb-3-3.gem by E. Newman

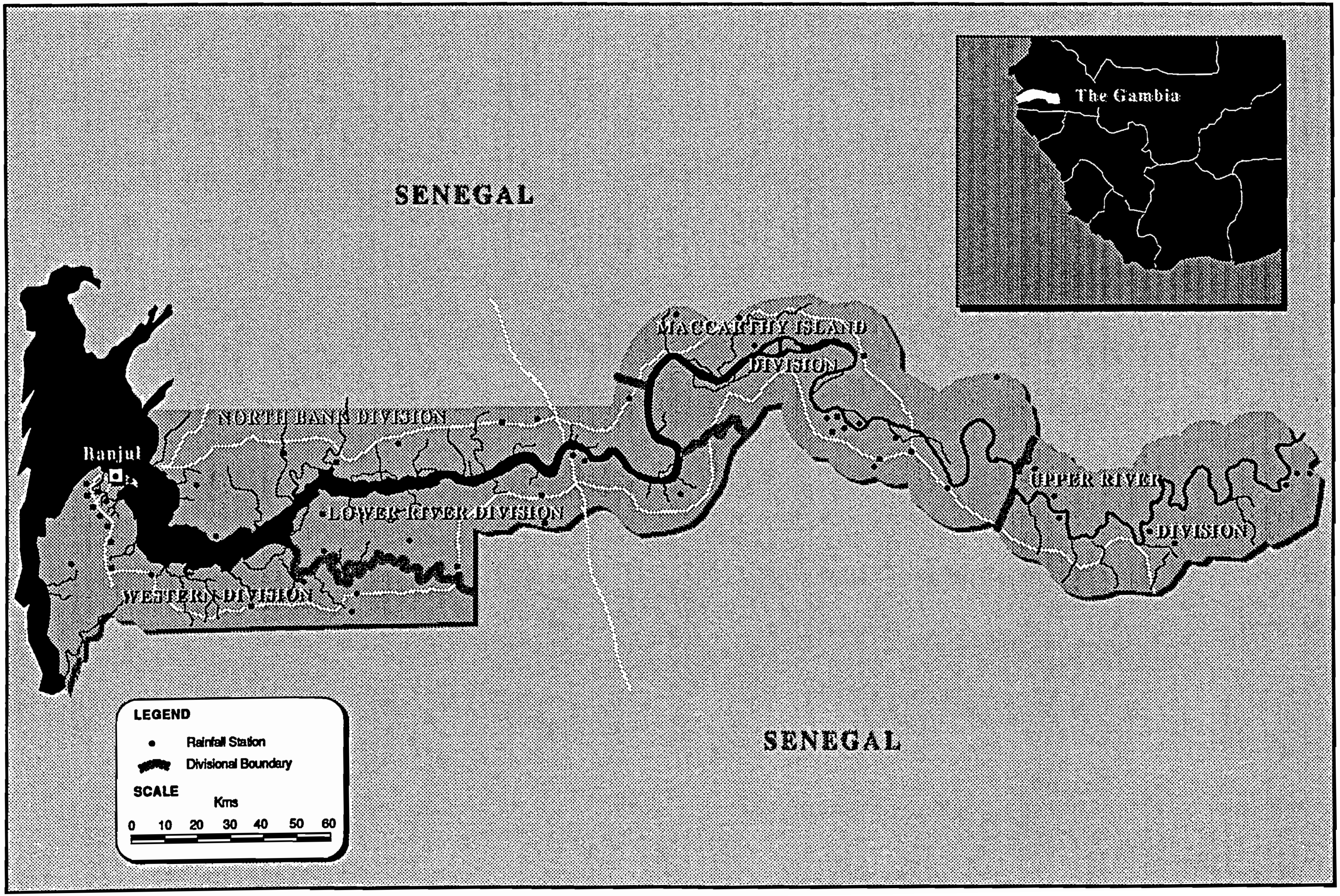


Figure 3.4
Rainfall Stations

3.3.3 Maintenance and Field Support

Whereas the climate stations are visited regularly, in the course of data collection for the 10-daily bulletin, the visits to the raingauges are much less frequent, normally only one visit per annum is made, at the end of the rainy season in November. This gives only limited possibilities for quality control. Raingauges are manned full time during the wet season but traditionally the population in some rural areas move between the seasons. The observer may therefore move away from the gauge site for part of the year resulting in incomplete records. The timing of this move varies from year to year and in some instances the Meteorology Division staff on their annual data collection visit may miss the observer and the season's data for the site will have to be collected the next year. There have been problems reported of the performance and lack of diligence of the observers at certain stations.

3.3.4 Data Processing

The available computer equipment and software are discussed in the section on the climate data processing. During our visit it was not easy to get monthly rainfall for all the stations. In the case of data up to 1980 the data was readily available in the technical report of a previous WMO project which published all the data for all stations up to and including 1980. (Technical Report Nr 8 - Monthly Rainfall Data for The Gambia to 1980). After this date, there is data in the published year books up to and including 1983. All the data for all the stations up to and including 1984 was transferred to the PDP 11/34 computer by the data rescue project but this is has not yet been converted to PC compatible format (see Section 3.2.4). Our request for monthly rainfall data from 1985 onwards for all stations produced monthly data for the 11 climate stations and a few others only. It did not appear to be possible to get a table of monthly rainfall from the CLICOM system, nor even details of what data was available for each station. For this reason the information presented in Figure 3.3 contains a number of years shaded to indicate that information was not available.

3.3.5 Data Quality

Appendix D contains details of double-mass plots carried out on samples of rainfall data from The Gambia. The earlier data comes from the published Technical Report Number 8 and the later data was provided on typed sheets by the Meteorological Division. It should be noted that the data as presented contained a number of anomolies. Where there was an overlap there was sometimes a difference between the earlier published data and the more recent typed sheets. There were also differences between data appearing on two different typed sheets. A further problem was that sometimes the sum of the monthly values on the typed sheets did not agree with the annual totals.

3.3.6 Data Availability

There is an inventory of rainfall stations available. This is produced as a computerised printout. The column on data availability appears to have been copied from the Technical Report quoted above and to contain information on missing data up to 1980 only.

There is no way of getting data in a computer compatible format other than for the few years recently entered into the CLICOM system. In particular there is no way of getting data on daily rainfall other than going back to the original sheets. It is obvious that storing data in such a way carries with it a risk of data being lost or destroyed, although none has been reported as being lost so far. A further problem is that as the data from the rainfall stations is collected on annual visits, and these visits do not always coincide with the presence of the observer, then at some stations data for more than one year is held at the site of the station and is only transferred to Banjul later.

CHAPTER 4

SURFACE WATER

4.1 Organisation and Management

4.1.1 The Hydrological Division

The Hydrological Division comes under the Department of Water Resources of the Ministry of Natural Resources and the Environment. The headquarters are in Banjul and there is one regional office, at Bansang.

4.1.2 Other Organisations

No other organisations or ministries collect hydrological data. There have recently been some new gauging stations constructed and equipped in the context of an OMVG project. These stations will however be operated by the Hydrology Division.

4.1.3 Staff and Training

The staffing of the Hydrology Division is shown on Table 4.1. At present the Senior Hydrologist, who has a first degree from England and a post-graduate MSc. degree from the Belgian Free University, is acting as the Principal Hydrologist. Apart from that person there are no other graduates employed in the hydrology service. There is also at present one United Nations volunteer hydrologist, working on the national component of the AGRHYMET project, who is also a university graduate.

The DWR training school runs courses for observers. These courses last eight months and cover general subjects such as mathematics and physics as well as more specific topics. There is an overlap in the training of the hydrological and meteorological staff.

Apart from the DWR school there are no other training facilities in the country. One particular problem is that the country has no university, therefore all staff have to go abroad, even for a first degree, which makes their training very expensive.

TABLE 4.1

Staffing of the Hydrology Division

Post	Nr	Remarks
Principal hydrologist	1	Vacant. Senior hydrologist acting
Senior hydrologist	1	Masters degree from Belgian Free University
Hydrologist	2	One vacant, other on study leave in Switzerland
Senior hydrological superintendent	1	
Senior superintendent	1	
Hydrological assistant - I	4	
Hydrological assistants - II	5	Two vacant
Hydrological officers - II	4	One vacant
Hydrological assistants - III	8	Have finished training school
Hydrological trainees	7	Five at training school
Senior quartermaster	1	Captain of boat which is no longer operational
Quartermaster	3	Also for boat
Engine drivers	3	Also for boat
Sailor - I	1	Also for boat
Sailor - II	2	Also for boat
Watchman	6	

4.1.4 Budget

The Department has a small capital budget and this has been used for some station rehabilitation. Most of the funds come from the AGRHYMET project and it is this project which pays for items such as charts and pen ink. Were it not for the support of this project it is understood that it would very difficult to import equipment or consumable items such as the charts.

4.2 Hydrological Data

4.2.1 Hydrometric Network

The network of hydrometric stations is presented on Tables 4.2 and 4.3. The first of these tables lists the stations with details of their equipment and their periods of operation. The second gives their location, the most recent value of zero of the scale datum and, mainly for stations with a rating curve, the catchment area and the number of current meter gaugings.

TABLE 4.2
Inventory of Hydrological Stations - Equipment

River/stream	Station name	Equipment installed		Date of installation	Existing equipment		Data	Remarks
		Recorder type	Nr of gauge boards		Recorder type	Nr of gauge boards		
Gambia	Banjul	Ott X	3	02-12-78	Ott X	1	WL,S	Operational
Jurunkumani Bolon	Jibanack	Staff gauge	1	11-09-76	Staff gauge	1	WL,Q	Re-established Apr 1990. No current rating curve
Bintang Bolon	Brumen Bridge	Ott R16	3	03-10-73	Ott R16	2	WL, S	Operational
Gambia	Tendaba	Ott X	3	05-01-78	Stevens	3	WL, S	Non-operational since Oct 1973. Rebuilt Jun 1991.
Gambia	Balingho	Ott X	3	23-03-77	Stevens	3	WL, S	Non-operational since Mar 1985. Rebuilt May 1991.
Sofaniama Bolon	Pakaliba	Ott X	2	22-03-77	Ott X	1	WL, S	Operational
Gambia	Kaur	Ott X	3	04-03-77	Stevens	3	WL	Non-operational since May 1985. Rebuilt May 1991.
Nianija Bolon	Charmen	Ott X	2	23-03-77	None	None	WL	Non-operational since May 1985. Contract to rebuild from National Budget.
Gambia	Kuntaur	Ott X	3	23-03-77	Stevens	3	WL	Non-operational since May 1985. Rebuilt May 1991.
Jahally Canal	Jahally	Ott R16	3	20-06-77	Ott R16	1	WL	Operational. Rehabilitation Jun 1991.
Patchar Bolon	Patcharr	Ott R16	2	??-08-77	None	None	WL	Non-operational since May 1985.
Gambia	Georgetown	Ott X	3	01-05-77	Stevens	1	WL	Non-operational since Oct 1986. Rebuilt May 1991.
Gambia	Bansang	Ott X	3	24-03-77	Stevens	2	WL, Q	Flow data up to 1983. Rebuilt Jun 1991. No rating curve.
Sandugu	Sami Wharf Town	Ott R16	2	07-06-77	Stevens	2	WL	Non-operational since May 1984. Rebuilt May 1991.
Gambia	Basse	Ott X	4	03-06-77	Stevens	4	WL	Non-operational since Jan 1981. Rebuilt May 1991.
Prufu Bolon	Dampha Kunda	Staff gauge	2	20-09-76	Staff gauge	1	WL, Q	Operational. Has rating curve.
Shima Bolon	Suduwol	Staff gauge	1	??-08-78	None	None	WL, Q	Non-operational since Mar 1984.
Gambia	Fatoto	Ott X	5	05-06-77	Stevens	5	WL	Non-operational since Mar 1984. Rebuilt May 1991.

TABLE 4.2 (cont)

River/stream	Station name	Equipment installed		Date of installation	Existing equipment		Data	Remarks
		Recorder type	Nr of gauge boards		Recorder type	Nr of gauge boards		
Massarin Ko Bolon	Kerr	Staff gauge	1	16-10-76	None	None	WL, Q	Non-operational since 1984. No rating curve.
River Benefit	Sanyang	Staff gauge	1	14-09-76	Staff gauge	2	WL	Operational. Staff gauge. Re-installed Apr 1990.
Allahein	Kartung	Ott X	2	15-02-85	None	None	WL	Non-operational since Aug 1988.
Allahein	Sifoe	Staff gauge	1	??-04-90	Staff gauge	1	WL	Operational. Staff gauge re-installed Apr 1990.
Allahein	Darsilami	Staff gauge	1	??-04-90	None	None	WL, Q	Non-operational. Rebuilt by DWR in Apr 1990. No rating.
Bao Bolon	Illiassa	Staff gauge	2	??-05-90	Staff gauge	2	WL, S	Operational
Miniminium Bolon	Jowara	Staff gauge	2	??-05-90	Staff gauge	2	WL, S	Operational.

Note: Data collected
- WL Water level record
- Q discharge measurement
- S salinity measurement

TABLE 4.3

Inventory of Hydrological Stations - Location

River/stream	Station name	Coordinates		Catchment area (km²)	Level of scale zero	Number of gaugings
		North	West			
Gambia	Banjul	13° 27'	16° 35'	77 054	-1.274	-
Jurunkumani Bolon	Jibanack	13° 12'	16° 07'	4.69	7.624	20
Bintang Bolon	Brumen Bridge	13° 15'	15° 50'	-	-0.793	-
Gambia	Tendaba	13° 26'	15° 48'	-	-1.412	-
Gambia	Balingho	13° 30'	15° 36'	-	-0.291	-
Sofaniama Bolon	Pakaliba	13° 30'	15° 15'	-	-0.500	-
Gambia	Kaur	13° 42'	15° 20'	-	0.277	-
Nianija Bolon	Charmen	13° 43'	15° 10'	-	-2.907	-
Gambia	Kuntaur	13° 40'	14° 53'	-	-0.772	-
Jahally Canal	Jahally	13° 34'	14° 57'	-	-0.943	-
Patcharr Bolon	Patcharr	13° 32'	14° 52'	-	0.010	-
Gambia	Georgetown	13° 33'	14° 46'	-	-0.449	-
Gambia	Bansang	13° 25'	14° 40'	-	-1.378	-
Sandugu	Sami Wharf Town	13° 30'	14° 28'	-	-0.014	-
Gambia	Basse	13° 19'	14° 13'	-	0.274	-
Prufu Bolon	Dampha Kunda	13° 20'	14° 12'	340	5.474	9
Shima Bolon	Suduwol	13° 22'	13° 58'	750	7.510	9
Gambia	Fatoto	13° 24'	13° 54'	-	0.519	-

TABLE 4.3 (cont)

River/stream	Station name	Coordinates		Catchment area (km^2)	Level of scale zero	Number of gaugings
		North	West			
Massarin Ko Bolon	Kerr	-	-	-	-	-
River Benefit	Sanyang	13° 16'	16° 46'	-	3.801	-
Allahein	Kartung	13° 05'	16° 45'	-	-	-
Allaheim	Sifoe	13° 10'	16° 41'	-	-	-
Allaheim	Darsilami	13° 10'	16° 39'	-	0.364	-
Bao Bolon	Illiassa	13° 35'	15° 47'	-	-	-
Miniminium Bolon	Jowara	13° 34'	16° 06'	-	-	-

As with the rainfall there seems to be some inconsistency in the information taken from different sources. The above tables were based on a table handed over by the DWR, this table is in turn based on a computer printout which was prepared around 1978 by the Gambia River Project. This printout gave a lot of then up to date (1976 to 1977) details on the stations but did not often give details of equipment which had existed earlier at the stations. On the other hand the Hydrological Monograph on the Gambia River published in French by ORSTOM does give some of this earlier information (the date of publication is not given but on internal evidence, such as dates of last gauging quoted, it was around 1989). In an attempt to clarify the situation, and since the ORSTOM report is not available in English, Appendix E gives a summary of the details of each station taken from all of these reports and more recent information given verbally.

As will be seen the network consists of 25 stations of which 9 are on the Gambia River itself. Some of the other stations, such as the one on the Jahally Canal also effectively measure levels in the Gambia. Many of the other stations, such as that at Brumen Bridge on a tributary some 80 km from the main river, are also tidal and therefore influenced very much by the levels in the main river. The locations of these stations are shown on Figure 4.1.

It is difficult to assess the effectiveness of the network. Most of the stations are on the main river for which rating curves are difficult, if not impossible, to develop. Of the stations on the tributaries only a few have rating curves and these only cover a small percentage of the country's surface. There are not enough stations to enable even an approximate assessment of the country's average runoff to be made.

The last published year book, for 1983/84, gave flow for four stations. These were Prufu Bolon at Dampha Kunda, the Jurungkumani at Jibanack, the River Benifet at Sanyang, and the Lamin Bolon at Abuka. The last of these four had a staff gauge and sharp crested rectangular weir and had been installed by Howard Humphreys and Sons as part of their study. From the 1983/84 flows it is difficult to draw any conclusions about runoff. For Prufu Bolon it was 37 mm, for Jurungkumani it was 67 mm and for the River Benifet it was 0.02 mm.

At the moment the only record of flow for the Gambia River which is available to the country is at Gouloumbo in Sénégal 30 km upstream of the border. The station started in 1951 and has continued, with breaks in 1957 and 1963, to the present. In their monograph on the Gambia ORSTOM give flows at this station up to 1986-87 but only when above a threshold of 90 m^3/s since the recorded levels are affected by tidal influences when the river flow is less than this. This means that for most years they only have published flows for the months August, September and October. In some years there are also flows for parts of July and November. The DWR in Banjul also has on file flow records for the Gambia at Gouloumbo, they run from 1951 to 1981 and were taken from OMVG/ORSTOM publications. These flows include the monthly flows for the period 1970-71 to 1981-82 and annual flows before that year. To get as complete a flow sequence as possible relationships were developed using the published ORSTOM monthly figures to extend the annual flow record to the water year 1986-87. This model used measured flows where these were available, where a partial month of flow was available this was used to estimate the flow in the full month, and for most other months a recession curve was used. For June, whose flows were variable but in general small, the average was taken. The accuracy of this model for the period of overlap (1970-71 to 1981-82) is shown in Figure 4.2. There are in fact some differences between the monthly figures that the DWR has and those published by ORSTOM so the errors, which can be seen to be small, are probably not significant. From this a sequence of recent annual flows for The Gambia has been produced. This is shown in Figure 4.3.

4.2.2 Methods of Discharge Measurement

There is relatively little information on how the rating curves were derived in the past. For example, the rating at Jibanack was prepared on the basis of nine gaugings between 1977 and 1982. The maximum gauged level was 0.24 metres and while the curve has been extrapolated for levels above this there is no indication of what method was used.

On the main river there have been two attempts at gauging within The Gambia, one by Howard Humphreys and one by the British Hydraulic Research Station (HRS).

The first study was that published by Howard Humphreys in 1974. They initially thought that gauging for one tidal cycle (about 13 hours) would be long enough. However when gaugings were carried out over 26 hours, two tidal cycles, the results from the two 13-hour periods were not the same. Later during the analysis of their gaugings, which were spread over a period of several weeks, they came to the conclusion that it would be necessary to gauge during at least half of a lunar cycle, 14 days, or perhaps even a complete lunar cycle of 28 days. They estimated the net flow at the time of their study as 3 m^3/s but, as the tidal flux was of the order of 300 m^3/s, it would have needed an accuracy of gauging of better than 0.1% for this figure to be accurate to 10%.

The HRS study was carried in March 1974, after the above study had been completed but before the results had been published. These gaugings were carried out at Bansang, which is 315 km from the mouth of the river, from 14 to 24 March 1974. At the time of the study the flow at Gouloumbo, some 200 km further upstream, was 5 m^3/s.

The gaugings were carried out in a thorough way. The river was 200 m wide and nine verticals were used. The centre vertical used eight readings and the other verticals five readings. Each set of readings was carried out over two full tidal cycles. Four boats were used to enable gauging at different verticals to be carried out simultaneously. Eighteen level measurements were made to check the river profile. The results were as follows:

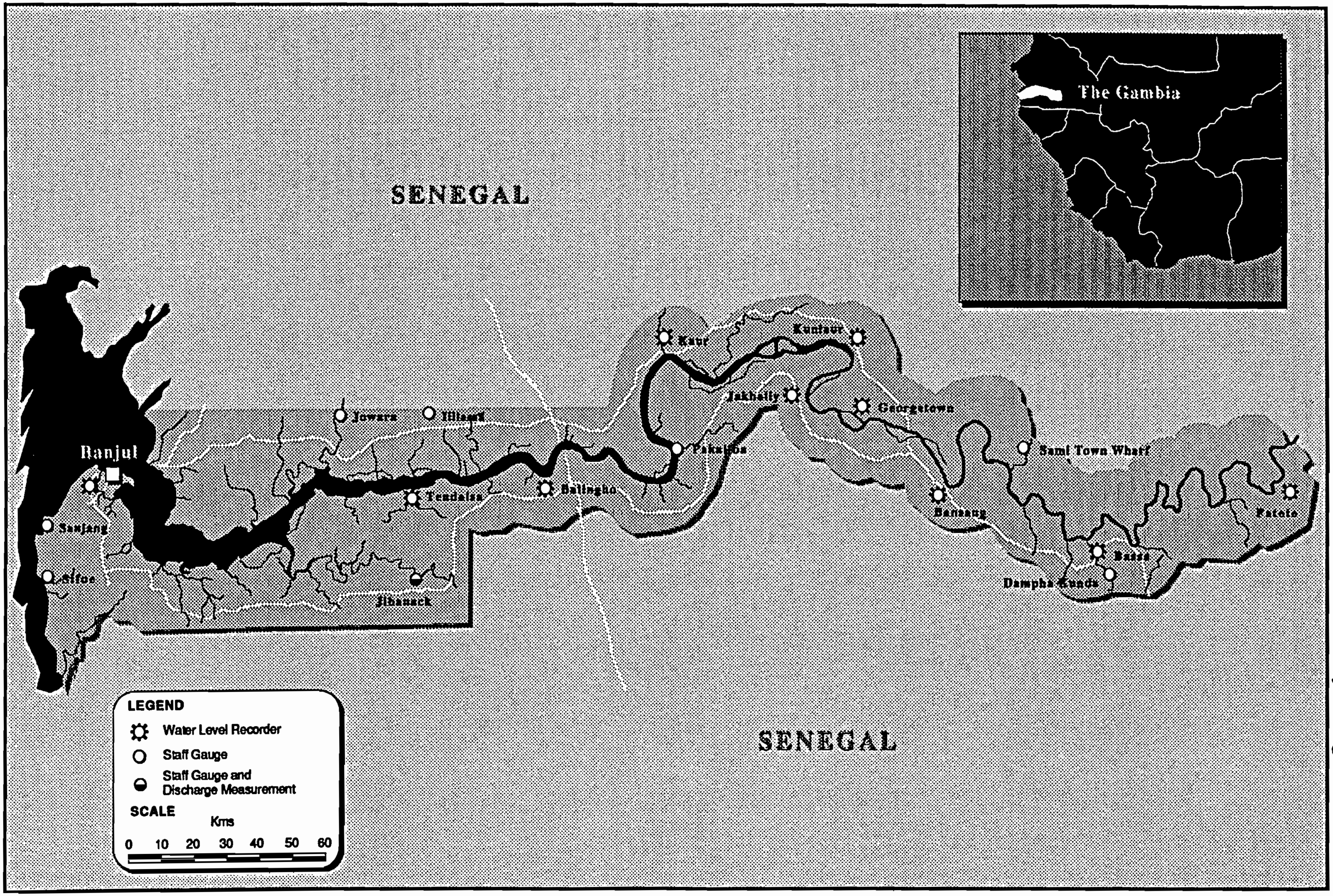
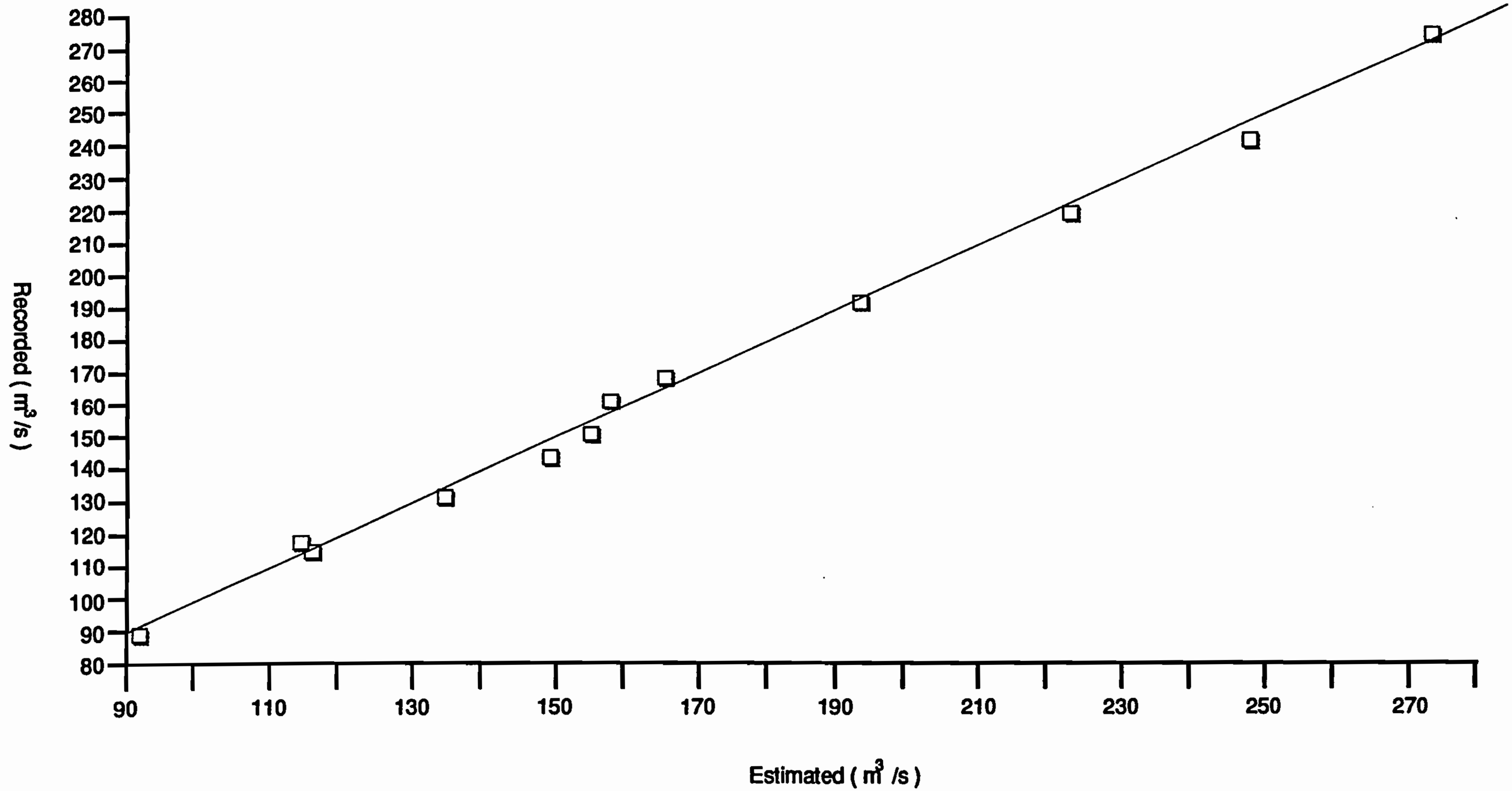
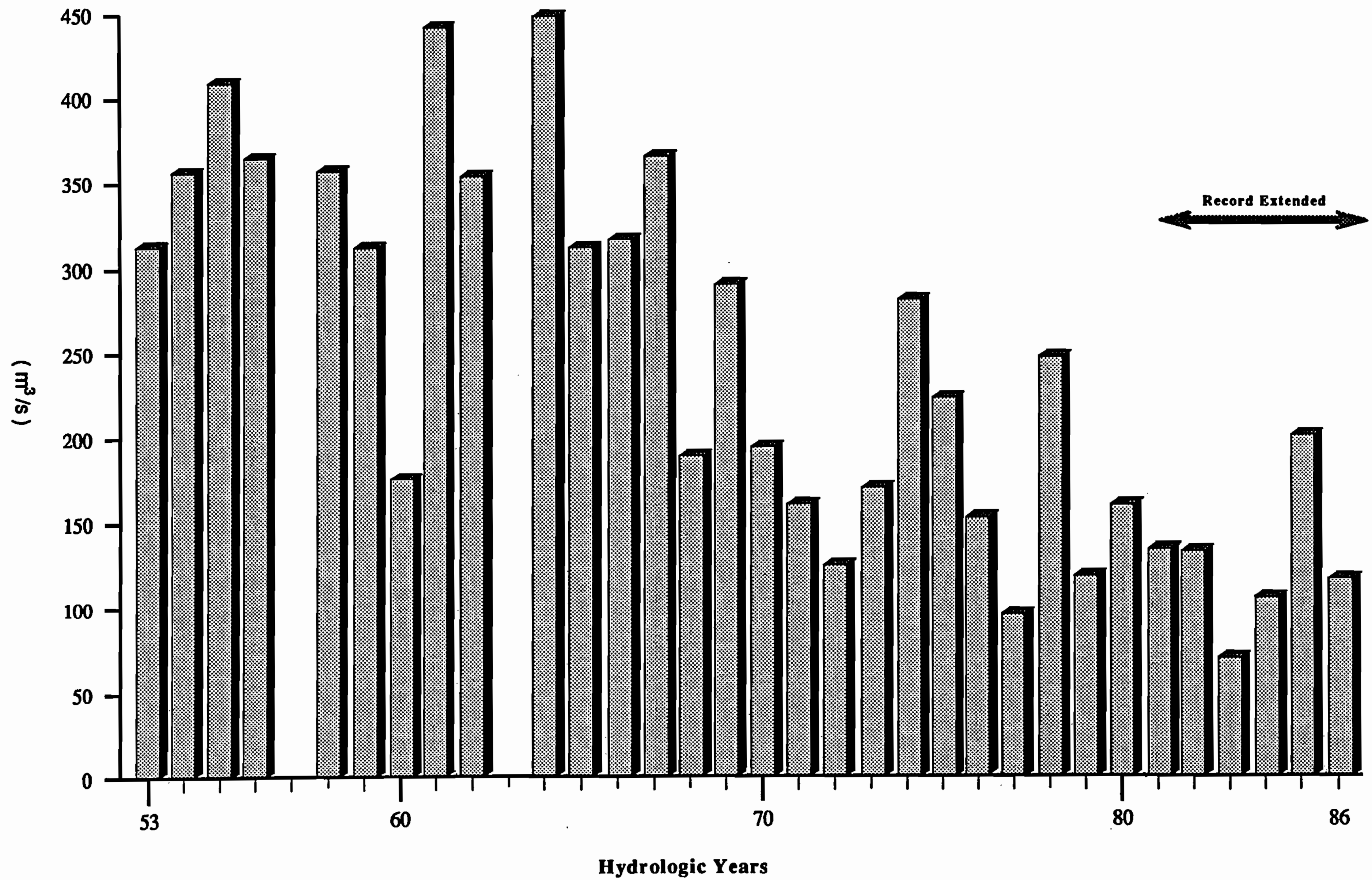


Figure 4.1
Hydrological Network

Figure 4.2

Flow Extension - Gambia at Gouloumbo





Mean Annual Flow - Gambia at Gouloumbo

Figure 4.3

Date	Residual Average Discharge (m^3/s)
14/3/74	+45.9
16/3/74	+50.9
18/3/74	+19.5
20/3/74	+12.0
22/3/74	-14.6
24/3/74	-32.3

During the gauging the mean tidal flows were 360 m^3/s so the average flows were the difference between two large values.

Given the efforts which were made to ensure the accuracy of the readings, which are described in more detail in their report, it is a pity that the gauging did not continue for a full lunar cycle. The explanation put forward for the differences in discharge was that during the tidal cycle water entered in to and flowed out of riparian groundwater zones and they proposed that piezometers be installed to evaluate the extent of this. This explanation appears unlikely and the suggestion of Howard Humphreys, that flows have to be gauged over a full lunar cycle, seems more probable. No such exercise has ever been carried out.

4.2.3 Equipment

In the mid-1970s many of the stations were equipped with Ott water level recorders. Most of them were Ott type X. Often these replaced an earlier Ott R16 recorder. During the first half of 1991 eight stations on the main river were equipped with Stevens water level recorders. At the same time new float wells and shelters were constructed. This was done in the context of a regional USAID project in association with the OMVG. At the time of our visit these stations had been constructed but had not become fully operational. In all but two of the cases the new stations replaced a former station which had fallen into a state of disrepair.

At many sites the only equipment consists of gauge boards. While the use of gauge boards is appropriate for large rivers with a slow response time it is not suitable for some of the very small catchments in The Gambia. Recording levels two times a day will not give a good idea of hydrograph shape for the small catchments.

We were taken to a number of gauging stations and in general the equipment seemed to be working well though in many cases the charts had not been changed for several of the rotations of the drum.

For flow gauging the Hydrology Division has two small Ott current meters with three 0.5 m rods which are therefore only suitable for measuring flows in small shallow streams. The meters had never been recalibrated and when one of the propellers was spun vigorously it rotated for 15 seconds only, a sign that it was not in the best condition.

The DWR had received a boat in 1980 as part of an OMVG project. This boat, described as a speed boat, was not really suitable for gauging work. Its motor broke down in 1983 and could not be repaired. Since then there has been no boat available for gauging.

None of the stations has a permanent cableway.

The Hydrology Division has a stock of the most commonly needed spare parts, such as floats and cables, for the Ott recorders. It is understood that a similar stock will be provided for the new Stevens water level recorders.

The only vehicle available for field visits is a 4-wheel drive vehicle which has to be shared with the Meteorology Division. As this vehicle has to visit all the synoptic stations and phenological stations every 10 days during the rainy season to prepare the 10-day bulletin in the context of the AGRHYMET project, this severely hampers the field visits that the hydrologists can make.

The Department also has two conductivity probes, an LF 91 and an LF 191 made by WTW, a German company. They are equipped with 50m cable so could also be used for well work. To measure salinity the probes were calibribated by tests at the water laboratory operated at Yundum. The calibration agreed with USGS norms.

4.2.4 Maintenance and Field Support

There is a problem of transport which limits the frequency with which visits can be made to the field. For some stations visits are only made every six-months. The problem of charts not being changed is reported to be fairly typical and often daily charts are only changed once a week. Many of the observers are also reported to be unreliable. There have been problems in getting their payment to them due to loss of money in transit and at present they are expected to come to Banjul to get paid. This means that during the time it takes to get to Banjul the station is left without an observer and the fact that a significant proportion of their salary goes on travel to Banjul also discourages them. Morale among the observers is low and many leave the service. Of four water level observers who had been through the previous course at the DWR training school, only one was still in the service of the Hydrology Division.

4.2.5 Data Processing

The collection of data is largely carried out during visits to the stations on an *ad hoc* basis.

There appear to be no regular quality control procedures.

At present there is only limited processing of data and it is understood that flows are only calculated for the stations which are included in the 10-daily AGRHYMET report. In some cases these stations use a rating curve which has not been checked in recent years.

The HYDROM hydrological data processing software package from ORSTOM is available to the Division but at the time of our visit had never been used. That this was so was reported as being due to internal administrative difficulties which have now been resolved.

4.2.6 Data Quality

Due to the short period of the visit and the difficulty of getting data it was not possible to carry out any quality control checks on sample data. However the variation in runoff, published for 1983/84, mentioned above, suggests that only limited quality checks were carried out before publication. Figure 4.4 is a plot of the published discharge hydrograph for Prufu Bolon at Dampha Kunda for the hydrometric year 1983/84 which shows a number of anomalies.

4.2.7 Data Availability

There is an inventory of stations but there is no inventory of data. What data there is, is either in the form of tables in files, or the original charts. At the moment it is not possible to obtain data in a computer compatible format. The latest available year books have typed data - so it appears that none of the data has ever been computerised.

4.3 Solid Transport

There is no measurement of solid transport. This topic was raised in the Howard Humphreys' report. The opinion they expressed was that measuring flow in the tidal river was difficult enough, given the variations due to the tidal cycle and the lunar phases, and the net flows were only a small proportion of the tidal flux. In the case of sediment the problem is even more severe. Not only would the river flow vary throughout the cycle but there would be sediment moved as a result of tidal action in addition to that carried down the river by fluvial action. This would make it virtually impossible to identify any net transport toward the ocean.

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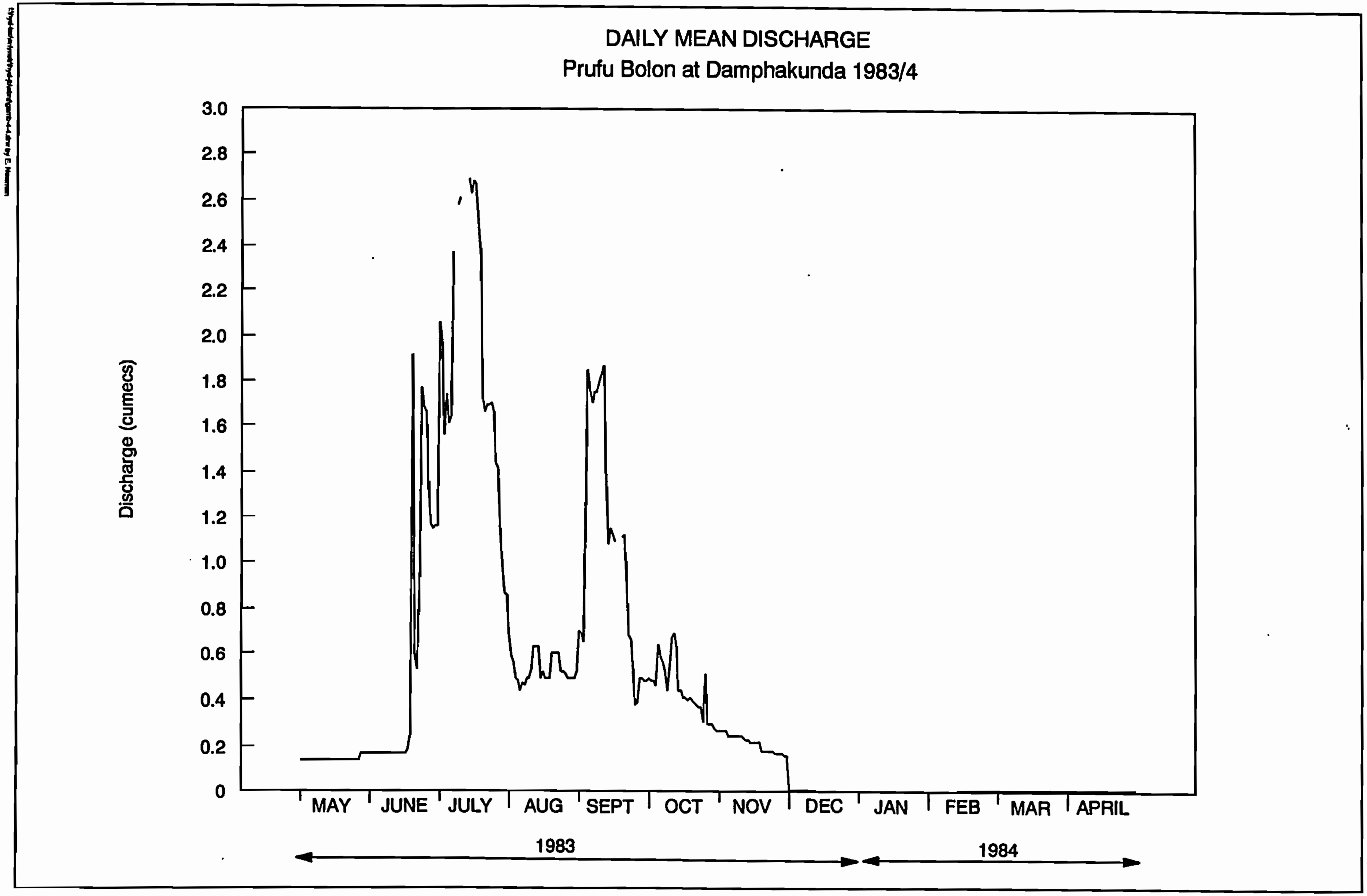

Discharges 1983/84 Prufu Bolon at Dampha Kunda

Figure 4.4

TABLE 4.4

Position of Saline Interface (km from sea)

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973	150	180	195	205	230	240	235	185	75	80	120	140
1974	160	180	193	213	225	238	235	150	76	85	100	118
1975	140	180	200	215	225	235	220	170	135	130	125	120
1976	135	155	175	210	220	228	227	200	150	95	110	120
1977	135	150	175	195	222	242	230	200	170	130	115	140
1978	165	185	200	225	240	243	230	208	170	120	110	118
1979	130	145	170	195	215	240	235	220	190	165	130	125
1980	140	150	170	190	215	240	230	190	170	150	140	150
1981	160	185	195	221	225	235	244	240	210	150	120	135
1982	155	170	185	195	210	215	235	241	210	160	130	140
1983	155	165	190	210	225	240	220	180	135	122	135	155
1984	175	185	205	220	242	255	230	190	170	150	140	145
1985	153	160	174	205	235	248	254	210	150	100	127	138
1986	149	167	193	205	235							
Mean	150	168	187	207	226	238	233	199	155	126	123	134

Source: DWR

CHAPTER 5

GROUNDWATER

5.1 Organisation and Management

5.1.1 The Hydrogeology Service

The principal government organisation responsible for groundwater investigations, studies, development and protection, is the Rural Water Supply Division of the Department of Water Resources (DWR), Ministry of Natural Resources and the Environment. The Division consists of five sections, as follows:

- Hydrogeology
- Well Digging
- Drilling
- Rehabilitation
- Mechanical Services.

The headquarters of the Division is in Banjul, though many of its activities are in the field all over the country and the Mechanical Services Section runs two provincial workshops, one at Yundum near Banjul Airport, the other at Basse in the extreme east.

The organisation of the Rural Water Supply Division is shown in Figure 5.1.

Up to very recently, the Division was headed by the only Gambian in the country with specialist post-graduate qualification in hydrogeology, but he has been promoted to Deputy Director of DWR; nevertheless, in the absence of any replacement for his previous post, he still takes a major interest in all groundwater activities in the country.

The nominal staff establishment of the Rural Water Supply Division comprises some 115 posts in total, including the following personnel:

Post	Number of staff approved	Comment
Principal Hydrogeologist	1	Post vacant
Senior Programme Officer	1	In post; Law graduate from a USSR university
Engineer	2	Both in post; one Civil Engineering (CE) graduate trained in USSR and Holland; the other CE graduate from Sierra Leone, currently on study tour in the UK
Hydrogeologist	1	Post vacant
Works Superintendent	3	All in post
Principal Technical Officer	2	Both in post
Inspector (Groundwater)	1	In post
Groundwater Assistant	1	In post
Groundwater Assistant Trainee	1	In post
Senior Survey Assistant	1	In post
Draughtsman	1	Post vacant

Non-graduate technical staff include two Principal Technical Officers, both trained in the USA and two Groundwater Assistants (one trainee); there is also an unfilled post of Draughtsman.

Because of the lack of indigenous groundwater experts in The Gambia, the DWR relies on foreign personnel, supplied by international and bilateral agencies under the various aid projects, to provide such expertise. The UNDP assistance is in the form of the Groundwater Resources Planning and Development Project supplying a chief technical adviser and three volunteer experts (one hydrogeologist, one driller and one mechanical engineer). UNICEF has provided one senior consultant, who has been trying to introduce a degree of co-ordination into the water supply and sanitation activities in the country, by convening regular meetings of the Water and Sanitation Working Group, involving all the interested parties. Lastly, the bilaterally assisted rural water supply programmes, notably the German funded GITEC project, operate under expatriate technical and administrative supervision, currently without any Gambian graduate counterparts.

Thus the Hydrogeology Section is virtually synonymous with the UNDP Groundwater Resources Planning and Development Project (GAM/87/012), with the key staff being a Czechoslovakian project manager and a Somali hydrogeologist. The prime objective of the project is stated as institution building, but in the absence of any counterpart hydrogeology experts, the UN staff tend to undertake many routine groundwater tasks themselves in liaison with the DWR management, rather than direct and train local personnel.

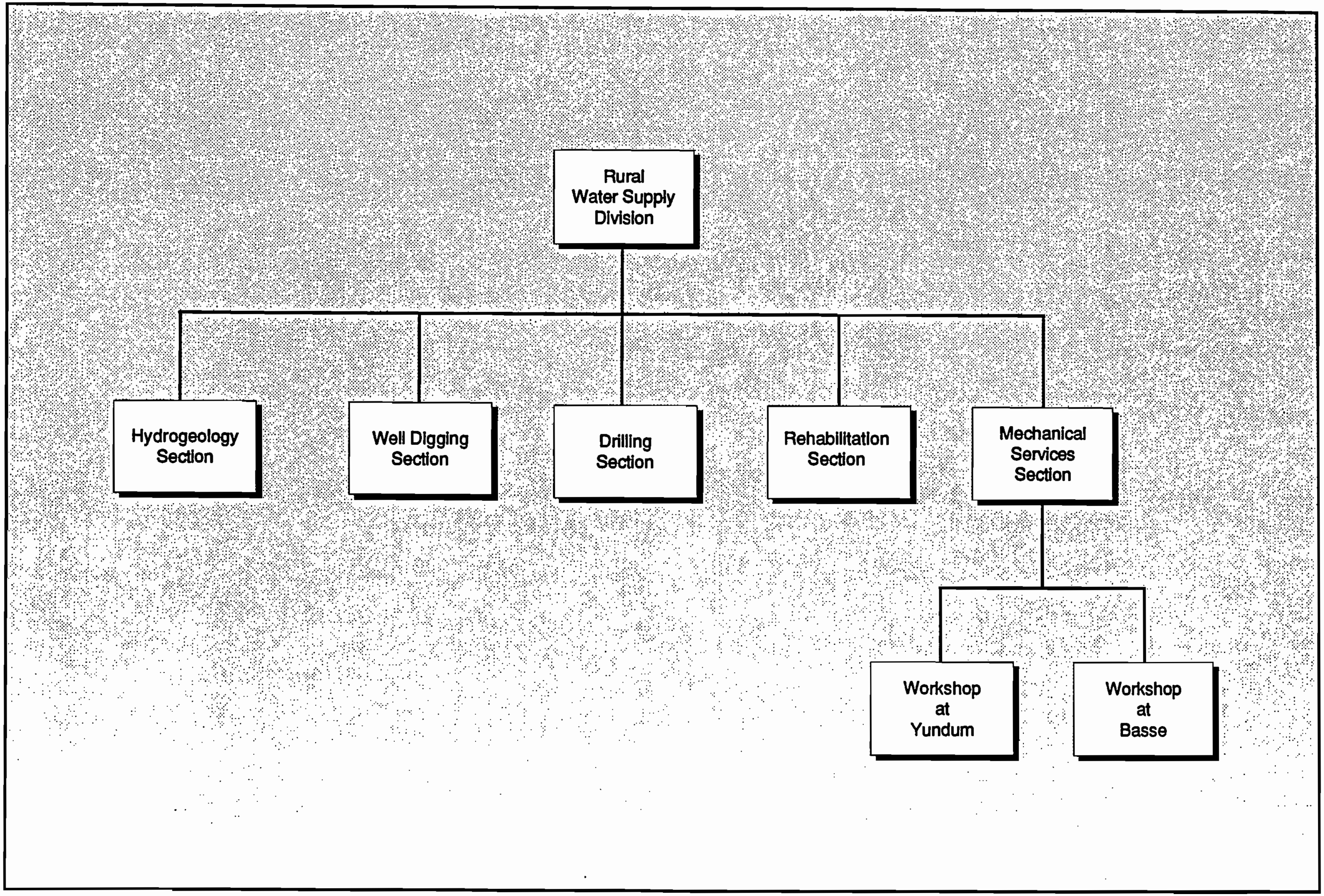

Figure 5.1

Organisation of the Groundwater Service, Department of Water Resources

The Well Digging Section comprises the projects involved in this field, that is the UN assisted programmes and, nominally, the GITEC operations. Though both of these report to the Directorate of the DWR, they operate in rather different ways. The UN projects are staffed mainly by Gambians (under GAM/87/012 supervision); in line with the present policy of the government, the construction of the wells has been privatised and contracts issued to several local firms. Nine such local contractors have been prequalified and graded by DWR. All of them rent equipment, such as dewatering pumps and a mechanical excavator from DWR. Contracts are not awarded on the basis of competitive bidding; instead prices are fixed by the DWR and the amount of work awarded to a particular firm is decided on an evaluation of its capabilities. In contrast, GITEC well construction is by community participation with project equipment, under German expert supervision, with minimal involvement of any DWR staff.

The Rural Water Supply Division has its own drilling unit. Of the three drilling rigs in its possession, two are cable tool and one is rotary. Both of the former have been out of operation for more than a year, and although at least one could be rehabilitated, there are no plans to do so. The rotary machine is operational and is currently working on an EDF assisted project, under the jurisdiction of the Directorate of DWR. The drillers are mainly local, but are supported by a UN volunteer from Bangladesh. The productivity has been poor with only five boreholes constructed over the last year; difficulties with obtaining foreign exchange for spare parts and accessories have been blamed for this poor performance.

The main current task of the Rehabilitation Section is the implementation of the EDF funded Rural Water Supply Rehabilitation Programme concerned with reconditioning of dug wells, boreholes and pumps. The procedures are according to concepts developed by GITEC. The staff involved are mainly local employees of the DWR.

The field of operation of the Rehabilitation Section overlaps with that of the Mechanical Services, which, through its two workshops (at Yundum and Basse), is engaged in the maintenance and repairs of rural water supply facilities. The staff is mainly local, strengthened by one UN volunteer mechanical engineer.

As already mentioned, the Rural Water Supply Division has a considerable amount of heavy equipment under its jurisdiction, including drilling rigs, compressors, dewatering pumps, an excavator and a fleet of vehicles of different kinds. Minor equipment items include electrical conductivity (EC) meters, pH-meters and water level indicators.

The Division also has access to computer facilities. Both the UNDP Groundwater Resources Planning and Development Project and GITEC's Hand-dug Well Programme use computers with peripherals for data (particularly well records) storage and processing. Unfortunately they use different software.

The DWR has a water laboratory under the control of the Water Quality Control Division, which provides analytical services to the other Divisions and some outside interests. The laboratory is located at Yundum with a chemical engineer (qualified in China) in charge. The staff comprises two biologists (one graduate from Sierra Leone University, the other with a qualification in Environmental Studies in Holland), three laboratory technicians and one field assistant (used for collecting water samples).

The laboratory is equipped for chemical determinations by atomic absorption, gas chromatography as well as conventional spectrometry and titrations. Because of limited peripheral equipment, atomic absorption can only be used for sodium, potassium and lithium, and gas chromatography only for organochlorides. Nevertheless, all the common chemical constituents of natural waters have been successfully measured in the past.

Amongst other services offered by the laboratory are the following bacteriological determinations:

- total bacteria
- total coliform organisms
- faecal coliforms.

The laboratory also has some portable equipment in its care, including:

- EC meters
- pH meters
- bacteria kits
- Hach DREL 4 portable laboratories (with no reagents and probably defunct).

The greatest problem reported by the laboratory, is lack of a reliable water supply; a borehole with a small electric pump and a storage tank would be the most effective way of correcting this deficiency. Other equipment requirements have been reported as follows:

- peripherals for the atomic absorption and gas chromatography apparatus to make them more widely useful;

- new BOD and COD measuring equipment;

- computer hardware and software for data processing, storage and printing.

Apparently foreign exchange for purchase of reagents of any kind is a major problem. Lastly, trained manpower availability is reported as difficult, with the private sector offering better pay and conditions.

The current head of the laboratory has been in post only since the beginning of 1991. During the first six months of that year the throughput has been chemical analyses of about 20 water samples and approximately 50 bacteriological determinations.

The DWR laboratory is reported to be the only water laboratory in The Gambia.

5.1.2 Other Public Agencies with Interest in Groundwater

The other agency with a major interest in groundwater is the Gambia Utilities Corporation (GUC). This is a parastatal organisation under the Ministry of Works and Communications, with responsibility for electric power and urban water supply. The most important water component under its jurisdiction is the municipal supply to Banjul and the urban/tourist areas of the North Kombo Peninsula. However, the division of responsibilities between the GUC and DWR is not entirely clear cut, as the former apparently looks after the following:

Type of supply	Number of boreholes	Daily abstractions (m^3)
Urban (Banjul-N Kombo)	18	21 000
Township	7	290
Rural	6	34
Village	1	11

Source: UNCDF 1988 and GUC 1991.

It is understood that all these abstractions, except for the 'village' borehole, include electrical turbine pumps and storage tanks, and that 'rural' supplies may serve standpipes in more than one village.

GUC was established in 1972 with the specific responsibility for providing electricity country-wide, and potable water and sanitation facilities to the urban centres, particularly to the rapidly growing commercial and tourist developments of Banjul and North Kombo. It was set up as a semi-autonomous body to derive its income from sales of electricity and water, with much of the profit to be used for financing of further developments. However in recent years the GUC has not made sufficient profits to finance any significant investments.

The organisation of the Water Division of the GUC is shown in Figure 5.2. The Divisional Manager (Acting) is a mechanical engineer and the agency as a whole is geared to keeping the water supply systems functioning rather than the evaluation of resources and design of works for further development. For such tasks the GUC traditionally used the services of international and local consultants; their reports provide the fullest hydrogeological database for The Gambia as a whole, but particularly for the urban/tourist area of the capital city (Ceesay and Howard Humphreys 1987, Lewin & Fryer 1988).

At one time (1980) the GUC's Water Division was building up its own groundwater development capability and operated two drilling rigs (Ruston Bucyrus cable-tool machines) and a crane truck as well as concrete vibrators, compactors, tripod/winch units and heavy transport. However, much of its specialised equipment such as the drilling rigs and the crane truck, is now defunct. It is uncertain what drilling had been accomplished by the equipment when it was functional, but it seems that all the GUC Banjul area production boreholes were constructed by contract, using foreign contractors (British, German and Chinese), usually those with representatives in The Gambia or in the adjacent countries.

GUC's equipment situation has now deteriorated to such an extent that even pulling out of the borehole pumps is done by hand using a tripod/winch unit. Its technical work, relevant to further development, is virtually limited to, admittedly very valuable, monitoring of groundwater levels in the Kombo area.

The Ministry of Agriculture takes some interest in groundwater through its Department of Agricultural Services and the Soil and Water Management Unit. Though significant groundwater irrigated horticulture is practised in The Gambia, and further development potential exists, the Ministry has no groundwater development expertise of its own and relies on private enterprise, DWR, UN agencies and foreign experts for technical assistance. It is understood that there is one experimental project of special interest, namely irrigation of some 15 ha by groundwater using solar pumps, financed by NORAID and monitored by the ministry.

The Ministry of Economic Planning and Industrial Development (MEPID) also has some involvement in groundwater investigations and development in The Gambia. Firstly, its Geological Unit produces geological maps, and collects and compiles all borehole evidence in its general geological work; these maps and compilations are very useful to groundwater workers. Secondly, the Division Development Committees established in 1975 under the auspices of the MEPID, have been given responsibility for selecting water supply projects for priority financing, implementing them if the funding is approved and maintaining the completed facilities.

Lastly, the Ministry of Local Government and Lands takes an interest in water supply through its six Area Councils and the Department of Community Development. However, its expertise in the field of groundwater is negligible.

5.1.3 Non-governmental Organisations

As in much of West Africa, some charity based non-governmental organisations (NGOs) have been involved in the rural water supply sector, particularly in constructing dug wells, some of them equipped with hand pumps. Amongst these are Caritas, WaterAid, Action Aid and the Rotary Club. All have made use of the indigenous expertise in digging wells.

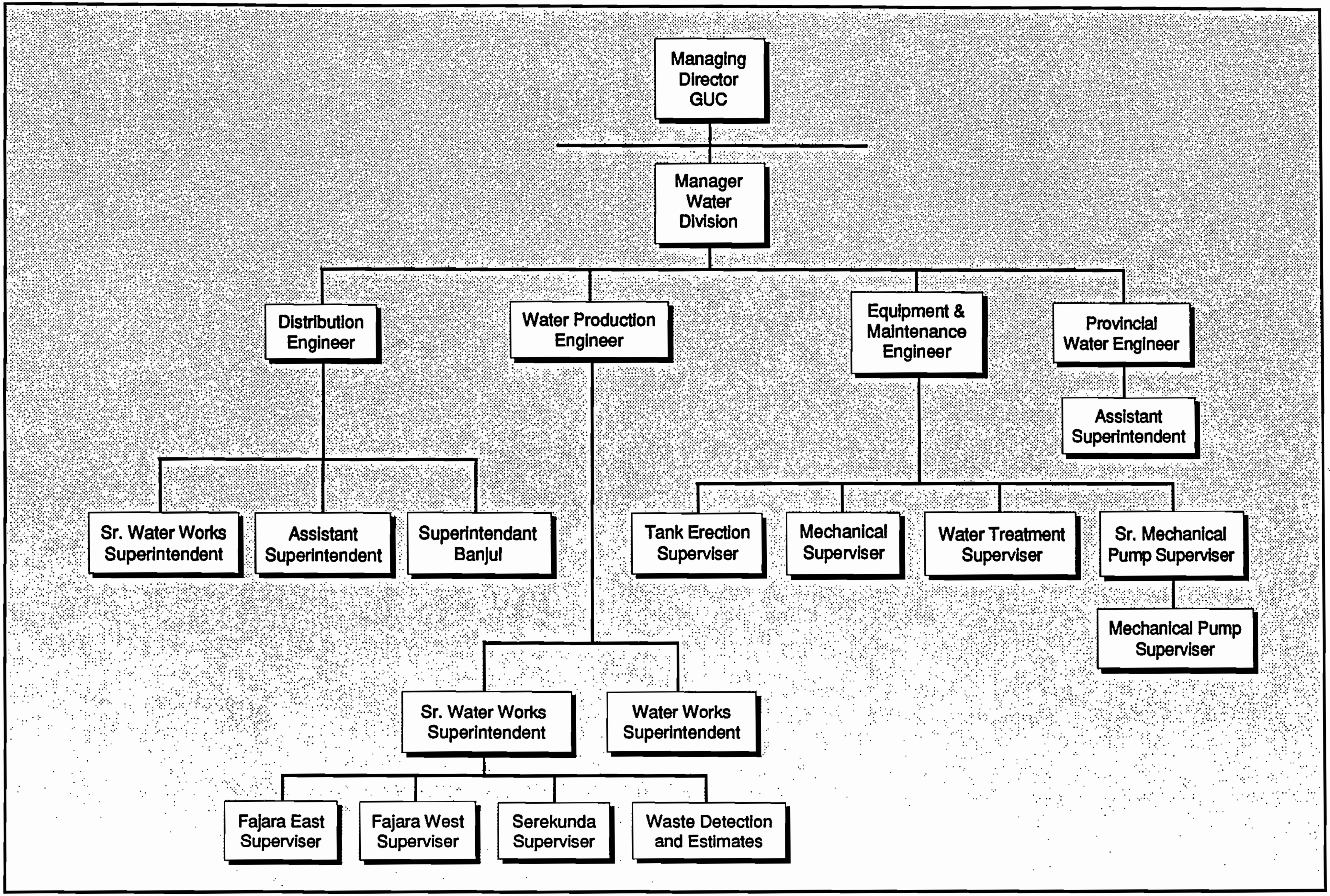

Figure 5.2

Organisation of the Water Division of the Gambia Utilities Corporation

Local consulting firms, of which the best known is S Ceesay & Sons Ltd, have no groundwater expertise of their own, but have provided such to their clients by associating with foreign consultants for particular projects. There are no Gambian drilling contractors, though George Stow Ltd (British) is reported to maintain an office in Banjul. In addition, Polish, German and Chinese companies have undertaken drilling programmes in The Gambia; some these are still operating in nearby countries (Senegal and Guinea).

As already mentioned, the Gambian Government has recently decided to privatise much of the well digging business and several local firms have taken up the challenge. However, at present the situation is well short of competitive free enterprise; none of the new contractors can operate without the assistance of the DWR, in the form of equipment rental; moreover contracts are not awarded to the lowest bidders, but are issued at fixed prices to firms judged as competent at the tasks involved.

5.1.4 Staff and Training

As must be apparent from the preceding sections, the lack of local expertise in groundwater related disciplines is one of the major problems of the water sector industries in The Gambia. This situation is particularly difficult to correct because there are no university or polytechnic educational facilities in the country; consequently, training of a Gambian hydrogeologist or a groundwater engineer involves both undergraduate and postgraduate training abroad (at least four years total), which is not only expensive but also longer than most water sector projects, which therefore find it difficult to organise such training.

The DWR has attempted to correct this deficiency by asking for and getting foreign groundwater experts assigned to The Gambia under various UN institution strengthening projects, such as the on-going UNDP Groundwater Resources Planning and Development Project. However, useful as these projects have been, they are no substitute for strong local expertise.

Inevitably the UN experts on temporary assignments (even overlapping), do not provide the necessary continuity that the groundwater sector requires. Moreover, there is a tendency for such projects to be treated as yet another amongst many, rather than the coordinating authority with responsibility to impose uniformity of data acquisition and reporting, develop standard designs and ensure sharing of relevant information.

The problem of the lack of institutions of higher education in The Gambia has already been mentioned. Consequently there is a shortage of graduates in all disciplines and relatively few join any government agencies.

The DWR undertakes some training of its staff at the technician level. The Department's Training School, though directed towards meteorological and hydrological observers, has in 1986 and 1987 included groundwater training; four hydrogeological technicians qualified during that time, but only one of them is still with the DWR. The fact that the private sector offers salaries 1.5 to 2 times higher than government service, makes it difficult to keep bright young men in the service.

The Training School continues its activities, but these have not included groundwater during the last few years. Only ad hoc on-the-job training of hydrogeological technicians is currently undertaken by the DWR.

The situation is somewhat better in the case of computer assistants. Both the UNDP and GITEC projects have established data banks for borehole records and use local assistants for punching in the data. Both offer training and report few problems with obtaining suitable staff.

DWR's competence in drilling has been strengthened by the assignment of a UN volunteer expert, but it is reported that the availability of local expertise in this field is relatively good. Most if not all of the drilling companies who have operated in The Gambia have trained some drillers and these are either working for DWR or are available for employment if offered suitable inducements.

None of the other organisations in The Gambia have much groundwater expertise. The GUC has always used international consultants (sometimes in association with local firms) for its resource evaluation and well design work. As a result the past work on the Banjul and North Kombo water supply is exceptionally well documented. Other government organisations with interest in groundwater have relied on DWR for technical advice in that field.

5.1.5 Budgets

The government budget allocations to the DWR, listed in the 'Estimates of Recurrent Revenue and Expenditure 1990/91', are as follows:

Financial Year	1988/89	1989/90	1990/91
DWR Budget	1 864 921[1]	3 182 240[2]	3 164 540[4]
Development Expenditure on Water	1 743 739[1]	18 628 777[2] (20 375 610)[3]	43 021 019[4]
Total Government Spending on Water	3 608 660[1]	21 811 017[2] (23 557 850)[3]	46 185 559[4]
Total Government Budget	422 940 838[1]	488 109 420[2] (517 703 260)[3]	633 274 130[4]
Spending on Water as Percentage of Total Budget	0.85	4.5 (4.5)	7.3

Notes: All amounts in Dalasis

[1] Actual expenditure [3] Revised estimates

[2] Approved estimates [4] Estimates.

Source: Government of the Republic of The Gambia 1990

The 'DWR Budget' is the actual and planned expenditure for the routine running of the Department and for various institutional improvements such as office accommodation, equipment and local training. 'Development Expenditure' is the allocation for the government inputs for internationally and bilaterally assisted projects as well as for DWR's own development programmes.

The level of foreign aid provided to the water sector varies from year to year and is difficult to estimate; however, it is probably currently running at about US$ 1 500 000 to 2 000 000 per year (Dalasis 11 250 000 to 15 000 000 per year) on average. Of course, only a part of this budget is spent on groundwater, but this cannot be separated from the total on the basis of information available at present.

The details of the normal operating budget of the GUC are not known. The total gross revenue from its water services was approximately D 1 614 000 in 1980/81 and D 5 795 962 in 1985/86, that is, growing by about 20% annually. However, it is understood that, because of the government's determination to reduce inflation (under an agreement with IMF and the World Bank), GUC has recently not been allowed to raise water and electricity tariffs, and consequently it has not been making sufficient profits for a reasonable investment in improved services. The water supply facilities in the urban area of the Banjul region are in urgent need of expansion, but this will be done by the use of foreign loans and grants; apparently much of the required capital has been secured from several international and bilateral sources.

5.2 Hydrogeological Data

5.2.1 Maps and Air Photos

The map base for The Gambia is good, with a wide range of general and thematic maps and remote sensing imagery available, including:

Type	Scale	Comment
Physical map	1 : 250 000	1 sheet with the west and east of the country printed above each other.
Land use maps	1 : 125 000	Whole country; 4 sheets
Topographic photo-maps	1 : 50 000	Whole country; 20 sheets
Orthophoto-maps	1 : 25 000	Whole country; 84 sheets
Land use photo-maps	1 : 10 000	Whole country; 526 sheets
Air photos	1 : 25 000	1980 stereo pairs
Air photos	1 : 50 000	1983, colour stereo pairs of the whole Gambia River Basin
Geological map	1 : 250 000	1 sheet; accompanied by a memoir 'Geology and Mineral Resources of the Gambia', 1988
Hydrogeological maps	1 : 125 000	2 sheets; prepared by Ceesay & Howard Humphreys, 1987

The various physical maps are all based on aerial photography; the quality is good, though only spot heights, rather than elevation contours are shown. Most of these are readily available from the Department of Lands and Surveys in Banjul. A full list of available maps and aerial photographs is given in Appendix F.

The geological map is also of good quality, though the mapping units are understandably dominated by surface features such as alluvia and lateritic crusts. The accompanying memoir (Whyte & Russell 1988) discusses paleo-geography, stratigraphy and structure of the region and gives several geological sections of The Gambia.

A good groundwater planning base is provided by the 1 : 125 000 hydrogeological maps enclosed with the report ' Groundwater Survey Studies of The Gambia' (Ceesay & Howard Humphreys 1987). The report presents a synthesis of groundwater information available for the whole country, much of which is summarised on the maps including:

- geology;
- locations and characteristics of boreholes completed in the deep sandstone aquifers;
- locations and characteristics of some boreholes and/or wellfields completed in the shallow aquifer;
- locations of dug wells included in the then current monitoring network;
- iso-conductivity contours;
- piezometric contours of the shallow aquifer.

The main maps are surrounded by insets of sketch maps, histograms and other diagrams, including:

- mean annual isohyet map;
- mean monthly rainfall and potential evapotranspiration histograms;
- hydrogeological sections of the shallow aquifer;
- hydrographs of groundwater level oscillations;
- GUC wellfield abstractions in North Kombo;
- a Piper diagram showing the hydrochemistry of the shallow aquifer;
- piezometric contour map of the deep sandstone aquifer;

- isopachs of the aquiclude above the deep sandstone aquifer;
- elevation contours of the top of the deep sandstone aquifer;
- total mineralisation of the groundwater of the deep sandstone aquifer;
- a Piper diagram showing the hydrochemistry of the deep sandstone aquifer;
- head difference between the shallow and deep aquifers;
- geological cross-section of The Gambia.

This compilation provides a good groundwater database for future development planning and only minor criticisms on presentation are offered. All the information given on the main 1 : 125 000 scale maps could be easily shown on a map of half that scale (ie 1 : 250 000), which would make its use much more convenient. An important subject which is not treated adequately on the maps or in the accompanying report, is that of the variability of the yield (or specific capacity and estimated transmissivity) at the drilled well sites; the hydrogeological sections show more or less similar shallow aquifer dimensions everywhere, whereas the well characteristics are hugely variable, to the extent that some drilling sites have been abandoned for insufficient production potential, even for a livestock or village supply borehole. The balance of aquifer variability, well design and construction procedures responsible for this variation needs further analysis.

5.2.2 Aquifer Data

As already mentioned, the available geological mapping is of good quality, though because of the flat topography and a cover of thin superficial alluvial and residual deposits, surface geology does not offer much insight into the subsurface conditions. Nevertheless, general geological considerations suggest that both the shallow and the deep aquifers underlie the whole country and that both aquifers should thicken towards the west, though the sands might become finer in the same direction.

As always, the main sources of aquifer data have been wells and particularly boreholes. In this respect the situation in The Gambia is very good, as most of the organisations involved in groundwater investigations and development projects have kept good records.

As already indicated there are probably some 10 000 old traditional dug wells in the country, supplying water to villages for drinking and for small scale manual irrigation (of village allotments). Though there are few, if any records for these wells, relevant to the nature of the aquifers, they provided the original evidence of the wide-spread occurrence of shallow groundwater of good quality in exploitable quantities.

There are reportedly good records for most if not all modern dug wells. GITEC actually reproduces all the well documentation in the project's progress reports; this includes the initial site appraisal and the well completion report for every well. The UN dug well records are reportedly stored in the files of the Chief Technical Adviser, Groundwater Resources Planning and Development Project (at least some are in the form shown in Appendix G), but are not routinely compiled, reproduced or published. The Saudi Sahelian Programme records are summarised in the consultant's project reports. It is not known what has been done with the data collected during construction of wells by various NGOs.

In total there are about 1 000 modern dug wells in The Gambia. They normally penetrate the phreatic aquifer only, to between 3 and 6 m below the watertable. Unfortunately, only a few of these wells have been subjected to formal pumping tests, but it is reported that aquifer productivity is not a problem; apparently there have been very few failures and all of these have been due to construction difficulties rather than insufficient water yield. In most cases, few groundwater quality data are routinely collected from dug wells; periodic post-construction surveys suggest that chemical quality is generally good but organic contamination may be common.

Though some of the dug well construction projects have been restricted to particular areas of The Gambia, the overall coverage of the country is good. It clearly shows that the shallow aquifer underlies the whole country and that at least small amounts of groundwater (sufficient to sustain a hand pump) can be obtained by dug wells virtually everywhere.

Most of the boreholes in The Gambia penetrate the phreatic unit and, partially or fully, the semi-confined unit of the shallow aquifer. Several different organisations have been involved in the drilling, as detailed in Table 5.1.

TABLE 5.1

Boreholes in The Gambia

Organisations Responsible	Number of Boreholes
GUC/Consultant/Contractor[1]	c 45
DWR/UNSO/Polservices	28
DWR/SSP/Prack GMbH/Prakla	c 75
DWR/EDF	7
Others[2]	c 60
Total	c 215

Notes: [1] Consultants included Howard Humphreys and Hydrogeological Services International; contractors include George Stow Ltd, China - Henan, and GUC's own drilling unit.

[2] Mainly NGOs, using contractors such as Prakla Seismos.

Source: DWR 1991, GUC 1991 and UNDP 1991

The coverage of the whole country is reasonable, though the greatest concentration of boreholes is in the Kombo Peninsula, near to the main urban and tourist centres. Numbers of boreholes in the various Divisions are listed in Table 5.2.

TABLE 5.2

Distribution of Boreholes in The Gambia

Division	Number of boreholes
Western	c 75
North Bank	c 20
Lower River	c 40
MacCarthy Island	c 35
Upper River	c 45
Total	c 215

Source:UNDP 1991

Most of the boreholes are well documented; the available records include details of depth, lithology penetrated, well design, and yield and drawdown. In some cases data on formation grading, step and constant discharge testing, and hydrochemistry are given as well. Some of the pumping test data have been converted to aquifer transmissivity and average lateral permeabilities. No credible results of overall aquifer storage can be derived from the test records.

Within the Gambia only three boreholes have been installed and tested in the deep sandstone aquifer. However, many useful data on this aquifer are available from Senegal and a coherent picture of its geometry and properties can be deduced.

It should perhaps be mentioned that the deep sandstone aquifer is of marginal interest to The Gambia's water sector and no further work on it is envisaged in the immediate future. In contrast, development of the shallow aquifer is set to continue with the UN and GITEC assisted dug well construction, DWR/EDF drilled wells/solar pumps programme and a new, Japanese aided rural water supply project (about 30 boreholes with mechanical pumps and storage tanks).

Summarising, the aquifer database for The Gambia is good. The geology is well understood on the evidence of regional considerations, amplified by information from oil and water drillings within the country and in Senegal. The documentation of some of the dug wells is comprehensive and gives a good, though admittedly mainly qualitative, overall picture of the phreatic aquifer. Over 200 boreholes, penetrating the phreatic and semi-confined units provide a good insight into the occurrence, geometry and properties of the Continental Terminal aquifer as a whole. Lastly, although only three boreholes have been completed in the deep Maestrichtian-Palaeocene aquifer in The Gambia, a synthesis of these records together with data from Senegal, gives a coherent picture of the occurrence and properties of this aquifer.

5.2.3 Piezometric Data

Groundwater levels are routinely measured in old dug wells during the pre-construction site appraisals and in all newly completed wells and boreholes. In addition, monitoring of such levels has been undertaken intermittently over the last 25 years.

The earliest water level monitoring system was set up in the late 1960s by Howard Humphreys & Sons in the Banjul area as a part of their work on improvement of water supply to the capital; the system was reportedly later extended to the whole of the Kombo Districts. Hydrographs based on these records are reproduced in some of the old reports, but it is uncertain whether the complete data could still be found.

A nation-wide monitoring network was set up in 1973, also by Howard Humphreys, as a part of the River Gambia Basin Study. The details of the extent of this system are not known; measurements were not continued after the completion of the study in 1974.

In 1981/82 GITEC, then engaged in the planning of the German aided 'Hand-dug Well Construction Programme', monitored 44 wells in 38 villages (GITEC, 1984), measuring the following parameters:

- well depth
- depth to static water level
- temperature of the water
- electrical conductivity
- pH.

The purpose of these measurements was essentially to aid the design dug wells, which would produce potable supplies throughout the year, including at times of low groundwater levels, when many traditional wells go dry. This monitoring was not continued after 1982. However, in 1984 GITEC recommended that, in the area of its activities namely the North Bank and MacCarthy Island Divisions, the DWR should monitor 58 wells, with monthly measurements.

Concurrently (starting in 1983), the UN assisted Rural Water Supply Programme undertook the monitoring of water levels in 110 dug wells all over the country, with three monthly measurements; a further 25 wells was added to this network in June 1986, with planned daily measurements.

The Ceesay & Howard Humphreys study seems to have taken over groundwater monitoring in 1987. It selected a network of 145 dug wells (monitored previously), 5 GUC boreholes and 24 new points in the Upper River Division, which was apparently neglected up to then. Measurements were monthly for 48 points and quarterly for the rest. The system was levelled to a common datum to give the overall piezometry for the hydrogeological maps. However, predictably the observations of such an extensive network, were not kept up after the completion of the study.

In 1990, the UN Groundwater Resources Planning and Development study resuscitated the Ceesay/ Humphreys' network (albeit in a slightly reduced form) with 120 points measured quarterly and 35 monthly; an additional item has been one borehole in the deep sandstone aquifer (at Sankwia). This network is currently being observed.

In addition to the above attempts at country-wide monitoring systems, some measurements have been carried out intermittently by GUC in the Kombo area. Currently the Water Division of GUC is monitoring five observation wells with weekly measurements and 26 points (two production boreholes, eighteen slim observation wells and six dug wells) at monthly intervals.

As should be apparent from the above, a considerable amount of groundwater monitoring work has been done in The Gambia; extensive networks have been set up measured for a while and then abandoned, usually because of transport difficulties. Exactly what monitoring records are still available is uncertain, but they should be collected, organised into a standard form and processed as a matter of urgency; otherwise there is a strong chance that many of these valuable data will be lost.

5.2.4 Water Quality Data

Since few groundwater quality problems have been perceived to exist, this subject has been somewhat neglected in the Gambia. Apparently no routine measurements of standard quality parameters are carried out as a part of well and borehole construction; rather, sporadic studies of this subject have been undertaken, based on records issued in previous reports, complemented by spot measurements. The important features of the overall macro-pattern, that has emerged from these studies, are as follows:

(a) Shallow Aquifer

- low pH (5.5 to 6.0) and consequently high corrosiveness;

- low mineralisation (less than 500 mg/l), except in the zone of influence of marine and estuarine conditions;

- locally high dissolved irón content (>1 mg/l);
- locally high nitrate content (>100 mg/l);
- groundwater from some wells organically contaminated (including by faecal coliforms and *Salmonella* sp).

(b) Deep Aquifer

- neutral to alkaline reaction (pH 7 to 8.2);
- mineralisation increasing from east to west (to about 1 800 mg/l at Banjul);
- increase in fluoride in the same direction (to 5 mg/l at Banjul).

Despite the continuing installation of many dug and drilled wells in the shallow aquifer, the hydrochemical pattern is not being refined and updated. Even when some easy to measure quantities (such as pH and EC) are determined at a new well, the results are filed, rather than compiled, collated and reviewed in the context of the established pattern.

There is a need for all agencies involved in groundwater development, to include a standard list of hydrochemical measurements in their well and borehole completion reports. Moreover, both chemical and biological parameters should be included in the monitoring system. Lastly, groundwater quality data should be continually processed, compiled and plotted to establish any significant patterns and correlations.

5.2.5 Groundwater Abstractions

Groundwater abstractions in The Gambia are mainly for domestic supply, urban and rural, with small amounts used for livestock watering and for irrigation. All this water is derived from the shallow aquifer by means of dug and drilled wells, with lifting devices varying from rope and bucket, through hand pumps to submersible turbine pumps. Typical designs used in The Gambia are shown in Figures 5.3 and 5.4.

Abstractions by the traditional dug wells are not measured at all. It is known that many are used for irrigation of village allotments and that, because only a small penetration below saturated sand is possible for an unlined well, many go dry as the watertable declines during the dry season. Mean abstraction per well has been estimated as 2 m^3/d at peak demand and productivity (UNCDF 1988), but is probably about 1 m^3/d or 365 m^3/annum on average.

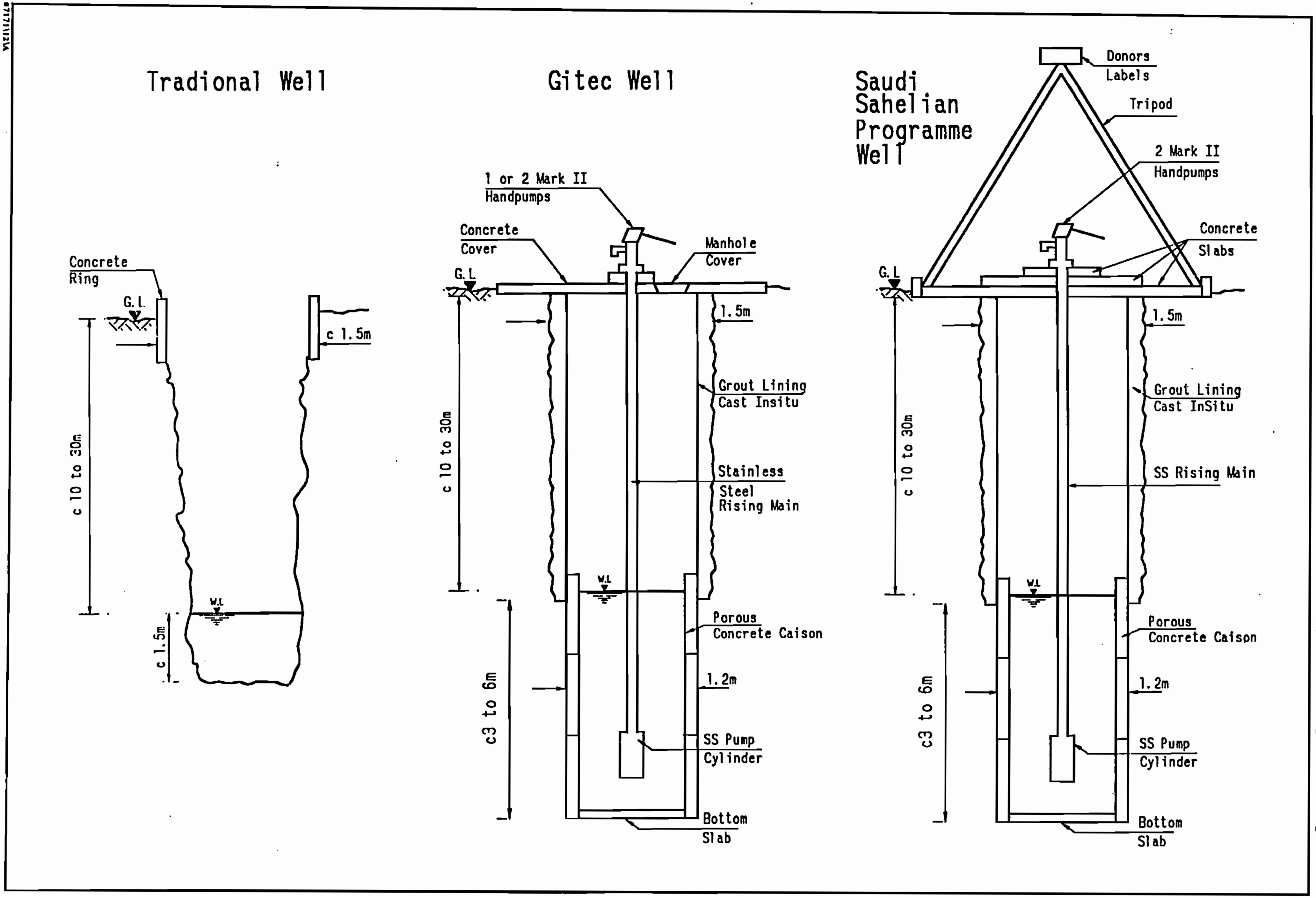

Figure 5.3
Typical Designs of Dug Wells

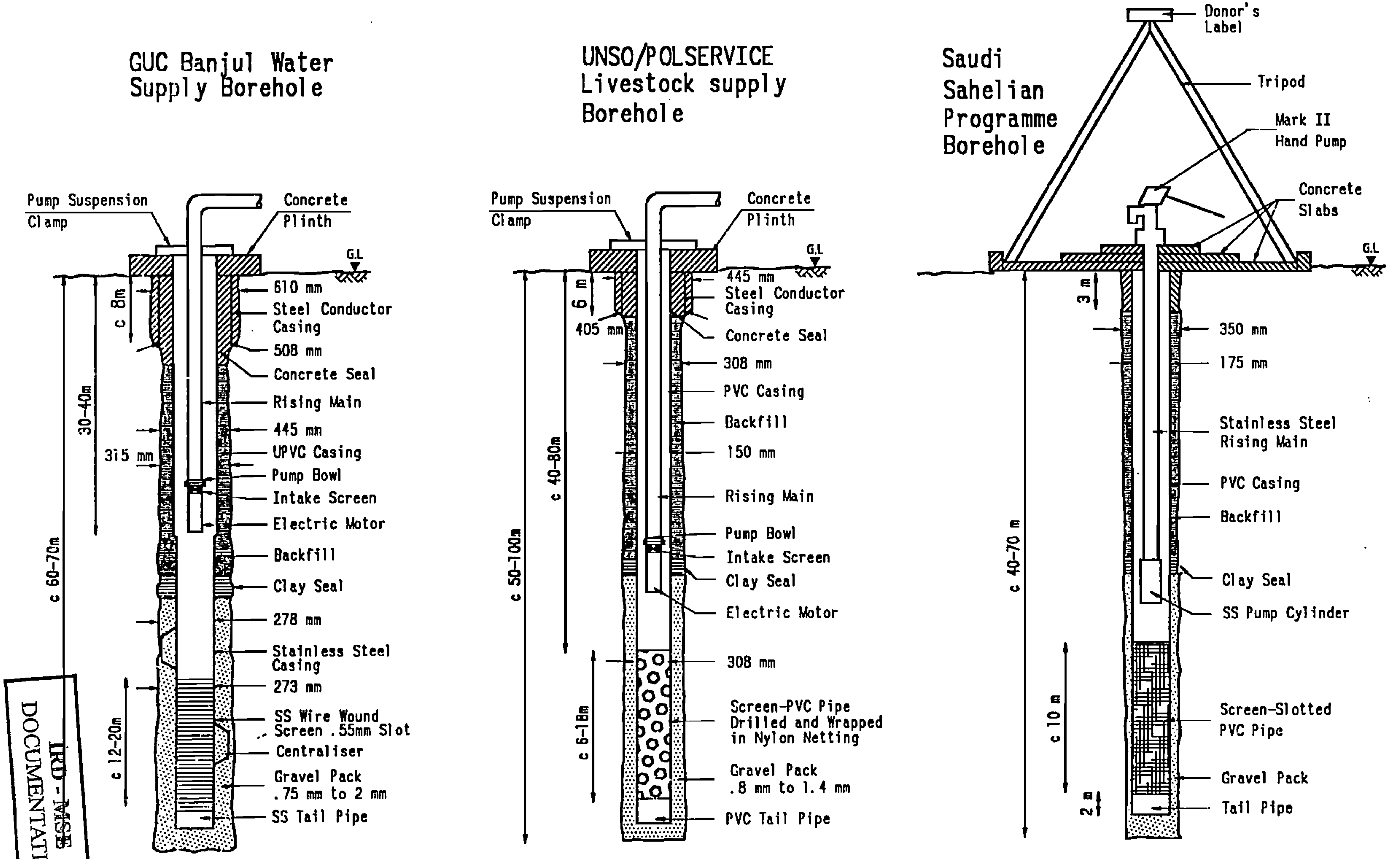

Figure 5.4
Typical Designs of Drilled Wells

Because of the unsatisfactory nature of the traditional dug well from the point of view of sustaining its yield in the dry season and of protection from bacterial contamination, the government, with the assistance of international and bilateral aid agencies, introduced modern dug wells into the country. These are concrete lined, protected from pollution by concrete covers at the surface and equipped with hand pumps.

Installation of such wells in quantity started in the 1970s and accelerated during the 1980s under the impetus of the UN Water Supply and Sanitation Decade. Major programmes were assisted by the UN, German aid, the Saudi Sahelian Organisation and NGOs; the most active of the last, Caritas, installed many lined dug wells without hand pumps.

The design of the modern dug well in the Gambia has evolved over the years, particularly with respect to the hand pump. Originally the Indian made India Mark II was used, made of mild steel components (galvanised in the case of the rising main). However, as might have been expected from the chemistry of the groundwater, corrosion became a problem; eventually a wholly stainless steel version of the Mark II pump, made in Germany, has been and is being used by the Saudi and the German assisted programmes. All the Saudi and some of the German project dug wells are equipped with two pumps to increase productivity and reliability of the supply. In both cases the quality of the work is of a very high standard. It takes about 3 months to construct a modern dug well. The cost is approximately US$ 12 000 (D 90 000) of which about US$ 2 000 is the cost of the pump.

The abstractions of these rural supply wells are not measured, but GITEC has carried out a study of hand pump use in its feasibility study (GITEC, 1980). Based on this work an average abstraction per well is estimated at about 6 m^3/d.

The Saudi Sahelian Programme installed 67 shallow (40 to 70 m depth) boreholes with handpumps for water supplies for relatively small villages. The pumps and surface works at these boreholes are the same as for dug wells of the same project, except, of course, only one pump per site was installed. The pumpage from these wells is not measured but average abstraction per well is thought to be about 5 m^3/d.

Some villages or groups of villages have been provided with borehole based water supply systems that include electrical pumps with generators, storage tanks and standpipe distribution. In addition an UNSO assisted project installed 28 such boreholes for livestock supplies. Abstractions by these systems are not monitored but are estimated at about 450 m^3/d in total.

Groundwater abstractions by modern dug wells and boreholes for irrigation are mainly in private hands and amount to some 20 boreholes and about 100 dug wells; the pumpage is not monitored but has been estimated from the area irrigated as approximately 1 million m^3/year.

The largest groundwater abstractions are for urban water supplies. There are the responsibility of the GUC and comprise 18 boreholes in the capital area plus 7 boreholes in provincial townships. The Greater Banjul abstractions are metered at each borehole and are well documented. The actual records are held by GUC and although the latest data have not yet been processed, Table 5.3 shows the kind of summarised details that can be obtained.

TABLE 5.3

GUC Groundwater Abstractions - Banjul Area
(1 000 m^3)

Month/Year	1984	1985	1986	1987	1990
Jan	482	464	507		
Feb	432	480	449		
Mar	432	444	496		
Apr	440	415	495		
May	426	435	494	Details	Details
Jun	405	411	493	not	not
Jul	420	415	519	available	available
Aug	425	438	488		
Sep	416	444	497		
Oct	462	464	508		
Nov	465	466	508		
Dec	499	502	543		
Annual Total	5 304	5 378	5 997	c.6 600	c.7 670

Source: Ceesay & Howard Humphreys 1987 and GUC 1991.

The township abstractions are insignificant in comparison, amounting to about 0.1 m^3/annum in total. It is understood that at least some of the discharges of these boreholes are metered.

Some of the recent innovations, though insignificant from the point of view of total abstractions, may be of relevance to future development. In 1982 UNIFSTD initiated an experimental project with the installation of one solar and two windmill pumps; it is reported that these are still operational and are being closely monitored by DWR/UNDP, under the Groundwater Resources Planning and Development Project. The solar pump option is being followed further under an EDF assisted project, which is installing such systems in boreholes, to be used for water supplies at some of the larger centres of population outside the capital area.

5.2.6 Equipment

The majority of the technical equipment relevant to groundwater studies and development projects is that provided under the externally assisted projects. The exception has been the drilling rigs, which have been purchased by DWR and GUC from private overseas contractors (namely George Stow Ltd and Prakla Seismos). Currently only one rig is operational; this is a rotary machine of German manufacture. It is supported by compressors, pumps, transport and other ancillaries. It is understood that DWR, which operates the rig, has problems with obtaining foreign exchange for spare parts and consumables. Hence its productivity has been low (only five boreholes in 1990).

Smaller items of equipment, mainly obtained under the various UN assisted projects, include a geophysical (resistivity) set, water level indicators, pH-meters, EC-meters and portable laboratories. Some of these is still being used; however items which use consumables (such as the reagents for the chemical kits) have the worst record. Again the main problem is availability of foreign exchange for purchases abroad.

Computer hardware has been provided for DWR's groundwater work by GITEC and the UN Groundwater Resources Planning and Development Project. Both sets include processors, monitors, printers and various peripherals and are adequate for the processing and storage purposes for which they are being used. However, there is no co-operation or co-ordination of effort between the two computer centres, as they use entirely different software.

5.2.7 Data Processing and Storage

Data processing has traditionally been done by the individual projects; the methods used for calculations and compilation have generally been satisfactory. Some of the consultants' compilations are very good, presented in well produced reports. Similarly, some of the specialist subjects studied by the UN, such as the use of solar and windmill pumps, are well treated and reported. However, as far as this assessment could ascertain, no one in the country is doing the job of continually processing and compiling the routine groundwater records available from well and borehole construction and monitoring programmes. The groundwater system in the Gambia is reasonably well understood and documented, but the situation could be considerably improved by proper treatment of routine records.

The setting up of two independent computerised data banks for well records using different software, is symptomatic of the poor co-ordination of groundwater work in the Gambia. GITEC uses dBase IV for its records, with the objective of documenting and predicting maintenance requirements of hand pumps and wells; GITEC's 'List of Wells' gives the following information:

- reference number
- location - name of village
- construction - starting and completion dates
- well depth

- depth to static water level
- height of water column
- number of hand pumps in the well
- dates of installation of the pumps
- type of pump cylinder
- aggregate used in the concrete cover
- type of fencing around the well.

Further information is given under the heading of 'Maintenance Monitoring - Payment for Maintenance'; this gives the reference number, village in which the well is located, and dates and details of costs of repairs.

Examples of this database output are given in Appendix G.

The UN Groundwater Resources Planning and Development project uses PARADOX 3 software for its database, which contains borehole, dug well and monitoring information.

The borehole data include:

- reference number
- location - name of village, district and division
- organisation responsible for installation
- well number according to that organisation
- water use
- map reference and coordinates
- construction date
- drilling contractor
- total depth
- depth to water level
- number of pumps (in boreholes always 1)
- pump installation date.

In the case of dug wells, the information stored is similar, but includes village population and well diameter, and excludes drilling contractor and date of pump installation.

This database already contains all the boreholes but so far, only some of the dug wells. Examples of the output are given in Appendix G.

The monitoring system includes the following information:

- serial number
- location - name of village, district and division
- organisation responsible for well installation

- elevation of reference point
- water levels at particular dates (month and year only).

So far only one reading (for March 1991) is available for 54 of the wells (146 wells are listed). The print out for the monitoring database is shown in Appendix G.

5.2.8 Data Availability

The availability of hydrogeological data in The Gambia is generally good. There are many useful technical reports with good documentation of background information. Unfortunately there is only one well organised library (at the Ministry of Agriculture) in Banjul. This has all the groundwater reports relevant to agriculture, but only some of those dealing with potable water supplies. It provides an excellent service to bona fide technical organisations, including cross-indexing of publications, an air-conditioned reading room and copying facilities.

The DWR has most (but not all or at least not all could be found) of the technical reports dealing with The Gambia's hydrogeology. Most of these are kept in the Director's office and are not listed anywhere. Apparently GUC's records are in a similar state and may be difficult to find.

The UN library consists of a collection of various publications stored in the conference room; apparently there is no index, but it appears to have few of the reports relevant to The Gambia, issued by organisations other than the various UN agencies. The USAID office in Banjul holds some useful technical publications, particularly those prepared by American organisations, and has been helpful to this assessment.

The output of the databases of GITEC and the UN is readily available to bona fide technical interests, though there is some reluctance to supply full print-outs because of their extensive size. However, these contain only limited data of hydrogeological interest; in particular they provide no information on borehole yield and drawdown and none on groundwater quality parameters.

CHAPTER 6

EVALUATION AND ASSESSMENT

6.1 Data Needs

One of the main areas where hydrological data are required is for agricultural planning and evaluation. In terms of planning such data are necessary for the calculation of duration of the growing season, which is very dependent on the rainfall patterns. This is particularly important as in recent years the average rainfall in The Gambia has tended to decrease (see Appendix D). Associated with this is the need to calculate crop losses due to evapotranspiration.

Within The Gambia itself there is likely to be a continuing need to evaluate runoff in relation to the barrage plans. Although at the moment the plans do not appear to be very cost effective this situation could change in the future. In particular there is no information on the runoff which enters The Gambia donwstream of the station at Gouloumbo in Senegal which is more than 500 kilometres from the mouth of the estuary. In particular, the catchment area of the river to Gouloumbo is 41 240 km^2 while the area at Banjul is 77 054 km^2. That is, almost half the catchment area is downstream of what is currently the lowest gauging station in the basin. Of the 36 000 km^2 between Gouloumbo and the mouth some 12 000 km^2 are upstream of the current dry season saline limit and a similar area between the present limit and the site of the proposed barrage. There is therefore some interest in evaluating the flows in this part of the basin, which at present is not done, indeed can not be done with the existing stations. Since in the calculation of the effectiveness of the proposed barrage there is a delicate balance between the inflows and the evaporative loss these factors will need more precise calculation in the future.

6.2 Rainfall

6.2.1 General Assessment

In terms of its coverage the present network can, in theory, be considered almost adequate (see Table 6.1). But this disguises the fact that the data from the stations is not always reliable and is often collected several months after it has been recorded, leaving little opportunity for quality control. In effect the problem lies not with the network as such, but with the logistics of manning it and operating it. Staffing levels are compared to UNESCO/WMO guideline figures in Table 6.2.

Whilst the national budget for this purpose is minimal the continuing support of the AGRHYMET project has enabled the network to function much better than would otherwise have been the case.

TABLE 6.1

Evaluation of Precipitation Network

Element	Recommended minimum density	Actual density
Precipitation stations: non-recording (Number 10^4 km^2)	40	29.2
Precipitation stations: recording (Number per 10^4 km^2)	2	9.7
Evaporation stations (Number per 10^4 km^2)	3	9.7
Repair and maintenance shops for meteorological equipment (Number per 200 precipitation stations)	1	6
Inspectors of meteorological stations (Number per 100 precipitation stations)	5	-
Superstructure staff - meteorology (Number per 100 precipitation stations)	3	-

Note: Recommended minimum density from UNESCO/WMO guidelines (1988).

6.2.2 Present Situation

It follows from the above that the network is in principle able to satisfy the present needs of the users. However many of the agro-climatological studies rely heavily on long term historical data. Given the apparent changes in climatological patterns in the Sahel this might give rise to false conclusions.

TABLE 6.2

Evaluation of Staffing Levels - Meteorology

Item	Number of staff per 100 stations			
	Professional	Technicians		Observers
		Senior	Junior	
Recommended staffing levels				
- Field operations and maintenances	0.5	2	2	100
- Data processing, analysis and interpretation	1	2	2	-
- Supervision	0.25	-	-	-
Total	1.75	4	4	100
Actual staffing levels[1]				
- Field operations and maintenance	3	36	36	100
- Data processing, analysis and interpretation	6	15	15	-
- Supervision	3	10	10	-
Total				

Notes: [1] The stations at the mixed farming centres and staffed by Ministry of Agriculture are not included in this table.

Recommended levels from UNESCO/WMO (1988).

6.2.3 Future Needs

The main area of use in the future is likely to be in the planning of crop cycles and selection of strains suitable for current Gambian conditions. In so far as long term planning is concerned then the current network with improved management should be adequate. However for management of planting times during the rainy season then better means of data transfer have to be made available. This point is discussed more fully in the section on climate.

6.3 Climate

6.3.1 General Assessment

As with the rainfall data the present network seems to be of adequate density and as the stations are visited regularly for the AGRHYMET bulletins the problems of data collection and transfer are not as severe as they are for rainall. The stations also seem to have an adequate stock of spare parts, except perhaps for the maximum and minimum thermometers, so there should be few problems in their operation. All the stations also have staff who have been trained by the DWR at their school though some of the problems of observers also effect these stations.

One of the major problems relates to communication between these stations and the forecasting office at Banjul. The stations are all equipped with radios but the radios cannot be operated in almost all the cases because of problems of electricity generation.

There is a well equipped workshop at Banjul which should be capable of repairs to some equipment.

The DWR has benefited from a number of projects executed since 1976 in the context of the CILSS/WMO/UNDP AGRHYMET project. Aid has been given in the form of equipment and technical assistance. For most of this period support to the running and operation of the network has been given. In addition international experts, both United Nations volunteers and consultants, have given advice to the project. AGRHYMET has also attracted other donors who have aided particular components of the the project. Among the aid in this context has been the support of USAID for computer activites. In the case of national centres, such as the one in The Gambia, this took the form of a PDP 11/34 mini-computer which became operational at the end of the 1970s. The current computer equipment, consisting of four PC-AT compatible micro-computers with peripherals, was also provided by the same donor.

The current UNDP/AGRHYMET project (GAM/87/009) originally had a budget of $449 900. This has been increased during the life of the project and now stands at $710 623. The current project is due to be completed at the end of 1991 but plans are already being made for a further project to continue the support of the national service.

6.3.2 Present Situation

As with the rainfall, the density of the climate station network is adequate for present needs. A particular sign of its adequacy is its use for the 10-daily agro-climatological bulletins which are produced regularly. Where there is need for improvement is in the transmission of data for synoptic forecasts.

One major drawback effecting both climate and rainfall is the difficulty of retrieving data in computer compatible form for analysis and use in other studies.

6.3.3 Future Needs

The needs for data in the future are likely to be essentially similar to the present needs. That is, there will be a need of data for agro-climatological analysis, to estimate crop losses and rainfall. With the growing awareness of how agricultural productivity can be improved by judicious choice of planting times and by the selection of strains of plants which are better adopted to the possible growing cycle this need can but increase.

A further area where data is likely to be needed is in water resources studies. Whilst the barrage/bridge proposed for Balingho at present seems not to be feasible, it is a project which many people in The Gambia and neighbouring Senegal would like to see completed. There is therefore likely to be a continuing need for data to enable the usefullness for the barrage for irrigation to be evaluated and also for the calculation of water losses due to evaporation.

Data is also likely to be needed in the future for the estimation of groundwater recharge. There are already signs that overpumping is occuring in the Banjul area and increasing use of groundwater is being made in rural areas both for potable water and for irrigation. Most of the irrigation is small scale but if this increases then the availability of groundwater could become a problem.

6.4 Hydrology

6.4.1 General Assessment

The UNESCO/WMO guideline figures in Table 6.3 are perhaps rather misleading in the case of The Gambia. In a hydrological sense the country consists of a series of small river basins which are tributaries to the River Gambia. At present, few of the gauging stations are able to measure flows. Those on the main river and many of the tributaries are affected by the movement of the tide in the river and of the others on tributaries those which have rating curves sometimes rely on observers who make only two readings a day. In short the network is neither able to measure flow in the River Gambia nor to enable estimates to be made of the contribution of tributary runoff.

The data that is available does not have any comprehensive quality control nor is it readily available in computer compatible form.

A problem which hydrology shares with other services is that of a shortage of qualifed staff - particularly at the higher levels (see Table 6.4.)

TABLE 6.3

Evaluation of Hydrological Network

Element	Recommended minimum density	Actual density
Surface water level stations: non-recording (Number per 10^4 km^2)	24	5.31
Surface water level stations: recording (Number per 10^4 km^2)	1	11.50
River discharge stations (Number per 10^4 km^2)	20	2.7
Sediment discharge stations (Number per 10^4 km^2)	3	0
Water quality stations (Number per 10^4 km^2)	3	0
Current meters (Number per 10 discharge stations)	1	6.7
Rating facilities for current meters (Number per 200 current meters)	1	0
Repair and maintenance shops for hydrological equipment (Number per 200 discharge stations)	1	10.52
Water sediment laboratories (Number per 100 sediment stations)	3	0
Water quality laboratories (Number per 100 quality stations)	3	0
Hydrological field teams (2 to 3 persons) (Number per 10 discharge stations)	1	3.3
Special survey teams - surface water (3 to 4 persons) (Number per 10^5 km^2)	1	0
Superstructure staff - surface water (Number per 100 river discharge stations)	4	5.3

6.5.3 Future Needs

The greatest future need of the groundwater industry in The Gambia remains the establishment of a trained cadre of local groundwater experts, who would plan, direct, co-ordinate, interpret and document all the development and investigatory activities in the country. This is a long term task which can only be attained by academic and on-the-job training but a start to a rational programme with this aim needs to be made as soon as possible.

A related but somewhat easier task is the upgrading of the DWR laboratory; a project has been formulated with this objective in view and is specified in Appendix B.

It is also recommended that the approach to groundwater monitoring be modified; it should be made much more target-oriented that it had been in the past.

The country-wide groundwater level monitoring network should be tailored to the following objectives:

- to quantify the natural annual wet/dry season watertable oscillations from the point of view of well design and aquifer recharge assessment;

- to identify any long term decline/rise of the groundwater levels as a result of climate changes or significant abstractions;

- to obtain piezometric calibration data for modelling the aquifer system's response to possible intensive development in the future.

General groundwater quality monitoring should be focused on any natural hydrochemical changes induced by abstractions (particularly in coastal and estuarine areas) and on organic contamination of drinking water sources.

In addition there is a special requirement for more intensive monitoring data in the area of North Kombo, where the only major groundwater abstractions in the country are located. Here, the objective would be primarily to obtain calibration data for a groundwater model, with regard to piezometric response and possible salt water invasion (vertical and horizontal), resulting from intensified development to satisfy the rapidly growing water demand of the urban and tourist facilities. Detailed monitoring of abstractions, water levels and the movement (if any) of the fresh/saline water interface in key areas, is required.

Data processing, storage and compilation also need some improvement in the future. Two ongoing projects have set up computerised databases for well and borehole records. The GITEC system is essentially an aid to the maintenance of wells constructed under the German Dug Well Programme and as such is adequate. The UN system is a general purpose database, and valuable as it is in the present form, should be continually improved and augmented. As a first step, discharge and drawdown of boreholes, some yield function of dug wells, and some hydrochemical parameters should be introduced. Later a digital mapping option for well locations, combined with contouring packages would be useful, as would a plotting facility for the monitoring data.

The details of future data requirements should be formulated by the forthcoming EDF-aided groundwater study.

CHAPTER 7

RECOMMENDATIONS

7.1 Introduction

Over the last few years the Gambian government, in common with many other governments, has been constrained to limit its expenditure. It would therefore be unrealistic to propose any project or changes which called for a large increase in staff or spending on maintenance. One problem does seem to be that there is some difficulty in retaining staff in the service and it may therefore be necessary to consider ways in which the attractiveness of posts can be increased. This is likely to include increased remuneration. This applies at all levels of the service - to observers as much as professional staff.

In the following sections recommendations are made to improve the hydrometric data collected to better serve the country's future water development needs. Some of the recommendations are beyond the capacity of the existing bodies and will require outside technical and financial assistance. These recommendations have been grouped into 'packages' which are detailed in Appendix B. In the case of The Gambia four such packages have been identified (shown in Table 7.1).

7.2 Rainfall and Climate

7.2.1 Organisational Structure

In few, if any, countries does the meteorological service have its own ministry. In many cases it forms part of the ministry with responsibility for transport due to its importance for air traffic. In The Gambia - which has no internal air transport service - the main role of the meteorological service is for water resources planning and it therefore seems logical that it should be part of the Department of Water Resources.

7.2.2 Network Size and Density

The tables in Chapter 6 suggest that, compared to international norms, the size of the network is adequate and from an inspection of a map of the stations this seems indeed to be the case. There is therefore not felt to be any need to increase the size of the network. What perhaps is critical is the management of this network. In the case of the stations used for ten-day bulletins there is not a major problem. The stations included in the regular bulletin consist of ten with climate data and a further eight with rainfall data. They are visited every ten days to gather data for the bulletin and therefore any missing data or other problems are quickly spotted and can be corrected. There are however up

TABLE 7.1

Proposed Project Packages

Ref	Title	Executing Agency	Objectives	Total Duration (months)	Inputs (months)			Costs US$			Total $
					Experts	Counterparts	Volunteers	Experts	Equipment	Training (1)	
GAM-1	Improved Data Processing for the Meteorological Division	Meteorological Division, Dept. Water Resources	To improve computerised database	36	9.5	?	-	221 750	87 000	35 000	343 750
GAM-2	Improved Flow Measurement for Hydrology Division	Hydrological Division, Dept. Water Resources	Improve monitoring of flows in the river Gambia and to measure flows in tributaries	36	15			335 500	165 000	35 000	535 500
GAM-3	Improved Salinity Measurement in the Gambia River	Hydrological Division, Dept. Water Resources	To better identify the location of the saline front	12	5			98 500	49 500	-	148 000
GAM-4	Upgrading of the Water Laboratory	Department of Water Resources	To increase both capacity and capability of the existing laboratory facility at Yundum	36	36			816 000	152 500	16 000	984 500

Notes: (1) The projects have only a small budget for overseas courses because of an emphasis on 'on-the-job' training; up to 80% of the time of the experts will be devoted to training.

to 20 other rainfall stations which are reported as being operational but for which data is not collected on a regular basis. With these stations the data is collected by the Meteorological Division during an annual visit after the rainy season but if on that visit it is not possible to obtain the data then it remains uncollected until the following year. As a result of this, data has been known to accumulate for several years at certain stations. In this case little can be done about quality control or correcting any defects in the measurement procedure. Unless a system of data despatch by mail could be reliably instituted it would seem appropriate that a proportion of these stations should be visited during the ten-day collection cycle so that each of them is visited at least once a month. This would of course put extra pressure on the limited number of vehicles that are available.

Another problem related to the network is the fact that although many of the stations have single-side band radios for data transmission these are frequently not operable due to break down or non-availability of the electrical power generating equipment. For synoptic purposes it would be useful if more climatic data were available to the forecasters and means should be found to improve the data transmission facilities. One possibility which would seem appropriate would be to use solar panels and batteries for electrical generation. These would be able to generate enough power for radio transmission and, having no moving parts, need less maintenance than diesel or petrol fuelled generators.

One further very useful step which could be taken would to ensure that all the data which has previously been entered on to a computer system was available in Banjul. It appears that the data up to 1984, which had been prepared as part of the data rescue project (DARE), was stored on PDP 11/34 mini-computer. The exchangeable hard disc from this computer has crashed and has been sent to the AGRHYMET centre in Niamey to try and recover the data and then to transfer to a PC compatible computer, but the data has not so far been returned to Banjul. It is also important that all data from 1984 onwards, including daily as well as monthly data, be entered in to computer and the files of data be kept up to date.

7.2.3 Personnel

Despite the fact that further education facilities in the country are severely limited there did not seem to be a major shortage of staff with suitable skills. The DWR training centre is a very valuable asset and enables a regular number of staff to be trained as observers. There does however appear to be a problem of retaining staff once trained, even for the relatively specialised role of meteorological observers, and here the problem appears to be related to difficulties of payment. The difficulties relate both to the level of remuneration and the ease and regularity of getting the payments. These problems are difficult to address by an externally funded project and should perhaps be considered before any further project support is given to the service.

One area where it is felt more training of personnel would be advantageous is that of data processing. Staff had been trained in the use of the CLICOM system and were competent in its use. However the fact that the data for 1990 had been entered but could not be located or retrieved suggests that the training had not covered all aspects of the package's use in sufficient detail. It is felt that with a

Data processing, storage and compilation also need some improvement in the future. Two ongoing projects have set up computerised databases for well and borehole records. The GITEC system is essentially an aid to the maintenance of wells constructed under the German Dug Well Programme and as such is adequate. The UN system is a general purpose database, and valuable as it is in the present form, should be continually improved and augmented. As a first step, discharge and drawdown of boreholes, some yield function of dug wells, and some hydrochemical parameters should be introduced. Later a digital mapping option for well locations, combined with contouring packages would be useful, as would a plotting facility for the monitoring data.

The details of future data requirements should be formulated by the forthcoming EDF-aided groundwater study.

7.2.5 Maintenance

In the case of a broken meteorological instruments there is often no possibility of maintenance or repair, the only option is to have a good stock of spares.

In the case of electro-mechanical equipment, such as generators, maintenance is possible but here the difficulty is that of obtaining spares unless that particular model is widely used within the country. A situation which frequently arises is that equipment is provided by bi-lateral aid. The donor, not unnaturally chooses equipment from his own country, but this may not be compatible with that generally in use in the country.

For other equipment such as computers, repairs may be possible but there may not be technicians with the right test equipment, training, or spare parts to repair it. In that case the only options are to write off the equipment or to send it abroad for repair. It would seem that a useful role for AGRHYMET might be to introduce some standardisation of computers and to keep a pool of repaired computers and spare parts at Niamey. Given the rate of advance in computer technology however this might take longer to set up than the life of the equipment and the spare parts could be outdated before they had been used. However even today AT-computers, first introduced in the mid-eighties, are still considered to be useful machines and whilst this option might not always enable the latest 'state-of-art' equipment to be available it would help to provide continuity of operation.

7.3 Surface Water

7.3.1 Organisational Structure

The present organisational structure seems well suited to the size of the country and there would appear to be no need to change it.

7.3.2 Network Size and Density

At present, as far as could be ascertained, none of the hydrological data from The Gambia has been computerised. Even the hydrological year book for 1983/4, the latest published, appears to have been typed on to prepared forms. It would be useful if all level records, gaugings and rating curves could be entered to a computerised data processing system. It would also be useful if the level records at certain key stations on the main river, and even some of the tributaries, could also be entered. To do this effectively it would be necessary to digitise them. This is because the levels are tidal and therefore show a variation throughout the day. Another alternative would be to record the highest and lowest values and the date and time of occurrence. In some cases a combination of the two approaches might be needed. For example at a station with good records where the chart had been changed regularly then digitising should be relatively easy. However at other sites, where the chart

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Notes: (1) The projects have only a small budget for overseas courses because of an emphasis on 'on-the-job' training; up to 80% of the time of the experts will be devoted to training.

- Sofaniama Bolon. At present the levels are measured at Pakaliba. By installing a level recorder at Anias Kunda, some 10 km further upstream, it might be possible to develop a rating curve.

The above sites have been chosen for the size of their catchment area and also because they are all upstream of the proposed barrage site at Balingho. Many, if not all of them have some tidal influence, but the main interest would in recording flows during and immediately after the rainy season when the streams would be at their highest and the influence of tidal variations at its lowest.

Since the flows would have some tidal variation to obtain an accurate average level it would be necessary to analyse a large number of points each day. It would therefore seem appropriate that the equipment should be chosen so that levels at, say, 15 minute intervals were recorded in a format which is directly computer compatible.

It would also be of interest to try to develop rating curves for two sites on the main river. These could be at Fatoto, the furthest upstream site in the country, and at Kaur, still upstream of the barrage site but at a point where some seasonal variation in levels is still noted. At Fatoto it should possible to install a cableway which would facilitate the rating. At Kaur a boat, or boats, would have to be used. It would probably be necessary to have a relatively short but high intensity project to develop the rating curves during one, or possibly more, rainy seasons. The period should cover at least three complete lunar cycles. Further gaugings and bed surveys from time-to-time would be needed to ensure that the ratings were still valid. In conjunction with the gauging exercise there would need to be a detailed mathematical analysis of the levels during the time of the gaugings and also using the long term records. By techniques such as spectral analysis it might possible to filter out the tidal component at each site by relating it to the tidal variations at Banjul, where there are no level variations related to freshwater flow.

This approach with, hopefully, accurate flows at Fatoto, measured flow on a significant proportion of the relevant catchment downstream of Fatoto and a further flow record, perhaps not as accurate as Fatoto, at Kuntaur, would give a much better idea of the flow upstream of the barrage site than is at present possible.

Another factor related to the network is that of water quality. In the case of The Gambia the most important factor is the level of salinity. At present readings can only be made at irregular intervals and do not appear to take account of variations of salinity with depth. The salinity measurements should be improved. Firstly by ensuring that a number of readings are taken at each river cross section. As with the gaugings this might take the form of an initial study over a one year period. This would take a large number of readings at different depths and different vertical profiles at each river section. This would be done at regular intervals, at least once a month at each site throughout a 12-month period. These figure could be analysed to determine the minimum number of readings to enable the salt concentration to be assessed to a reasonable degree of accuracy. The effect of tidal variation could also be analysed. This data would enable a better picture to be obtained of where and when irrigation could safely take place or where salt resistant varieties should be grown.

computer system of the flexibility and complexity of CLICOM, continuing training should be offered. The country has a low installed computer base so many of the staff get little or no exposure to computing other than their use of work specific software packages. Someone who has worked regularly with computer systems over many years will, when confronted with a new program, note the similarities and differences between the new system and the ones he or she has used in the past; someone who has only limited experience depends entirely on the training they have received on a particular program. It would be useful if regular visits, for example once every six months, could be set up, possibly under the aegis of the AGRHYMET centre at Niamey.

7.2.4 Equipment

In general the stock of meteorological equipment is adequate, apart from the reported problem of spare parts for the maximum and minimum thermometers. That this is so is largely due the long term support given to the service by the AGRHYMET project.

The two areas where there do appear to be problems are in data transmission and in transport. The problems of data transmission have been discussed above. There are present eight stations equipped with SSB radios but only the radios at Banjul and Sapu are operational. Given that the radios are installed it seems that the limited extra cost of providing solar panels and batteries to provide power would be fully justified. If these stations were so equipped their data could be transmitted regularly to Banjul making data for the ten-day bulletins more easily available and possibly shortening the time taken to collect data for the other stations by vehicle. Greater use of radio transmission opens the possibility of having a vehicle based outside the capital which could collect data from a more limited area with a consequent reduction in milage and increased vehicle life. At the moment the radios use voice communication but another possibility would be the use of modems which enable the data to be entered locally into a computer and then transmitted automatically to Banjul. Since the data entered into the computer could be printed out and checked before transmission this would reduce the possibility of errors in the data sent over the radio.

As far as computer equipment is concerned the Meteorological Division seems to be well placed. The four PC-AT compatible computers are adequate for the needs of the service and are used in a good operating environment which is clean and air conditioned. The life of computers is however limited and given the lack of repair facilities in the country the need to replace them before they start to experience frequent breakdowns will have to be considered. When purchasing computer equipment in the future consideration should be given to modern 'lap-top' or even 'notebook' size computers. These computers now use the latest processors and have hard disks large enough to satisfy most needs. They cost rather more than their larger desk-top equivalents but the fact that they have internal battery back-up reduces the need for expensive UPS systems to maintain electricity during power cuts.

7.3.4 Equipment

At present, apart from two old, small, and possibly inaccurate current meters the department has no equipment for flow gauging. This coupled with a shortage of vehicles, particularly 4-wheel drive vehicles, means that few if any gaugings are carried out. If the recommendations for adding to the network of stations with flow measurement are implemented then this situation will have to be remedied. In addition to current meters, weights, rods, etc, there will also be a need for boats and other forms of transport. In the case of Fatoto it is also recommended that a permanent cableway be installed.

A further area where increased equipment is required is for computing. Although the computers themselves are adequate for the present level of activity there is a need for more to be done in the processing of hydrological data. In particular a digitiser should be obtained to enable the levels at tidal stations to be entered and stored at a relatively short time step, possibly 15 or 30 minutes. This would also be necessary for any charts which exist for tributaries at which level variations in response to flow would be rapid. At present the only software available for hydrological data processing is the HYDROM package from ORSTOM. The capabilities of these programs would have to be compared with others that are available to determine the most suitable package for the DWR.

7.3.5 Maintenance

The DWR has a stock of spare parts for its automatic water level recorders and no problems were reported in this regard. It is also understood that spare parts will be provided for the new stations being installed by the OMVG/USAID project. A regular supply of charts is also available financed out of funds from the budget for the AGRHYMET project.

Two problem areas, which are related to maintenance, are the regular changing of the charts and the calibration of the current meters. In the case of the charts they are often left in place for several weeks which makes it very difficult retrospectively to decipher the value which occurred at any particular date. It also means that, if at the time the chart is finally changed there are any discrepancies in the time or the level, it is almost impossible to apply corrections.

It also understood that the two current meters which are available have never been recalibrated. It would of course be uneconomical for a country the size of The Gambia to have its own calibration tank for current meters. Nevertheless unless the meters can be recalibrated, or at least checked at regular intervals, then major errors may occur. One possibility would be to use the tank at the Water Resources Institute in Kaduna, Nigeria, as a regional centre but it understood that the facility there is at present non-operational. The other alternative would be to make arrangements to return the meter to the manufacturer for re-calibration at regular intervals - say every two years unless it was obvious that the meter had been damaged before that time was up.

had been unchanged for several rotations, it might easier for an experienced hydrologist to analyse the charts and note the maximum and minimum values. The value of this is that would give a basis for analysing the relation between tidal and fluvial effects at stations which were at a different distance from the main river.

The hydrological network in The Gambia, with a long tidal river running the whole length of the country and a large number of small tributaries, is probably unique. Particularly as many of the tributaries are also tidal for several kilometres from the main river. At present the lowest point on the Gambia River for which flows are available is at Gouloumbo in Senegal but even here there are tidal influences. At this point however the catchment area is barely half the total area and the station is 500 km from the mouth of the river. The station in The Gambia which is furthest upstream is at Fatoto which is 35 km downstream from Gouloumbo. At Fatoto the tidal variation is about 400 mm, around four times the range at Gouloumbo. There is no rating curve for Fatoto.

Most of the tributaries which are measured are relatively small and do not flow all the year round. One peculiarity of the level recording network is that on the main river, where apart from tidal effects the levels change slowly, there are a number of automatic water level recorders, but on the tributaries which are 'flashy' there are mainly staff gauges. In particular there are not at present any stations with both rating curves and automatic water level recorders. It is suggested that automatic water level recorders be installed on the following tributaries:

North Bank

- Ninaija Bolon. The present site of the water level recorder is at Charmen where the tidal range is reported to be 1 m. There is no rating curve. A better site might be near to the village of Nyangen on the Njau/Kuntaur road. This is some 25 km upstream of the present site so tidal variations would be less and hence the accuracy of flow measurement would be greater.

- Sandugu Bolon at Sami. This site has an automatic water level recorder but no rating curve. The tidal range at the site is about 0.6 m. Seasonal variation in maximum or minimum water levels is around 1.0 to 1.2 m.

- Pallen Bolon. This tributary is not at present gauged and whilst definite figures for its catchment area are not known it appears to be large enough to warrant flow measurements.

South Bank

- Shima Bolon. This at present has no automatic water level recorder but it has a number of flow gaugings which suggest that it should be possible to produce a rating curve. A gauging station in Sénégal at Santhia Coundara could be used to provide comparisons.

- Prufu Bolon. The situation at this station is similar to the above. That is there have been flow gaugings but only staff gauges are used.

It is recommended that within the current UN monitoring system, a smaller network (say 20 to 30 points) is selected for much more frequent observations of water level, using local observers, either from provincial government agency bases, or hired especially for the purpose. The measurements should preferably be at daily, but at most, at weekly intervals. An ideal monitoring point would be an unused well or borehole, with no major groundwater abstractions within say 1 km radius. However such wells are few and far between, so that active sources of water will have to continue to be used. However, in such cases it should be ensured that no water is drawn from the source for at least four hours, immediately prior to the measurement; early in the morning (at dawn) is usually the best time as it does not interfere with the consumers.

It is considered that such an observation network would make a major contribution to the general objectives of water level monitoring, specified in Chapter 6.

The specific water level monitoring of the North Kombo region is probably best left to GUC, which observes a number of wells and boreholes already. However, the frequency of its observations should also be increased to daily intervals, where possible, and maximum weekly intervals elsewhere.

Groundwater quality monitoring should include a country-wide network of say 20 points to be observed quarterly and higher density in the North Kombo area. In the latter case, some measurements are being done already as a part of water supply quality control.

It is also recommended that the bacteriological status of rural water supply is monitored. The simplest possible test for the presence of *E coli* should be used, for say, 50 different wells each year, to evaluate the magnitude of the organic contamination of potable supplies. In some wells, not provided with access manholes, any required corrective action (normally disinfection) will be difficult.

7.4.3 Personnel

The problem of the lack of indigenous expert personnel trained in groundwater related disciplines has been discussed already.

It should be mentioned that in 1987, the government formulated a five year 'Manpower Development Project' for the water sector, for external financing (Government of the Republic of The Gambia, 1987); the details are shown in Table 7.2. However, so far no international or bilateral agency has taken it up.

The urgency of such manpower development must be apparent from the previous sections of this report. However, the objective may be more easily achieved by a longer term programme, of sending two suitable candidates to an appropriate educational institution abroad each year for four or five years. Different local or international agencies might be persuaded to sponsor and finance each batch of students.

In conjunction with the above it would be useful to position permanent conductivity sensors at perhaps three sites, one near to the downstream freshwater limit, one near to the upstream saltwater limit and one in between. The depth and position of these sensors would be determined from the results of the above tests. This would supplement data from continuing salinity surveys and enable the movement of the saline/freshwater interface to be traced accurately.

7.3.3 Personnel

At the time of our visit to the country in June 1991 there was no Principal Hydrologist in post and his duties were being carried out by his former deputy. A UN volunteer hydrologist employed in the context of the AGRHYMET programme was also providing support to the service. This complement of personnel was barely enough to keep the service functioning at a minimum level and left little extra time for analysis of the data or quality control.

Given the constraints on government expenditure it would seem to be optimistic to expect that this situation could be rapidly improved. Although beyond the terms of reference of this study it would seem appropriate that the government should discuss with the donor community its likely need for graduates in all disciplines without initially deciding where they would be placed at the end of their studies. When their studies had been completed then these graduates should be assigned to appropriate government departments with, as far as possible, the agreement of the graduates themselves. This would ensure a steady supply of graduates to appropriate government services. There would of course have to be binding legal agreements limiting the right of the graduates thus trained to seek more lucrative employment in the private sector until they had completed a certain number of years in government service unless their prospective employer was prepared to reimburse the cost of their training. There would also be a need to ensure that an equitable salary structure was established to avoid all the best graduates trying to get in to a particular service or quasi-statal organisation which offered better salary or conditions.

At a lower level the training courses at the DWR training school should be continued. In this case the problem seems not so much a question of training as of retaining qualified observers for a reasonable period of years after their training. There are a number of factors at play here including the low level of the honorariums, the difficulty the observers sometimes experience in receiving payment and the fact that due to transport constraints they can not be visited regularly. Without frequent visits to demonstrate that their work is important it is hardly surprising that they should develop a lethargic attitude to the readings at their stations or become irregular in the performance of their duties.

A further factor related to personnel, though also to equipment, is that of the use of computers. At present there is almost no computerisation of the process of hydrological data collection or analysis. This may in part be due to the fact that suitable computers have only recently become available and there were also reported to be administrative problems which have now been resolved. However if the available data is to be entered into a computer compatible system then it was seem that further training of the personnel of the department would be needed.

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7.4 Groundwater

7.4.1 Organisational Structure

The formal organisational framework of the hydrogeology service in The Gambia is adequate, but as stated before, the scarcity of middle level hydrogeologists, groundwater engineers, geophysicists and hydrochemists is the major problem of the groundwater sector. A long term scheme to correct this deficiency should be initiated. This problem is sure to exist in some of the other countries involved in this assessment and an international, regional solution, in the form of student exchange and a training centre should be considered.

Though local workers cite the setting up of a legal framework for groundwater development (under a general Water Resources Act) as an important requirement, it is not viewed as of immediate priority by this assessment. By all accounts the total groundwater abstractions (even in the North Kombo area) are well short of the safe yield; moreover the government has effective control over the groundwater sector purely because few (if any) private interests have the financial resources to develop significant groundwater abstractions. Therefore, the resource is not under threat of over-exploitation, or derogation, for the time being, and legislation to govern its use is not an urgent requirement.

Nevertheless, co-ordination of all groundwater activities is important and urgent. One major advance would be standard implementation procedures and reporting for well and borehole installation. These should routinely include a short formal pumping test and measurements of some important quality parameters. Completion reports for all wells should be a requirement and should all follow the same format (designed by the DWR).

7.4.2 Network Size and Density

The Gambia being a small country, with practically all its water supplies derived from groundwater, has densities of data collection usually much higher than the minima stipulated as acceptable by the UNESCO/WMO standards. This situation is, of course, satisfactory, but in some cases the extensive networks were not accompanied by sufficiently intensive measurements of particular parameters.

Most of the groundwater level monitoring systems (including the current one) were initiated by foreign aid projects, involved networks of more that 100 points (mainly dug wells) and have been measured at quarterly and monthly intervals. Most of the monitoring wells have been and are being used, but no attempt has been made to avoid or correct for drawdowns resulting from abstractions, so that the observed water level trend of any particular well could be questioned. Moreover, the sheer size of the networks practically ensured that the monitoring was abandoned once the particular project, responsible for setting up the network, ended.

TABLE 6.4

Evaluation of Staffing Levels - Hydrology

Item	Number of staff per 100 stations			
	Professional	Technicians		Observers
		Senior	Junior	
Recommended staffing levels				
- Field operations and maintenance	1	5	5	100
- Data processing, analysis and interpretation	2	3	3	-
- Supervision	0.5	-	-	-
Total	3.5	8	8	100
Actual staffing levels				
- Field operations and maintenance	2.5	8.3	8.3	0
- Data processing, analysis and interpretation	0	-	0	-
- Supervision	2.5	5	5	-
Total	10	8.3	8.3	100

Note: Recommended levels from UNESCO/WMO (1988).

6.4.2 Present Situation

In recent years there had been a detailed study of whole of the Gambia river basin. This has looked at different development options for hydro-power and irrigation which have included a dam in Senegal and a barrage in The Gambia. Unfortunately the barrage could only be designed on the basis of flows measured hundreds of kilometres upstream at Gouloumbo in Senegal. This station measures flow from a little over half the catchment area but the area between it and the proposed barrage site represents almost a further third of the basin area. Whilst it is true that much of the flow comes from the upper parts of the basin in Guinea it is unfortunate that the contribution from such a large area could not be accurately estimated.

TABLE 7.2

Details of the Manpower Development Project

Item	Nr	1987/88 year one	1988/89 year two	1989/90 year three	1990/91 year four	1991/92 year five	Dalasis Total
01 Master of Science-Meteorology	1-2	-	162 000	324 000	162 000	-	648 000
02 Bachelor of Science-Computer	1	162 000	162 000	162 000	-	-	486 000
03 Short-term Fellowships		337 500	187 500	-	-	-	525 000
04 Workshops for Technical Staff		105 000	75 000	-	-	-	180 000
05 Workshops for Well Attendants and Privatisation		161 250	116 250	3 750	3 750	3 750	288 750
06 Bachelor of Science-Hydrogeology	1	162 000	162 000	162 000	162 000	-	648 000
07 Bachelor of Science-Geophysics	1	162 000	162 000	162 000	162 000	-	648 000
08 Bachelor of Science Civil Engineering	1	162 000	162 000	162 000	162 000	-	648 000
09 Bachelor of Science Pure Mech Eng/Solar Energy	1	162 000	162 000	162 000	162 000	-	648 000
10 Diploma Well Drilling	3	30 000	60 000	60 000	30 000	-	180 000
TOTAL		1 443 750	1 410 750	1 197 750	843 750	3 750	4 899 750
10% Price Contingency:		144 375	141 075	119 775	84 375	375	489 975
GRAND TOTAL		1 588 125	1 551 825	1 317 525	928 125	4 125	5 389 725
US$ EQUIVALENT: at US$=Dalasis 7.50		211 750	206 910	175 670	123 750	550	718 630

Source: Government of the Republic of The Gambia, 1987.

7.4.4 Equipment

At present the equipment available to the groundwater sector in The Gambia is more or less commensurate with the manpower resources capable of using it. Consequently, only limited procurement of new technical equipment is recommended with the specific aims of:

- upgrading of the DWR water laboratory;
- making more efficient use of the equipment already available by procurement of spare parts and ancillaries.

7.4.5 Maintenance

No great maintenance problems with the available equipment relevant to groundwater studies and development, have been reported, apart from the lack of foreign exchange for spare parts. Consequently no specific action for the improvement of maintenance facilities is proposed at this stage.

The densities of various groundwater related measurements in The Gambia generally compare favourably with the UNESCO/WMO criteria as shown in Table 6.5. However, it is questionable whether these standards are applicable to a very small country like The Gambia. In the past, the groundwater level monitoring systems have utilised very large networks, infrequent measurements and have been discontinuous. In fact it is likely that the very large number of observation points, usually set up by foreign experts, practically ensured that the monitoring had to be abandoned when the projects, assisted by these experts, ended. The current monitoring network, just reactivated by the UN Groundwater Resources Planning and Development Project, comprises 155 wells, 120 of them measured quarterly and 25 measured at monthly intervals; it is unlikely that any use will be made of the data from most of these and most unlikely that the observation of the network will continue after the end of the UN participation in the monitoring. As before, the DWR will have difficulties with transport to cover the whole network.

TABLE 6.5

Groundwater Data Collection Activity Levels
(Surface Area of The Gambia - c 11 000 km²)

Item	Recommended minimum of UNESCO/WMO		Actual	
	Density	Number for The Gambia*	Number	Density
Groundwater level stations; non-recording (number per 10^4 km^2)	5	6	155	v high
Groundwater level stations; recording (number per 10^5 km^2)	2	1	1	OK
Groundwater stations measuring hydraulic characteristics (number per 10^4 km^2)	5	6	c150	v high
Groundwater quality stations (number per 10^5 km^2)	5	1	?	high
Well drilling sets (number per 10^6 km^2)	20	1	1	OK
Repair and maintenance shops for well drilling sets (number per 10 well drilling sets)	1	1	2	high
Special groundwater survey teams (each team 3 or 4 men) (number per 10^5 km^2)	6	1	?	OK
Superstructure staff groundwater (number per 100 groundwater monitoring stations)	4	8	?	low

Note: * All fractions rounded upwards

Source: DWR (1991), GUC (1991) and UNDP (1991).

REFERENCES (cont)

Whyte, W J and Russell, T S	1988	'Geology and Mineral Resources of The Gambia', Geological Unit, MEPID, Banjul
World Health Organisation	1984	'International Standards for Drinking Water', Geneva

APPENDIX A

PARTICULAR TERMS OF REFERENCE

APPENDIX A

PARTICULAR TERMS OF REFERENCE

A1 Hydrometeorology

The consultant shall:

- review the setup of the existing meteorological network and make recommendations for expansion or adjustments if considered necessary;

Sections 3.2.1 and 3.3.1 look respectively at the climatological and rainfall networks and their management. Sections 6.2 and 6.3 evaluate the networks and the meteorological service. Section 7.2 proposes that no changes are needed to the size of the present networks. Recommendations are however made for better management of the overall network.

- examine the status of works on the network with special consideration for transport facilities, workshops and spare parts furniture, maintenance costs;

Sections 3.2.2, 3.2.3, 3.3.2 and 3.3.3 deal with 'equipment' and 'maintenance and field support' for the climate and rainfall networks. Section 7.2.4 makes recommendations regarding transport, and Section 7.2.5 regarding maintenance.

- prepare recommendations concerning the reactivation of the network of stations equipped with telecommunications systems for transmission of meteorological observations;

Section 7.2.4 contains recommendations regarding the use of radios for the transmission of data and includes proposals for the use of solar power rather generators and the introduction of modems to improve data transmission accuracy. These recommendations are embodied in the proposed project GAM-1 (see Appendix B).

- prepare recommendations concerning the reactivation of the computerised activities, including adequate computer equipment specifications, computerisation of data processing, storage and retrieval, and training of the personnel;

Sections 3.2.4 and 3.3.4 cover the present situation in the Meteorological Division as regards data processing. In Chapter 6 the relevant sections also present an evaluation of the shortcomings of the data processing facilities. Section 7.2.4 recommends that more of the data should be available in a computer compatible form and the proposed project GAM-1 includes the training and purchase of equipment necessary to attain this end.

- prepare recommendations for the regular publication of meteorological monthly summary and year book.

The publication of reports is also addressed by the proposed project GAM-1. The software proposed is capable of producing summaries for report publication. The equipment includes a laser printer which gives the high quality of output necessary for reports.

A2 Surface Water

The consultant shall:

- review the gauging and water level stations network and make recommendations for expansion or adjustments if considered necessary;

The present status of the network is presented in Section 4.2.1 and it is evaluated in Section 6.4. Section 7.3.2 makes detailed recommendations for the enhancement of existing stations or the installation of new stations. These modifications are included in the proposed project GAM-2.

- examine the needs for methodology and instrumentation regarding the calibration of sections on the Gambia River to allow knowledge of fresh water discharge on a permanent basis;

Section 4.2.2 considers in some detail the methods of discharge measurement. The recommendations concerning the network mentioned above also include proposals for instrumentation and techniques for improved flow gauging on the main river and its tributaries. The project GAM-2 takes account of these recommendations.

- examine the status of works on the network with special consideration for transport facilities, workshops and spare parts furniture, maintenance costs;

Sections 4.2.3 and 4.2.4 consider 'equipment' and 'maintenance and field support'. Sections 7.3.4 and 7.3.5 make recommendations. It is concluded that better gauging equipment and means of transport, both on land and on water, are needed. These recommendations are included in project GAM-2.

- examine the needs for data to be collected for calibration of a mathematical model for forecasting of tidal levels in the estuary of the Gambia river and other estuaries or small tributaries;

Section 7.3.2 deals with the question of the combined effects of tides and fresh water flows on river levels. It recommends that a detailed statistical model be developed to separate the two components to enable a better estimation of fresh water flows. This forms part of the proposed project GAM-2.

- examine the need for data to be collected for monitoring the salt concentration in estuarian waters;

Section 4.4 looks at present methods of measuring the saline/fresh-water interface. Section 7.3.2 deals with proposals for improving the measurement of salt concentration. The proposed project GAM-3 is concerned solely with this question.

- prepare recommendations concerning the reactivation of the computerised activities, including adequate computer equipment specifications, computerisation of data processing, storage and retrieval, and training of personnel;

Section 7.3.4 makes recommendations for an increased computerisation of hydrological activities in The Gambia. These proposals, which include the purchase of plotters and digitisers, form part of the proposed project GAM-2.

- prepare recommendations for regular publication of hydrological year book.

The software and equipment proposed for procurement by the project GAM-2 are appropriate for the publication of a year book.

A3 Groundwater

The consultant shall:

- review the existing groundwater monitoring network (water levels and quality) for the three main aquifers and prepare recommendations on expansion or adjustment if considered necessary, with special consideration for new techniques;

The present status of the network is presented and evaluated in Section 6.5. Section 7.4.2 makes recommendations for increasing the frequency of monitoring but reducing the number of sites monitored are made to enhance the quality of data collected for planning purposes. Water quality monitoring is an area identified as in need of expansion and proposals for upgrading the DWR laboratory facilities have been brought together in project GAM-4.

- review the existing hydrogeological maps and groundwater studies and advise on priority requirements of new studies including geophysical investigations, drilling and testing;

Chapter 5 describes the information available from previous studies and on-going water supply programmes. The map base of The Gambia is good and the groundwater system is well documented and reasonably well understood. The variability of yield (or specific capacity and estimated transmissivity) at drilled well sites is an important subject at present inadequately dealt with, making it difficult to assess the influence of well design and construction methods on the observed variation in yield.

- review the existing computerised data base with consideration for equipment, software and stored parameters, and make proposals, if considered necessary, to allow planning and development of the groundwater resources;

Output from the existing data bases is discussed in Section 5.2.7. Section 6.5.3 contains general recommendations for improving the UN project database by the inclusion of discharge and drawdown of boreholes, some yield function of dug wells, and some hydrochemical parameters. For the longer term the forthcoming EDF funded groundwater study should formulate future data requirements in detail.

- review the existing groundwater studies and prepare recommendations for new studies on modelling of the different aquifers on selected areas.

As stated above the groundwater system in The Gambia is already well understood, and with the present level of development of the resource there is no pressing need for further modelling studies to assist planners, with the possible exception of the North Kombo area. It is expected that the forthcoming EDF funded groundwater study will examine the need for modelling of this particular area.

APPENDIX B

PROJECTS

Country:	The Gambia
Date:	August 1991
Project Nr:	GAM-1
Proposed Title:	Improved data processing for the Meteorological Division.
Government Implementing Agency:	Department of Water Resources.
Estimated Duration:	3 years
Tentative International Contribution:	US$ 343 750
Estimated Counterpart Costs:	To be calculated
Source of Funds:	To be decided

I Development Objective and its Relation to the Country Programme

1 Country Programme

The country has been undergoing a structural adjustment programme under the auspices of the International Monetary Fund. This is now starting to bear fruit with an improved balance of payments and a more stable currency. To improve the situation still further the government is keen to increase its level of self sufficiency in food production. This will need better management of its agricultural resources and, where possible, additional irrigation not only of staple crops such as rice but also horticultural produce.

An environmental division has also been set up within the Department of Water Resources which has the role, amongst others, of trying to ensure that any improvements in water use are environmentally acceptable.

2 Project Objectives

The principal objective of the project would be to ensure that the Meteorological Division had access to personnel and equipment so that all past data was readily accessible on a computer system in the offices of the Department of Water Resources (DWR) and future data could also entered into the same system. The project would provide training, both formal courses and on-the-job, and logistical support.

II Major Elements

- Ensure that all the meteorological data from The Gambia previously stored on computer by the DARE data rescue project of the Royal Belgian Meteorological Service and AGRHYMET are available in the offices of the DWR in Banjul in a computerised data bank.

- Improve methods of data collection and transmission so that up to date data is available in Banjul for synoptic purposes and for agro-meteorological calculations.

- Establish procedures to update the data bank on a regular basis.

- Train staff in the new procedures.

- Provide assistance with logistical support.

III Project Strategy

1 Who are the people and/or institutions who would benefit in the first instance from the project outputs and activities?

The primary beneficiaries would be the Meteorological Department of the DWR. The benefits would apply both to those who use the data for synoptic forecasts and to those who use it for agro-meteorological purposes. This would include the 10-day agro-meteorological bulletin but would also help steps being taken to improve crop yields by sowing, planting and harvesting at times estimated to be propitious from a meteorological and climatological point of view.

2 Target Beneficiaries

The target beneficiaries are all those who benefit from the forecasts produced by the Meteorological Division and the much larger number of people who depend on agriculture for their livelihood whose productivity and nutritional intake could be improved by agro-meteorologically regulated crop management.

3 Implementation arrangements for the project

The project activities would be centred on the offices of the DWR in Banjul but would also involve a lot of field activities at climatological and rainfall stations throughout the country. During the first six months of the project there would a consultant in The Gambia who would, with his Gambian counterparts, co-ordinate the specification and procurement of equipment and the initial training in its use. During the remaining life of the project the consultant would return at intervals to give additional training and to help resolve any difficulties in the application of the procedures.

4 Alternative implementation strategies

One possibility considered was to have a full-time expert in the project for the full three years. This however was rejected as it would be too expensive and, once suitable training had been given, the staff in Banjul would be able to implement the project without full time technical assistance. The option of a full time expert would also have been more expensive than the use of a consultant.

It has also been assumed that support will continue to be provided in the context of the AGRHYMET project and this project has been designed to be complementary to the longer term support activities of that project.

IV Host Country Commitment

1 Counterpart support

The counterpart organisation would be expected to provide both professionally trained counterpart staff and also field observers who would be able to use the equipment in the field. They would also provide staff for data entry. The counterparts would be expected to provide routine maintenance of any equipment bought with project funds.

2 Legal arrangements and future staffing

There has been a tendency for qualified staff to leave the service, often for the better salaries and conditions of para-statal companies or organisations. Any staff who receive training under this project should sign an agreement which limits their future employment for a defined period, at least three years, to the Department of Water Resources.

V Risks

This project is one of a number of complementary national and regional projects proposed within the context of the Sub-Saharan Hydrological Assessment. Unless these projects are carefully co-ordinated there will be a risk that outputs from one project will not be ready at the appropriate time as inputs to other projects.

VI Inputs

1 Outline of Inputs

Technical Assistance. A consultant would spend 4 months at the DWR at the start of the project. During this period he would work with his counterparts to procure equipment and, if necessary, software. He would also arrange for all data which had not been computerised to be assembled and inventoried. The data which had earlier been computerised would be transferred to Banjul. Later he would return to the project for short periods to deal with specific problems and to give further training, possibly for staff who had been newly brought in to the service. A second consultant, who was a specialist in the use of CLICOM, would also undertake a number of short assignments to the project.

Training. Much of the training would take the form of on-the-job training during the normal execution of the project. Special courses would be held in Banjul for observers and other staff from rainfall and climate stations to train them in the use of the new equipment and new techniques. Two study tours would be provided to enable the staff who were responsible for the management and operation of the system to study the use of equivalent systems and to learn the techniques of operation and maintenance.

Equipment. At all the climate stations a radio with solar panels and battery backup would be procured. The budget also allows for four key sites to be provided with a lap-top computer and modem. This would enable the data to be entered and checked before transmission. Although this would introduce a slight delay in sending the data it would mean that there would be less chance of errors due to unclear speech transmission or in copying down the figures transmitted. Additional computer equipment would be provided for the central service at Banjul. A 4-wheel drive vehicle to enable more frequent visits to the stations to check on the quality of the data and performance of the observers would also be required.

2 Skeleton Budget

Personnel

Post	Duration (months)	Rate (US$/month)	Amount (US$)
Principal consultant	8	20 000	160 000
CLICOM specialist	1.5	16 000	24 000
Subsistence			23 750
Travel			14 000
Sub-total			221 750

Training

Item	Amount (US$)
Course on use of radios	10 000
Course on use of computers	10 000
Two study tours	15 000
Sub-total	35 000

Equipment

Item	Amount (US$)
Two computers for Banjul	10 000
Eight radios with solar panel and batteries	40 000
Four modems and computers	12 000
Vehicle	25 000
Sub-total	87 000

TOTAL	343 750

3 Policy Issues

The project does not give rise to any policy issues which would need to be addressed before the commencement of the project.

Appendix A - International Personnel

1 Qualifications and Duties

The principal consultant should have a degree in meteorology or a natural science from a recognised University. An appropriate post-graduate qualification would be an advantage. The consultant should also have 10 years of experience in operational meteorology including several years experience of data processing. The consultant must have a good command of the English language.

During the first visit of four months the consultant would be expected to initiate procurement of the equipment, define the training programme and, in close co-operation with his counterparts, determine the priority for entering data to the data processing system. Thereafter the budget allows for two one month visits during each of the two subsequent years, preferably with one towards the end of the rainy season. During these later visits he or she would help to give training in the use of the equipment and software and recommend what quality control techniques should be applied to the data.

The CLICOM specialist should have similar qualification to the principal consultant and good experience in the operation of the CLICOM system. He or she would make three visits to the project each of two weeks duration.

Appendix B - Training

The training would have two main themes. These would be training in data processing techniques, and specific training in the software developed or purchased especially for data processing. This would take form of courses at Banjul at which the lecturers would be the Consultant and staff of the DWR.

Two staff of the DWR responsible for the management and operation of the system would be sent on study tours to enable them to appreciate what techniques in terms of staffing and maintenance were necessary to ensure the continuing operation of such systems.

Appendix C - Equipment

(a) Two 80386 based PC-compatible computers with VGA graphics, arithmetic co-processor and hard disk. One dot matrix printer and one laser printer capable of providing good quality printing for report publication.

(b) Eight single-side band short wave radios. Solar panels, regulators and batteries. The batteries should of the sealed no-maintenance type specifically chosen for use in a tropical environment with solar panels.

(c) Four lap-top PC compatible computers with modems to be connected to the radios.

(d) A four-wheel drive vehicle.

Country:	The Gambia
Date:	August 1991
Project Nr:	GAM-2
Proposed Title:	Improved flow measurement for the Hydrology Division.
Government Implementing Agency:	Department of Water Resources.
Estimated Duration:	3 years
Tentative International Contribution:	US$ 535 500
Estimated Counterpart Costs:	To be calculated
Source of Funds:	To be decided

I Development Objective and its Relation to the Country Programme

1 Country Programme

The country has been undergoing a structural adjustment programme under the auspices of the International Monetary Fund. This is now starting to bear fruit with an improved balance of payments and a more stable currency. To improve the situation still further the government is keen to increase its level of self sufficiency in food production. This will need better management of its agricultural resources and, where possible, additional irrigation not only of staple crops such as rice but also horticultural produce.

An environmental division has also been set up within the Department of Water Resources which has the role, amongst others, of trying to ensure that any improvements in water use are environmentally acceptable.

2 Project Objectives

The principal objective of the project would be to ensure that the Hydrological Division had access to personnel and equipment to enable the estimation of the run-off from tributaries which join the river Gambia within the country. The project would provide training, both formal course and on-the-job, and logistical support.

II Major Elements

(a) Set up automatic water level recorders on six tributaries of the Gambia upstream of Balingho.

(b) Install a cableway at Fatoto and carry out an intensive programme of gaugings over a period of three lunar cycles during the rainy season.

(c) Transfer as much of the presently available data as possible on to a computer system. This would included the digitisation of charts at some of the stations with a tidal influence.

(d) Analyse historic levels and those collected from new stations with tidal influence to seperate fluvial from tidal effects.

(e) Provide assistance with logistical support.

III Project Strategy

1. Who are the people and/or institutions who would benefit in the first instance from the project outputs and activities?

The primary beneficiaries would be the Hydrological Department of the DWR. They would have more accurate information on the water resources of the Gambia river donwstream of the gauging station at Gouloumbo in Sénégal.

2 Target Beneficiaries?

Over a number of years there have been a number of studies on the construction of a barrage/bridge on the Gambia at or near to Balingho. These have been very extensive and have studied a range of economic and environmental criteria. There is not however a gauging station on the Gambia which would enable an accurate estimation of the flows at that point on the river. The barrage project, if constructed, would cost $200 million (1988 prices) so any improvement in the accuracy of the estimate of the benefits would be useful.

3 Implementation arrangements for the project

The project activities would be centred on the offices of the DWR in Banjul but would also involve a lot of field activities at gauging stations throughout the country. During the first six months of the project there would a consultant in The Gambia who would, with his Gambian counterparts, co-ordinate the specification and procurement of equipment and the initial training in its use. During the initial period, three months would be spent on carrying out a concentrated series of gaugings on the Gambia at Fatoto and Kaur.

4 Alternative implementation strategies

One possibility considered was to have a full-time expert in the project for the full three years. This however was rejected as it would be too expensive and, once suitable training had been given, the staff in Banjul would be able to implement the project without full time technical assistance. The option of a full time expert would also have been more expensive than the use of a consultant.

It has also been assumed that support will continue to be provided in the context of the AGRHYMET project and this project has been designed to be complementary to the longer term support activities of the project.

IV Host Country Commitment

1 Counterpart support

The counterpart organisation would be expected to provide both professionally trained counterpart staff and also field observers who would be able to use the equipment in the field. They would also provide staff for data entry. The counterparts would be expected to provide routine maintenance of any equipment bought with project funds.

2 Legal arrangements and future staffing

There has been a tendency for qualified staff to leave the service, often for the better salaries and conditions of para-statal companies or organisations. Any staff who receive training under this project should sign an agreement which limits their future employment for a defined period, at least three years, to the Department of Water Resources.

V Risks

This project is one of a number of complementary national and regional projects proposed within the context of the Sub-Saharan Hydrological Assessment. Unless these projects are carefully co-ordinated there will be a risk that outputs from one project will not be ready at the appropriate time as inputs to other projects.

VI Inputs

1 Outline of Inputs

Technical Assistance. A consultant would spend 6 months at the DWR at the start of the project. During this period he would work with his counterparts to procure equipment and, if necessary, software. At an early stage all the data for computerisation would be collected and inventoried. Digitisation of this data would be an early priority. The consultant would also carry out the analysis of the levels. Later he would return to the project for short periods to deal with specific problems and to give further training, possibly for staff who had been newly brought in to the service. A second consultant, who was a specialist in flow gauging, would also undertake an assignment to the project to assist during the initial period of intensive gaugings.

Training. Much of the training would take the form of on-the-job training during the normal execution of the project. Special courses would be held in Banjul for observers and other staff from the gauging stations to train them in the use of the new equipment and new techniques. Two study tours would be provided to enable the staff who were responsible for the management and operation of the system to study the use of equivalent systems and to learn the techniques of operation and maintenance.

Equipment. Automatic water level recorders would be provided for six sites. A cable way would be provided for Fatoto. Two sets of gauging equipment, including rods and weights would be purchased. Transport equipment would consist of two boats with motors and one four wheel drive vehicle.

2 Skeleton Budget

Personnel

Post	Duration (months)	Rate (US$/month)	Amount (US$)
Principal consultant	12	20 000	240 000
Gauging specialist	3	16 000	48 000
Subsistence			37 500
Travel			10 000
Sub-total			335 500

Training

Item	Amount (US$)
Course on flow gauging	10 000
Course on use of computers	10 000
Two study tours	15 000
Sub-total	35 000

Equipment

Item	Amount (US$)
Two computers for Banjul	10 000
Six automatic water level recorders	60 000
Cableway	20 000
Two sets gauging equipment including weights	20 000
Two boats with outboard motor	30 000
Vehicle	25 000
Sub-total	165 000

TOTAL	535 500

3 Policy Issues

The project does not give rise to any policy issues which would need to be addressed before the commencement of the project.

Appendix A - International Personnel

1 Qualifications and Duties

The principal consultant should have a degree in engineering or a natural science from a recognised University. An appropriate post-graduate qualification in hydrology would be an advantage. The consultant should also have 10 years of experience in operational hydrology including several years experience of data processing and analysis. The consultant must have a good command of the English language.

During the first visit of six months the consultant would be expected to initiate procurement of the equipment, define the training programme and, in close cooperation with his counterparts, participate in the intensive programme of gaugings. He or she would also be required to undertake the analysis of the data. Thereafter the budget allows for a three month visit during each of the two subsequent years, preferably during the rainy season. During these later visits he or she would help to give training in the use of the equipment and software and recommend what quality control techniques should be applied to the data.

The flow gauging specialist should have similar qualification to the principal consultant and good experience in carrying out gaugings in wide rivers. He or she would make one visit to the project during the initial period of intensive gaugings.

Appendix B - Training

The training would have two main themes. These would be training in flow gauging , and specific training in analytical techniques and the software developed or purchased especially for data processing. This would the form of courses in Banjul at which the lecturers would be the consultant and staff of the DWR.

Two staff of the DWR responsible for the management and operation of the system would be sent on study tours to enable them to appreciate what techniques in terms of staffing and maintenance were necessary to ensure the continuing operation of such systems.

Appendix C - Equipment

(a) Two 80386 based PC-compatible computers with VGA graphics, arithmetic co-processor and hard disk. One dot matrix printer and one laser printer capable of providing good quality printing for report publication. A digitiser and a graph plotter would also be obtained.

(b) Six automatic water level recorders. To avoid a multiplicity of types of equipment these should either be the same as those previously installed (OTT) or those recently used on the main river (Stevens).

(c) One cable way to be installed at Fatoto.

(d) Two sets of gauging equipment this would consist of meters, rods, cables, weights etc.

(e) Two boats suitable for flow gauging, with motors.

(f) One four-wheel drive vehicle.

Country:	The Gambia
Date:	August 1991
Project Nr:	GAM-3
Proposed Title:	Improved salinity measurement in the Gambia River.
Government Implementing Agency:	Department of Water Resources.
Estimated Duration:	12 months
Tentative International Contribution:	US$ 148 000
Estimated Counterpart Costs:	To be calculated
Source of Funds:	To be decided

I Development Objective and its Relation to the Country Programme

1 Country Programme

The country has been undergoing a structural adjustment programme under the auspices of the International Monetary Fund. This is now starting to bear fruit with an improved balance of payments and a more stable currency. To improve the situation still further the government is keen to increase its level of self sufficiency in food production. This will need better management of its agricultural resources and, where possible, additional irrigation not only of staple crops such as rice but also horticultural produce.

An environmental unit has also been set up under the Ministry of Natural Resources and the Environment which has the role, amongst others, of trying to ensure that any improvements in water use are environmentally acceptable.

2 Project Objectives

The principal objective of the project would be to improve the measurement of salinity in the Gambia River. The saline front, defined as the point at which salinity is 1 ‰, varies between 100 and 250 km from the mouth of the estuary. Its position is important for irrigation. At present readings are made at only one point near the surface but as the salinity varies significantly with depth this single value could be misleading.

II Major Elements

(a) Conduct detailed salinity measurements in the Gambia river during a whole year to establish salinity profiles for different states of flow and tide. From these determine the best method of conducting regular sampling.

(b) Set up a sampling programme to measure regularly the salinity of the river to determine the movement of the saline front.

(c) Review existing salinity prediction models and develop and test new models as necessary.

III Project Strategy

1. Who are the people and/or institutions who would benefit in the first instance from the project outputs and activities?

The primary beneficiaries would be the Hydrological Division of the DWR. They would have more accurate information on the movement of the saline interface and would in the future be able to provide more accurate data without a major increase in sampling frequency.

2 Target Beneficiaries?

At present there are a number of irrigation schemes on the Gambia which use the river water. By establishing more clearly where the saline front is it would be possible to make better use of the fresh water with less risk a reduced yields from the use of water that was too salty.

3 Implementation arrangements for the project

The project activities would be centred on the offices of the DWR in Banjul but would also involve a lot of field activities at gauging stations throughout the country. A consultant would visit the project three times during the year of its operation. A first visit of two months, during the rainy season, would establish parameters during high flows when the saline front was a lowest point. A second visit towards the end of the year would study the river during low flows when the river was in recession and the front was moving upstream. The final visit would take place at the end of the dry season and start of the rainy season when the front would be at its highest point and starting to move downstream.

4 Alternative implementation strategies

One possibility considered was to have a full-time expert in the project for the full 12 months. This however was rejected as it would be too expensive and, once suitable training had been given, the staff in Banjul would be able to implement the project without full time technical assistance. The option of a full time expert would also have been more expensive than the use of a consultant.

IV Host Country Commitment

1 Counterpart support

The counterpart organisation would be expected to provide both professionally trained counterpart staff and also field observers who would be able to use the equipment in the field. The counterparts would be expected to provide routine maintenance of any equipment bought with project funds.

2 Legal arrangements and future staffing

There has been a tendency for qualified staff to leave the service, often for the better salaries and conditions of para-statal companies or organisations. Any staff who receive training under this project should sign an agreement which limits their future employment for a defined period, at least three years, to the Department of Water Resources.

V Risks

This project is one of a number of complementary national and regional projects proposed within the context of the Sub-Saharan Hydrological Assessment. Unless these projects are carefully co-ordinated there will be a risk that outputs from one project will not be ready at the appropriate time as inputs to other projects.

VI Inputs

1 Outline of Inputs

Technical Assistance. A consultant would spend three periods in The Gambia as outlined under the heading 'implementation arrangements for the project'. The likely periods of the visits would be August to September for the first visit, January for the second and June to July for the third.

Training. The training would be given by the consultant in the course of carrying out the sampling and analysis activities of the project.

Equipment. Two portable conductivity meters would be provided and thee fixed units to be placed at gauging stations on the river. One of the would be just above the lower saline limit, the second near to the upper saline limit and a third in between. A boat to enable sampling across a wide river section would also be bought.

2 Skeleton Budget

Personnel

Post	Duration (months)	Rate (US$/month)	Amount (US$)
Principal consultant	5	16 000	80 000
Subsistence			12 500
Travel			6 000
Sub-total			98 500

Training

No specific budget item

Equipment

Item	Amount (US$)
Two portable conductivity meters	2 000
Three permanent conductivity meters	7 500
Boats with outboard motor	15 000
Vehicle	25 000
Sub-total	49 500

TOTAL	148 000

3 Policy Issues

The project does not give rise to any policy issues which would need to be addressed before the commencement of the project.

Appendix A - International Personnel

1 Qualifications and Duties

The principal consultant should have a degree in chemistry or a natural science from a recognised University. An appropriate post-graduate qualification would be an advantage. The consultant should also have 10 years of experience in river chemistry monitoring including several years experience of data processing and analysis. The consultant must have a good command of the English language.

During the three visits the consultant would work closely with his counterparts to make measurements to determine the salinity profile at different positions at several river cross-sections. From an analysis of the results of the detailed sampling, recommendations would be made for a reduced sampling programme which would enable the movement of the saline/fresh-water interface to be tracked accurately over the year.

Appendix B - Training

Training would be given in the course of the field sampling and analysis of the results.

Appendix C - Equipment

(a) Two portable conductivity samplers, with cables.

(b) Three conductivity samplers which would be fixed in the river adjacent to a level monitoring station. Each sensor would have a data logger which stored the data at regular intervals in a computer compatible form.

(c) One boat suitable for sampling, with motor.

(d) One four-wheel drive vehicle.

Country:	The Gambia
Date:	August 1991
Project Nr:	GAM-4
Proposed Title:	Upgrading of the Water Laboratory.
Government Implementing Agency:	Department of Water Resources.
Estimated Duration:	3 years
Tentative International Contribution:	US$ 984 500
Estimated Counterpart Costs:	To be calculated
Source of Funds:	To be decided

I Development Objective and its Relation to the Country Programme

1 Country Programme

Practically all of The Gambia's urban, rural and livestock water supplies and a significant part of irrigation are derived from groundwater sources. The development of this resource is still being implemented at a rapid pace, trying to match supplies to growing demand of both the urban and rural sectors. Though the hydrogeology of the country is well documented and reasonably well understood, there is a weakness in the available database in the field of hydrochemistry. Moreover, it has been shown that bacteriological pollution of village wells is common and may present a health hazard. At present it very difficult to evaluate the severity of the groundwater quality problem and take any remedial action (if such is necessary), because of inadequate availability of analytical services.

2 Project Objectives

The primary objective is to upgrade the DWR laboratory at Yundum, so that a large number of water samples can be analysed each year for all important chemical constituents and for potentially harmful biological content. These data will identify any risks to health of the consumers, need for remedial measures such as well disinfection and, in addition, the hydrochemical analyses may offer an insight into natural groundwater circulation patterns which may have development implications. The laboratory would also provide services to aid surface water development and to quantify pollution problems, which are a growing concern in The Gambia.

II Major Elements

- Specification, procurement and installation of all additional analytical equipment required by the DWR Yundum laboratory.
- Installation of a water supply system at the laboratory.
- Establish system for regular purchasing of reagents and other consumables.
- Formulation and introduction of proper analytical procedures, including quality control.
- Formulation and initiation of a bacteriological monitoring programme of wells.
- Execution of disinfection trials of polluted wells.
- General advice to The Gambian authorities on groundwater quality protection.
- Provision of computer hardware and software for the laboratory.
- Training of local staff in analytical procedures, and interpretation and reporting of results.

III Project Strategy

1. Who are the people and/or institutions who would benefit in the first instance from the project outputs and activities?

In the first instance the main beneficiary would be the DWR, whose existing laboratory would be upgraded to capability of providing all the analytical services required and a reasonable throughput of samples each year. The benefits would be quickly transmitted to the whole water sector of The Gambia, by providing an efficient analytical service in the country, that all bona fide agencies could use.

2 Target Beneficiaries?

The target beneficiaries would be much of the population of The Gambia. With better analytical services, there would be a higher probability that potable water supplies, particularly those of rural communities, are safe from the point of view of health.

3 Implementation arrangements for the project

The project would be carried out in conjunction with the Water Quality Control Division, which runs the DWR laboratory. It would provide the services of a consultant/chief chemist, who would be resident in The Gambia for the duration of the project. He would organise the procurement of equipment and consumables, advise on the installation of all additional facilities in the existing laboratory, demonstrate operational procedures, advise on groundwater quality protection and organise training of local staff.

4 Alternative implementation strategies

The possibility of combining this project with other projects proposed as a result of the hydrological assessment, was considered and it may be practicable. However, it was decided to keep this project separate for the time being, because:

- it makes a convenient package, which on its own has a greater change of securing external financing;

- it is aimed at correcting the major deficiency of the groundwater sector; combining it with a less important project might delay its implementation.

IV Host Country Commitment

1 Counterpart support

The current staff of the laboratory is under-utilised, because other constraints limit the level of analytical activities. Consequently it is not proposed to increase local staff levels, at least initially.

2 Legal arrangements and future staffing

The legal arrangements between The Gambian authorities and the financing agency cannot be specified, as the latter, which is not known at present is likely to have its own rules on this subject.

The private sector offers limited opportunities in hydrochemical work in The Gambia and provided that reasonable pay and conditions are offered to specialist personnel, it should be possible to maintain the required staff levels at the laboratory.

V Risks

The project is one of a group of national and regional projects proposed as a result of the Hydrological Assessment of West African Countries. The planning of all the projects will have to be carefully co-ordinated to ensure that delays in starting or late delivery of outputs from one project do not lead to delays in starting or the execution of other complementary projects.

In this particular project, there is a risk that the process of upgrading of the laboratory will disrupt its normal activities; however, currently its throughput is so low, that even if this happens, it will be of minor significance.

VI Inputs

1 Outline of Inputs

The project would be run within the DWR over a period of 3 years, with the full-time participation of the consultant/chief chemist. The Department would initially maintain the present level of technical staff and possibly increase this in the second or third year. All counterpart staff would receive on-the-job training and two graduates would be sent on short courses overseas (3 months or less each).

The project would install a water supply system for the laboratory, procure all the required equipment and materials, and set up an efficient operational, quality control and reporting system. The equipment would include that used for analytical measurements as well as a computer centre for processing and presentation of the results.

DWR would maintain the present level of staff at the laboratory for the first year and possibly increase it in the future. Some of the graduates would be sent for training overseas. Other graduate and technician level staff might be able to take advantage of the regional training project, REG-2, also proposed as a result of the Hydrological Assessment project.

2 Skeleton Budget

Personnel

Post	Duration (months)	Rate (US$/month)	Amount (US$)
Consultant/chief chemist	36	20 000	720 000
Subsistence			90 000
Travel			6 000
Sub-total			816 000

Training

A small budget of US$ 16 000 has been allowed for overseas training, most training will be conducted on-the-job by the consultant.

Equipment

Item	Amount (US$)
Peripherals for atomic absorption and gas chromatography; BOD and COD equipment, incubator and sundry other	60 000
Installation of a water supply system (borehole, electrical pump, storage, piping)	40 000
Transport (4-WD pick-up)	25 000
Reagents and other comsumables (US$ 5000/year)	15 000
Books and periodicals (US$ 1 500/year)	1 500
Computer hardware and software	6 000
Photocopier	5 000
Sub-total	152 500

TOTAL	984 500

3 Policy Issues

This project is not considered to give rise to any policy issues.

Appendix A - International Personnel

1 Qualifications and Duties

Consultant/Chief Chemist

The candidate for this post should have a degree in chemistry or chemical engineering from a recognised university and at least 10 years' relevant experience including:

- hydrochemical analyses;
- bacterial sampling and analyses;
- water work in tropical countries;
- work in Africa.

Knowledge of hydrochemistry of groundwater would be an advantage and a good command of the English language an absolute requirement.

The main duties of the Chief Chemist would be:

- specification and procurement of equipment;

- specification and organisation of the supplies of consumables;

- formulation of proper analytical procedures, including quality control;

- advice on bacteriological contamination of wells and the required remedial measures;

- general advice of groundwater quality protection;

- training of the local laboratory staff.

APPENDIX C

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BIBLIOGRAPHY

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APPENDIX D

LONG TERM RAINFALL

APPENDIX D

LONGTERM RAINFALL

D1 Longterm Rainfall Records

The Gambia has two raingauges whose records can be used to study long-term variations in rainfall. These are Banjul Marina, which started in 1886, and Georgetown, which started in 1908. Unfortunately neither of them can be used directly. In the case of Banjul Marina the record ends in 1956 however there is an overlap of 13 years with another Banjul station, Half-Die, which started in 1943 (there is one missing year in the early part of the record). The Georgetown record has a gap from 1933 to 1946. There are other stations which can be used for quality control for the later part of the series. These are Yundum airport (opened 1946), Kerewan (opened 1931 but with several missing years from 1961 to 1973) and Basse (opened 1942 but with four years missing from 1968 to 1971).

D2 Quality Control

The Banjul record was completed by adding the necessary years of the Banjul Half-Die record to the end of the Banjul Marina data with an allowance for the difference in total for the period of overlap. All the other records, including Georgetown, were infilled for the period 1931 to 1990. The infilling was done using the following formula:

$$\hat{R}_{sy} = \frac{\bar{R}_s \times \bar{R}_y}{\bar{\bar{R}}}$$

where:

$\hat{R}_{sy}$=infilled value for year y and station s

$\bar{R}_s$=average for years 1931-90 for station s

$\bar{R}_y$=average for all stations for year y

$\bar{\bar{R}}$=average for all stations for all years

The method was used iteratively since as each new value was calculated the totals and the means also changed. It was continued until there were no significant changes in the calculated values between each iteration.

Figure D.1 is a double-mass plot of Banjul versus Georgetown from 1908 to 1990. Apart from a slight kink in the early 1920's the relationship is almost linear suggesting that the two records are of good quality and that the method used for extending the Banjul record is valid. The next six graphs

(Figures D.2 to D.7) show the relationship for each station against the average of all the stations. The only station which shows any significant deviation from linearity is Kerewan where the gradient changes around 1950; there is no recorded reason for this change.

The final two figures (Figures D.8 and D.9) are perhaps the most interesting. These show the annual rainfall totals for the Banjul and Georgetown for the whole period of their record. It also shows the averages for each 30 year period. On the assumption that the previous 30 years give a good indication of the average rainfall at a station this shows that in both cases the average was more or less constant until the mid 1960s but that after that there has been a marked decline. In the case of Banjul the 30-year average was around 1180 mm per year and then has continued to fall to 924 mm in 1990. At Georgetown there is a similar trend from 1000 mm per year down to 789 mm.

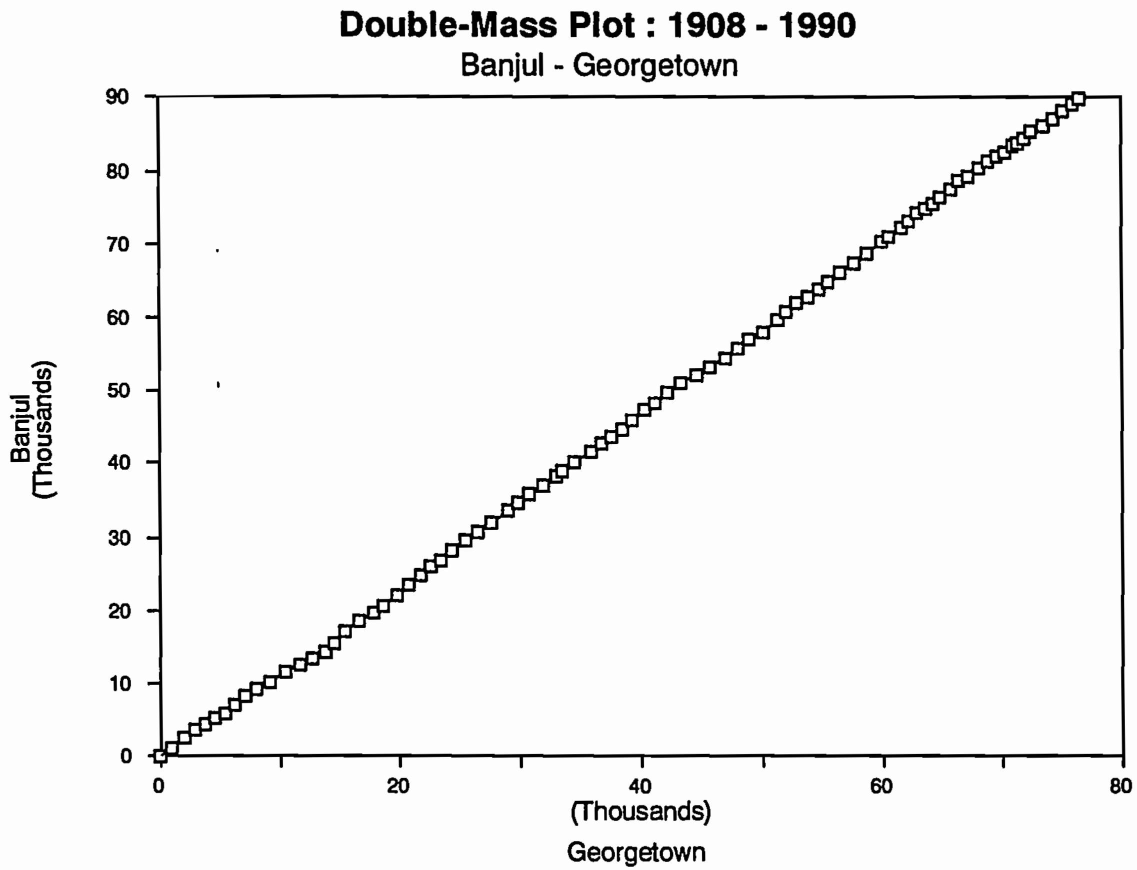
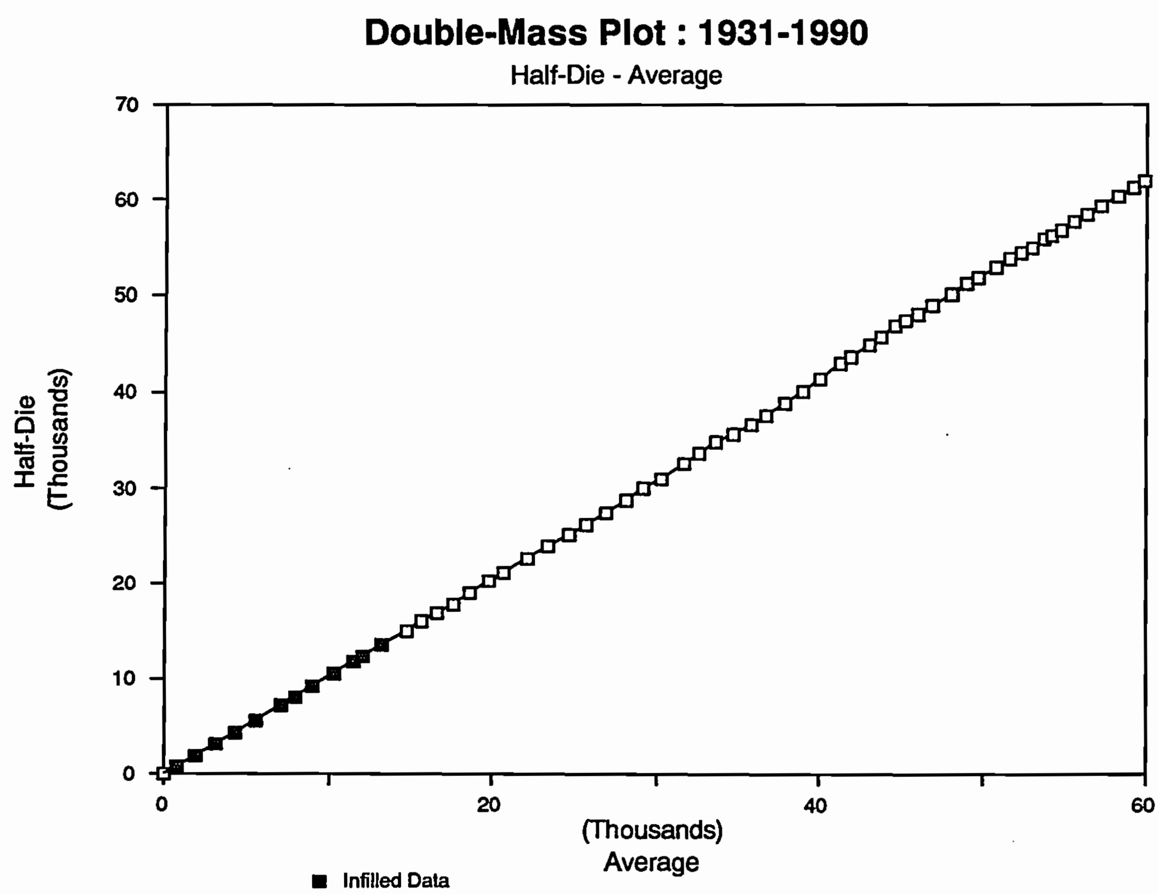

Double-Mass Plot : 1908 - 1990
Banjul - Georgetown
Banjul
(Thousands)
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
(Thousands)
Georgetown

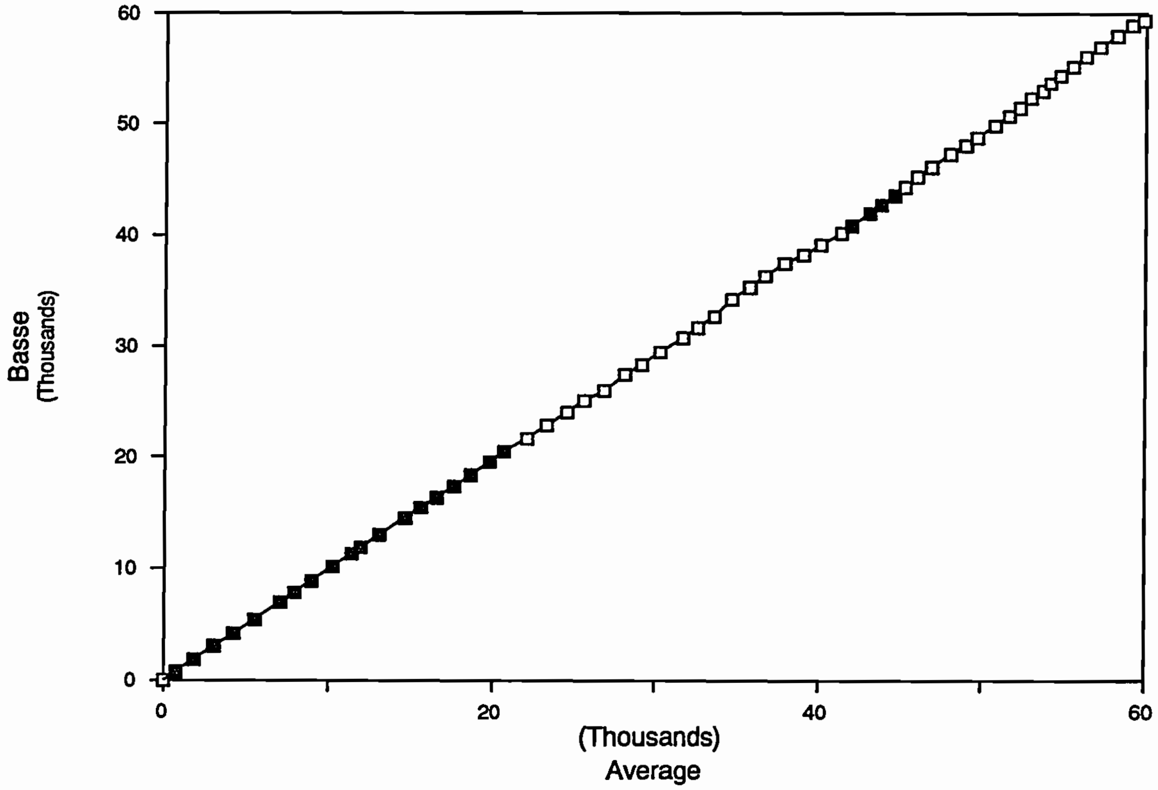
Figure D1


Double-Mass Plot : 1931-1990
Banjul - Average
70
60
50
40
30
20
10
0
Banjul
(Thousands)
0
20
40
60
(Thousands)
Average


Double-Mass Plot : 1931-1990
Half-Die - Average
70
60
50
40
30
20
10
0
Half-Die
(Thousands)
0
20
40
60
(Thousands)
Average
Infilled Data

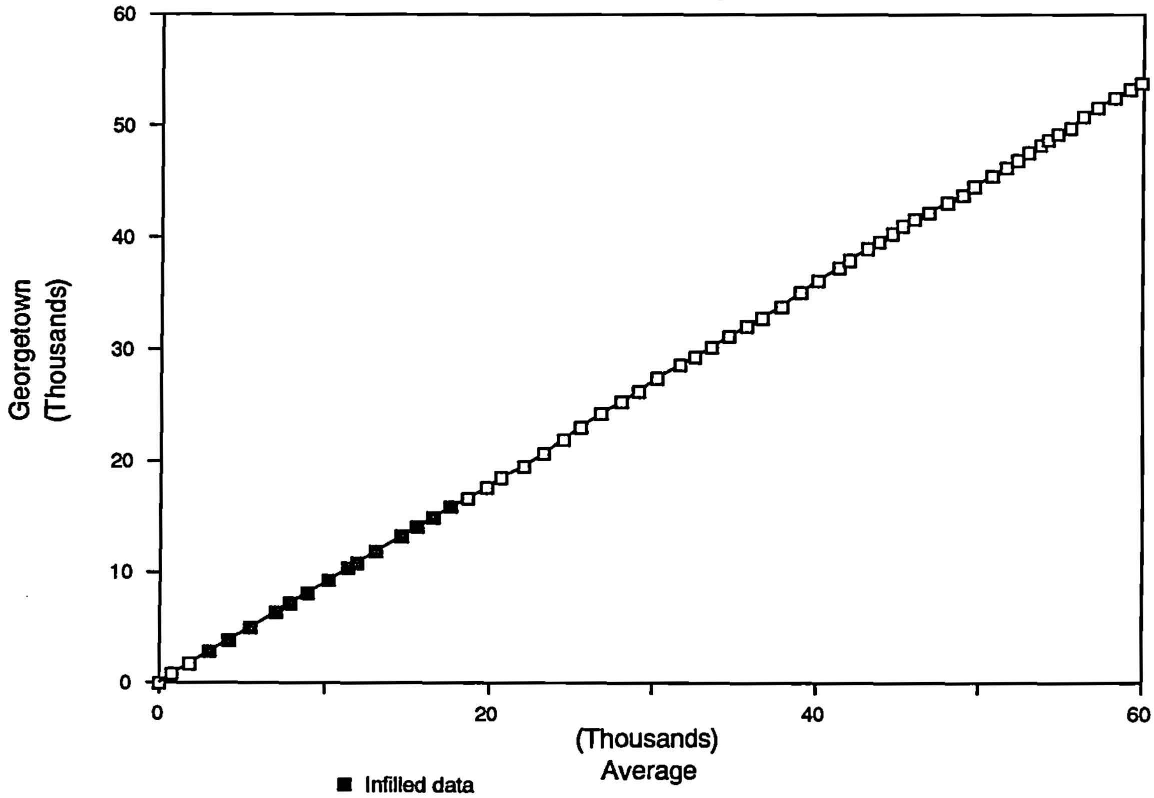
Double-Mass Plot : 1931-1990

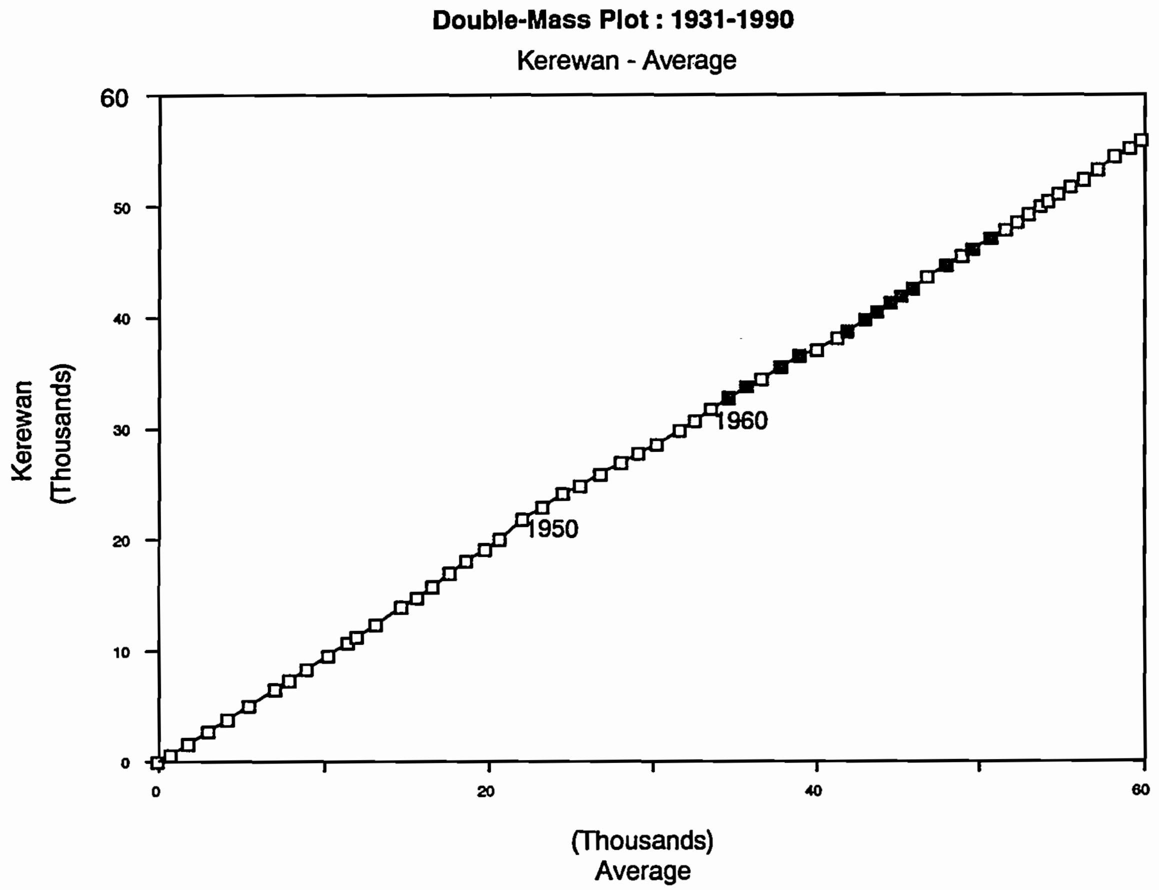
Basse - Average

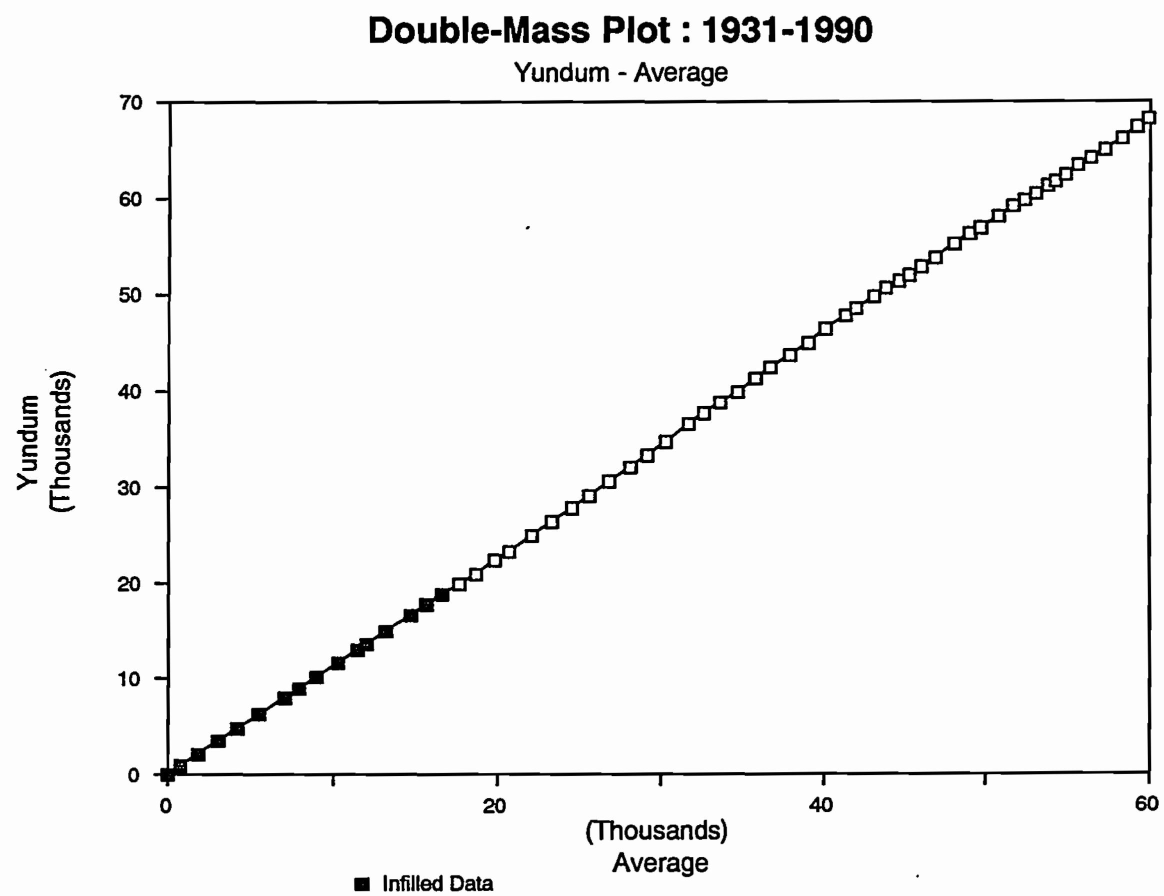


Double-Mass Plot : 1931-1990

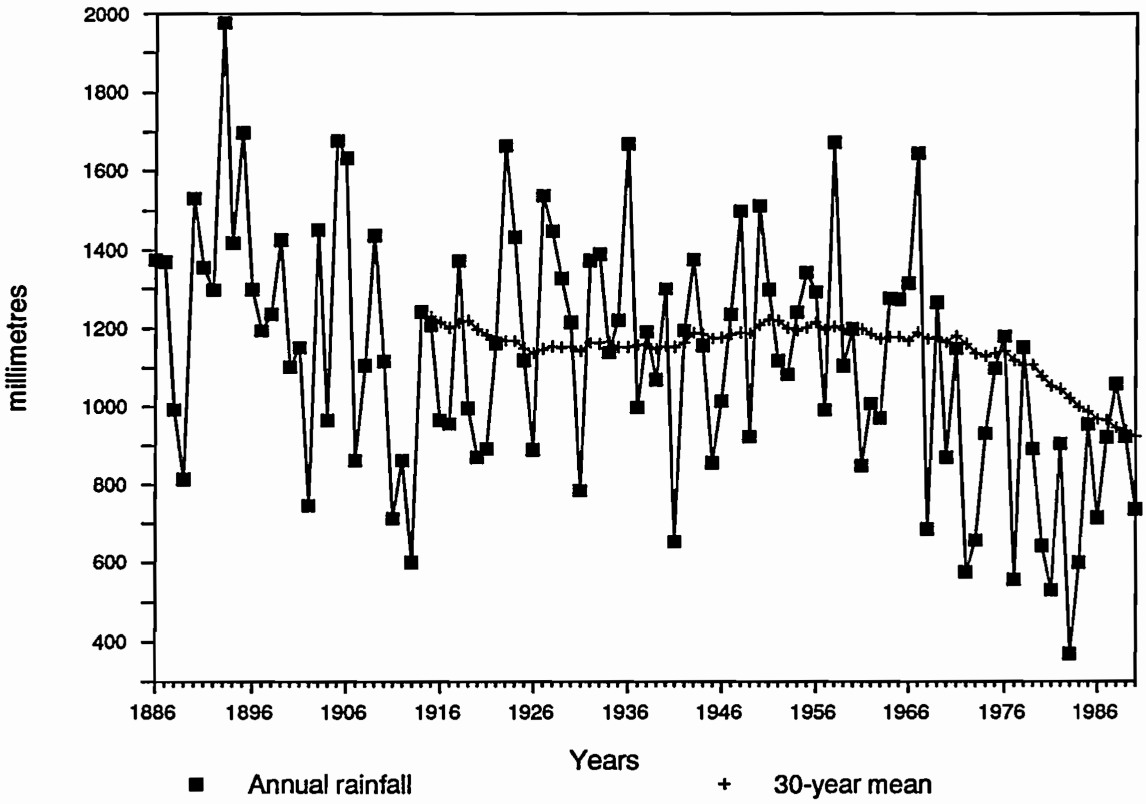
Georgetown - Average



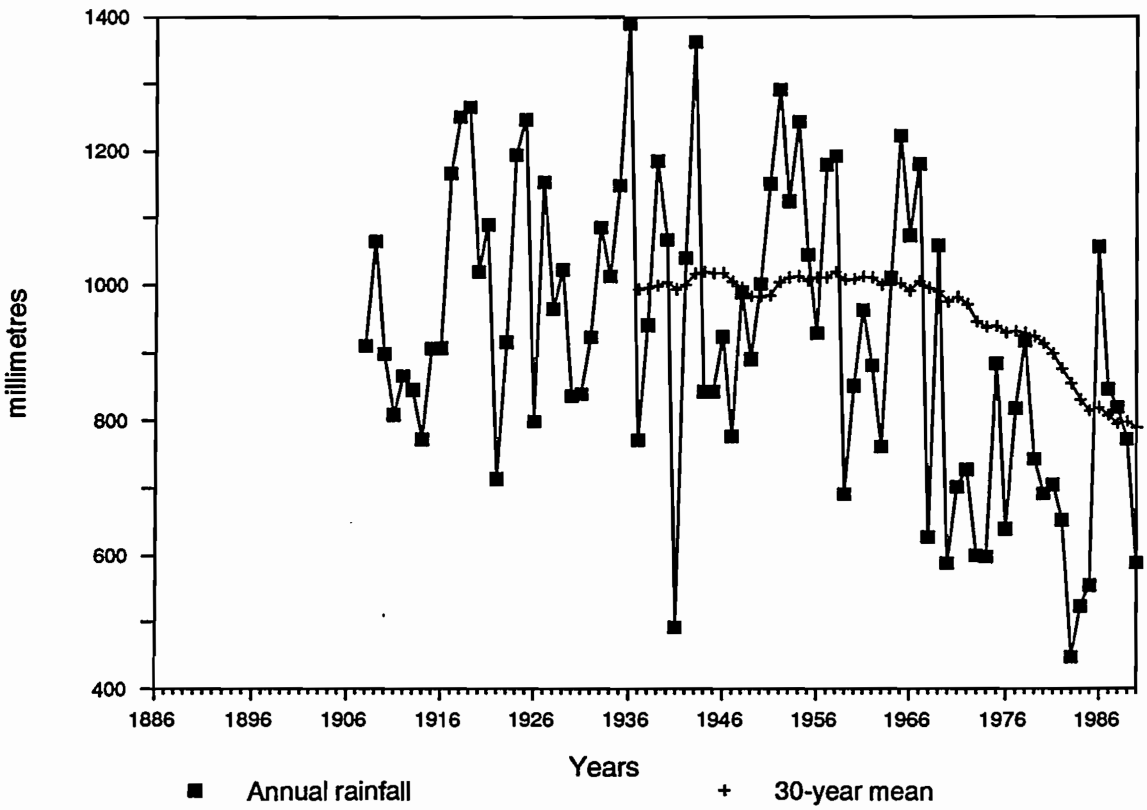

Double-Mass Plot : 1931-1990
Kerewan - Average
Kerewan (Thousands)
(Thousands) Average
1950
1960
0
10
20
30
40
50
60


Double-Mass Plot : 1931-1990
Yundum - Average
Yundum (Thousands)
(Thousands) Average
Infilled Data
0
10
20
30
40
50
60
70

Rainfall - Banjul : 1886-1990



Rainfall - Georgetown : 1908-1990



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APPENDIX E

HYDROMETRIC STATION HISTORIES

APPENDIX E

HYDROMETRIC STATION HISTORIES

River Gambia, Banjul

The first station was set up 9 November 1970. A type Ott R16 water level recorder was installed at the station on 20 December 1978 by the Department of Hydrometeorlogical Services (now Department of Water Resources). The station is placed on the left side of a bridge leading to berths in the docks area of Banjul

Water levels in the dry season do not change appreciably from those in the rainy season which is not surprising as the station is at the mouth of the estuary and therefore effectively measures sea levels and tidal changes. The tidal range is about 2.0 m. The station is a few metres away from the tidal recorder of the Banjul Port Authority which has been read since 1953.

Jurunkumani Bolon, Jibanack

The station is few metres upstream of a culvert at kilometre 100. The staff gauge was installed on 11 September 1976. No water level recorder has been installed. Twenty flow gaugings have been carried out dating from before 1974 up to 1981. The staff gauge was re-established in April 1990 by the Department of Water Resources.

Bintang Bolon, Brumen Bridge

A type Ott R16 water level recorder was installed at the station in October 1973 by the Gambia River Basin Project. The station is fixed to the bridge on the Banjul-Mansa Konko road one kilometre from the village of Kalagi. The station is fixed to the second column of the bridge on the right bank.

Water levels in the dry season do not change appreciably from those in the rainy season. The river is tidal at this station.

River Gambia, Tendaba

An Ott type X water level recorder was installed near the GPMB depot on 5 January 1978. It is on the left bank of the Gambia about 100 km from the estuary to the right of the village of Kwinella. The staff gauges were fixed to a wharf and were repaired twice in 1979. The station was resited in March 1979 with the same recorder. It was later replaced by a type R16 water level recorder on 28 August 1979. There are no records from October 1983 onwards. The station was rebuilt by the USAID/OMVG project in May 1991.

There are no appreciable seasonable changes. The river is tidal at this station and the tidal range is about 2.0 m.

River Gambia, Balingho

An Ott type 16 water level recorder was installed in November 1970 by the Gambia River Basin Project. The station is on the right bank of the Gambia close to the village of Balingho between Devil Point and the ferry on the Trans-Gambia Highway. Initially the water level recorder was to one twentieth scale and rotated once a fortnight. On 5 December 1970 the scale was changed to one tenth and the speed was changed to once per week. The station was resited on 23 March 1979 and was replaced by an Ott type X water level recorder by the Department of Hydrometeorlogical Services (now Department of Water Resources). The recorder was damaged in August 1986 and was no longer capable of providing data. The station was rebuilt and equipped with a Stevens water level recorder by the OMVG/USAID project in May 1991.

There are no appreciable seasonable changes. The river is tidal at this station and the tidal range is about 1.5 m.

Sofaniama Bolon, Pakaliba

An Ott type R16 water level recorder was installed at the station in October 1973 by Howard Humphreys and Sons. On 26 August 1975 the station was resited and an Ott type X water level recorder was installed by the Department of Hydrometeorlogical Services (now Department of Water Resources). The station is upstream of a bridge on the Banjul-Basse road near to the village of Pakaliba. It is about 180 kilometres from the estuary.

The station is on a tributary of the River Gambia. The water is fresh in the rainy season and salty in the dry season. There are however no appreciable seasonal changes in level. The tidal range is about 1 m.

River Gambia, Kaur

An Ott type 16 water level recorder was installed in November 1970 by the Gambia River Basin Project fixed to a wooden quay. The station was resited on 4 March 1979 and was replaced by an Ott type X water level recorder by the Department of Hydrometeorlogical Services (now Department of Water Resources). The new station was fixed to a concrete wharf. The station was rebuilt and equipped with a Stevens water level recorder by the OMVG/USAID project in May 1991.

There is some increase in level at this station during the rainy season.

Nianija Bolon, Charmen

An Ott type X water level recorder was installed on 23 March 1977 by the Department of Hydrometeorlogical Services (now Department of Water Resources). The station is the Njau-Charmen road bridge some 200 km from the mouth of the Gambia.

There are no appreciable seasonal level changes. The tidal range is about 1 m.

River Gambia, Kuntaur

An Ott type 16 water level recorder was installed in December 1970 by the Gambia River Basin Project. It was fixed onto a former wharf. In 1973 it was re-installed after a fire damaged the structure. On 4 March 1979 it was replaced by an Ott type X water level recorder by the Department of Hydrometeorlogical Services (now Department of Water Resources). The old wharf had disappeared and the new station is a few metres upstream. The station was rehabilitated and equipped with a Stevens water level recorder by the OMVG/USAID project in May 1991.

There are no appreciable seasonal level changes. The tidal range is about 1.5 m.

Jahally Canal, Jahally

An Ott type R16 water level recorder was installed on 23 March 1977 by the Department of Hydrometeorlogical Services (now Department of Water Resources). The station was rehabilitated and equipped with a Stevens water level recorder by the OMVG/USAID project in May 1991.

The tidal range is about 1.3 m.

Patcharr Bolon, Patcharr I

An Ott type R16 water level recorder was installed in August 1977 by the Department of Hydrometeorlogical Services (now Department of Water Resources). No satisfactory records could be obtained from this station because the height of the recorder was too short and the recorder could not function properly. No data at all has been received since May 1985.

The tidal range is about 1 m.

Patcharr Bolon, Patcharr II

An Ott type R16 water level recorder was installed in August 1977 by the Department of Hydrometeorlogical Services (now Department of Water Resources). Little data was available for this station due to access difficulties.

The tidal range is about 1 m.

River Gambia, Georgetown

An Ott type 16 water level recorder was installed in December 1970 by the Gambia River Basin Project. The station was resited on 1 May 1977 and was replaced by an Ott type X water level recorder by the Department of Hydrometeorlogical Services (now Department of Water Resources). This station is situated on the northern channel at a point where the river divides into two channels to form MacCarthy Island. A water level recorder was also built on the southern channel but this only functioned for a couple of months. The station was rebuilt and equipped with a Stevens water level recorder by the OMVG/USAID project in May 1991.

There are no appreciable seasonal changes. The tidal range is about 1.5 m.

River Gambia, Bansang

An Ott type 16 water level recorder was installed February 1976 by the Department of Hydrometeorlogical Services (now Department of Water Resources). The station was on the right bank close to the village of Bansang and about 310 kilometres from the mouth of the river. The station was resited on 24 March 1977 and was replaced by an Ott type X water level recorder. In January 1985 the water level recorder and staff gauge were struck by a ship and the staff gauge was tilted to 30° from the vertical. The station, including the water level recorder, was repaired on 14 August 1986. The station was rebuilt and equipped with a Stevens water level recorder by the OMVG/USAID project in May 1991.

Seasonal water level changes are noticeable. Higher levels up to 1.9 m occur during the rainy season. The tidal range is around 0.9 m. The flow is uni-directional in August and September only.

Sandugu, Sami Town Wharf/Sami Tenda

An Ott type 16 water level recorder was installed on 7 June 1977 by the Department of Hydrometeorlogical Services (now Department of Water Resources). I was about 360 kilometres from the mouth of the river some 200 m upstream of a disused road bridge. The station has been non-operational since 23 May 1984. The station was rebuilt and equipped with a Stevens water level recorder by the OMVG/USAID project in May 1991.

There are no appreciable seasonable variations in water level. The tidal range is about 1.7 m.

River Gambia, Basse

A type Ott R16 water level recorder was installed at the station in December 1970 by the Gambia River Basin Project. The first station was fixed to the Maurel Brothers wharf near to the village of Basse Santa Su about 405 kilometres from the mouth of the river. On 3 June 1977 the station was resited and a type Ott X water level recorder was installed by the Department of Hydrometeorlogical Services (now called the Department of Water Services). Silting of the inlet pipes from 1983 was the main cause of loss of data. The station has been non-operational since 10 January 1981. There was also a pneumatic level recorder installed at this site. This appears to have started operation at the same time as the other station but there is no indication of the period for which it provided data.

The station was rebuilt and equipped with a Stevens water level recorder by the OMVG/USAID project in May 1991.

Water levels vary greatly according to whether it is the rainy season or the dry season. Higher levels up to 1.9 m occur in the rainy season. Difference between high and low water is normally about 0.5m. Flow is uni-directional downstream during August and September only.

Prufu Bolon, Dampha Kunda

Staff gauges have been installed on several occasions at this site. The first was installed in September 1976. The station was situated upstream of a bridge on the Basse - Dampha Kunda road at two kilometres from the main river.

Prufu Bolon, Chamoi Bridge (formerly Chamoi Ferry)

The station was installed on this stream at the Chamoi Bridge on the Bassé-Fatoto road in 1973. The station was four kilometres from the main River Gambia. Observations were made from 16 September 1973 and nine gaugings were made between August 1973 and February 1974. There is no record of when this station ceased to operate.

Shima Bolon, Suduwol

This station is fixed to the Suduwol bridge on the Fatoto-Basse road, ten kilometres from the confluence of the Gambia. Staff gauges were installed in September 1973. It appears a further installation was made in August 1978. The station has not been operational since 31 October 1983. Nine flow gaugings were carried out from August 1983 to February 1974. No automatic level recorder has been used at this site.

River Gambia, Fatoto

A staff gauge was first installed at the station in 1972 by Howard Humphries and Sons. In January 1978 the station was resited and an Ott type X automatic water level recorder was installed by the Department of Hydrometeorlogical Services (now Department of Water Resources). The station is on the right bank of the Gambia near to the village of Fatoto and about 480 kilometres from the estuary. The station was rebuilt and equipped with a Stevens water level recorder by the OMVG/USAID project in May 1991.

Water levels at the station range widely between the rainy and dry seasons. The difference between the high and low tides is normally about 0.4 m. Water levels in the rainy season may rise up to 4.7 m from a low level of about 0.1m. Flow is uni-directional downstream during August and September only.

Massarin Ko Bolon, Kerr

At this site there is a single staff gauge only. It was installed in October 1976 but has not been operational since 1984.

River Benifet, Sanyang

This station was installed with only one staff gauge on 14 September 1976. a second gauge has since been added.

Allahein, Kartung

This station has an Ott type X water level recorder which was installed on 15 February 1985. There have been records since August 1985. There have been no gaugings at this site.

Allahein, Sifoe

This station, consisting of one gauge board, was installed in April 1990.

Allahein, Darsilami

This station with a single board was installed in April 1990 but was described as non-operational in June of the same year.

Bao Bolon, Illiassa

This station consisting of two staff gauges was installed in May 1990.

Miniminium Bolon, Jowara

This station consisting of two staff gauges was installed in May 1990.

River Gambia, Barra

This station was installed on the access bridge to the ferry in November 1970. The station was equipped with a water level recorder on 9 November 1970. Initially the rotation was twice a month but in December 1973 it was changed to once a week. The station was abandoned sometime before 1983.

River Gambia, Kemoto

This station was situated on the right bank of the Gambia near to the village of Kemoto at Mootah Point, opposite the confluence of the Tambana Bolon and the Miniminium Bolan, about 65 kilometres from the mouth of the river. The station was financed by the UNDP Gambia River Basin Project. It was installed on a wharf in 1970. A water level recorder was installed on 16 November 1970. It is not known for how long this station operated.

APPENDIX F

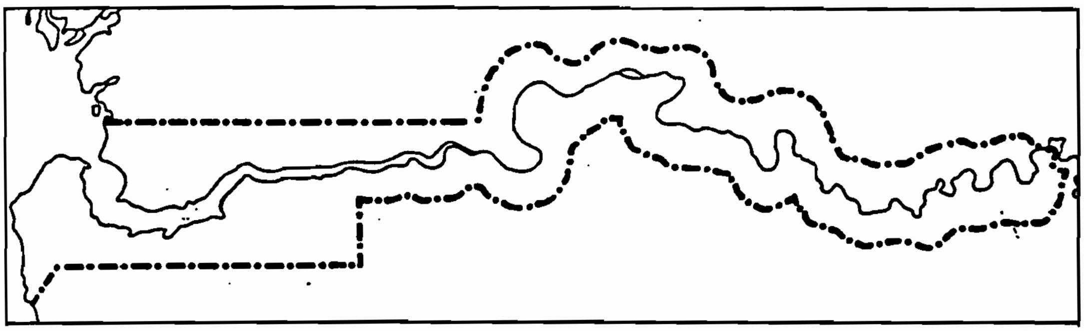
LIST OF MAPS AND AERIAL PHOTOGRAPHS

THE GOVERNMENT OF THE GAMBIA

THE REPUBLIC OF THE GAMBIA

MAPS & AERIAL PHOTOGRAPHS

PUBLICATIONS LIST 1990



PUBLISHED BY THE DEPT. OF LANDS & SURVEYS,
MINISTRY FOR LOCAL GOVT. & LANDS,
COTTON ST., BANJUL, THE GAMBIA

MAP PUBLICATION LIST 1990/1991

SMALL SCALES		PRICE	DATE OF PUBLICATION
1:250,000	The Gambia (East and West sheets) shows forest parks, administrative divisions and districts with major roads	D40.00	1980
1:250,000	Electoral Constituency Map of The Gambia (on diazo paper)	D27.50	1982
1:125,000	Soil Association Maps (4 sheets)	D25.50 (per sheet)	1976
1:125,000	Agricultural Lands Forested Lands, Rangelands and Land Use. USAID/ORS Project No.635-0203-01	D27.00 (per sheet)	1986
1:50,000	Photo Maps of The Gambia (Topographic series - 20 sheets, sheets 10 and 22 cost D35.00 each)	D17.50 (per sheet)	1976
1:50,000	Agricultural Lands, Forested Lands, Rangelands and Land Use. USAID/ORS Project No.635-0203-01	D27.50 (per sheet)	1986
MEDIUM SCALES			
1:25,000	Kombo Peninsula (8 sheets)	D26.00 (per sheet)	1977
1:25,000	Orthophoto Maps (contoured) of The Gambia (84 sheets)	D150.00 (per sheet)	1983
1:25,000	Electoral Constituency Map of Kombo St. Mary (on Diazo Print)	D25.00	1982
1:10,000	Coastal Strip (9 sheets). These maps cover the Atlantic Coast of the country eight Kilometres inland	D17.50 (per sheet)	1976
1:10,000	Orthophoto Maps (contoured) from Kaur to Georgetown (20 sheets)	D150.00 (per sheet)	1985
1:10,000	Land use Photomaps of The Gambia (526 sheets on Diazo Paper).	D25.00 (per sheet)	1985
1:10,000	Topomaps of urban growth centres series HZ 44.	D27.50 (per sheet)	1985
LARGE SCALES			
1:5,000	Electoral Constituency Map of Banjul (on Diazo Paper)	D25.00	1982
1:5,000	Banjul Street plan and public buildings (on Diazo Paper).	D25.00	1974

LARGE SCALES	(contd)	PRICE	DATE OF PUBLICATIC
1:1250	Cadastral Plans of Banjul, Farafenni, Bansang, Soma, Albreda and Juffereh (on Diazo Paper)	D27.50 (per sheet)	1983
1:2500	Plans on this scale cover principal Towns and Villages e.g Serrekunda Fajara/Bakau, Bakoteh, Kololi, Abuko Kotu Point, Kerr Serign N'Jagga, Bijilo, Wellingara, Sukuta, Busumballa, Brufut, Yundum, Brikama, Gunjur Mansakonko/Pakalinding, Kaur, Kuntaur, Georgetown and Basse (on Diazo Paper)	D27.50 (per print)	1983
1:1250	Cadastral plans of Kombo St. Mary Division, (123 sheets) Pakalinding and Soma (8 sheets).	D27.50 (per sheet)	1985
	Bansang (10 sheets). All on Diazo prints	D27.50 (per sheet)	

AERIAL PHOTOGRAPHY

1:10,000 1983	U.M.D.P	Banjul - 16° 30'W - 16° 50'W 13° 15'N - 13° 30'N
	U.M.D.P	Gunjur - 16°42'50"W - 16°47'45"W 13°08'50 N - 13°12'04"N
	U.M.D.P	Bansang Area - 14°40'20"W - 14°37'50"W 13°27'30"N - 13°23'50"N
	U.N.D.P	Basse Santa Su - 14°10'20"W - 13°13'20"W 13°17'10"N - 13°19740"N
	U.N.D.P	Farafenni and) Mansakonko) - 25km either side of main road linking the two towns.
1:50,000 1983	O.M.V.G/U.S.A.I.D	Black and white Area: Gambia River Basin (complete coverage)
1:50,000 1983	O.M.V.G	Coloured Area: Gambia River Basin
1:25,000 1982	O.M.V.G/U.S.A.I.D	Black and white (Area 1) Area: Kaur to Georgetown 14° 45'W - 14° 50'W 13° 30'N - 13° 43'N
1:12.000 1982	O.M.V.G/U.S.A.I.D	Black and White Area: Kaur to Georgetown (same extend as above)
1:25,000 1980	M.F.R.M.P	Complete coverage
1;25,000	D.O.S Air Photos	DOS Air photo Contract No. 124 (complete coverage)
1:10,000 1972	- do -	DOS Air photo contract No.124 from Kerewan to Sare Sofi (14° 30'W - 16°- 00'W)

..../2

1:25,000 Jan-Feb 1972	DOS Contract No.124	3Km and 10Km bands of photography covering Banjul and Camaloo and Sukuta to the Southern International boundary respectively. (Flown by Fairly Surveys Ltd. Maindenhead, Berks).
1:40,000	DOS Air Photos Series G504 Task No.227/69	From DOS Island to Koina (16°-30'W - 13° 30')
1:25,000 Dec. 1967 - Jan 1968	DOS Comtract No.98	The coastal Strip and major towns covers Yundum, Brikama, Gunjur and Kaur. (Flown by Hunting Surveys under DOS contract No.98)
1:12,500	- do -	The coastal strip and major towns covers Kuntaur, Georgetown and Basse. (Flown by Hunting Surveys under DOS contract No.98)
1:10,000 1964	DOS Contract No.78	DOS contract No.78 Kombo Peninsula Cape St. Mary, Barra and Essau (Flown by Hunting Surveys Ltd)
1:25,000 Dec.1964	- do -	DOS contract No.78 Kombo Peninsula 16° 15'W - 16° 50'W
OBLIQUE Dec.1964 1:700 (approx)		Banjul, Cape St. Mary, Barra, Essau - 16° 45'W
NORMAL Dec.1964		Banjul, Cape St. Mary, Barra and Essau - 16°30'W to 16°45'W
1:5,000 1960		DOS contract No.53 Banjul and Cape St. Mary. Photography flown both at high tide on panchromatic film and low

	tide on intra-ved film photography flown by Fairing Air Surveys.
1:22,000 1960	DOS contract No.53 Banjul and Cape St. Mary Photography flown both at high tide and low tide black and white.
1:20,000 Nov.1956	DOS contract No.23 from Kemoto Point to Georgetown (along side the River Gambia. (Flown by Aircraft operating Co. (Aerial Surveys) Ltd, Johaunesberg
1:32,000 1946	Basse Santa-Su to Fatoto (complete coverage) 16° 35'W to 16° 15'W
1:6,400	Kombo Peninsula 16° 35'W to 16°45'W

NOTE: Price per print of 9" x 9" (22.86 cm9 size for all Aerial Photo is D20 . 00

Purchase of some Photographs by certain users may be possible on application to the Director of Lands and Surveys, Cotton Street, Banjul The Gambia.

An additional 25% of cost of Publication is charged to cover parking/postage by Air.

APPROVED

BY THE DIRECTOR.

APPENDIX G

GROUNDWATER RECORDS

Vcode	Vname	District	Division	WFcode	Nr.	Use	Map	X	Y	Cnst.date	Firm	T.D.	D.T.W.	Pumps	Inst.date
1	BANJUL SOUTH	GREATER BAN	W E D	GUC	1	D	10	111	111	1.01.55	WHO?	*******	44.44	1	1.01.55
1006	KOLOLI	GREATER BAN	W E D	ITC	1		10			24.10.84		61.00	16.45		
1009	LATRI KUNDA	GREATER BAN	W E D	GUC	PN1		10	318	480	17.05.77		56.14	14.62		
1010	ABUKO	KOMBO NORTH	W E D	UNSO	1	L	10	981	321	11.12.78	POLS	59.00	10.30		
2101	BANJULUNDING	KOMBO NORTH	W E D	GUC	RS10		10	321	479	27.04.78		62.00	20.90		
2103	BIJILO	KOMBO NORTH	W E D	GUC	OB6		10	314	484	2.07.77		59.50	15.76		
2104	BRUFUT	KOMBO NORTH	W E D	GUC	OB7		10	310	480	12.07.77		63.50	11.47		
2106	BUSUMBALA	KOMBO NORTH	W E D	GUC	OB4		10	320	474	6.06.77		89.50	11.88		
2107	DARANKA	KOMBO NORTH	W E D	SSP	2/1	D		324	479	1.06.87	PRAK	54.00	13.36	1	1.06.87
2114	KEREWAN	KOMBO NORTH	W E D	GUC	OB5		10	324	470	26.06.77		71.50	9.10		
2114	KEREWAN	KOMBO NORTH	W E D	RWS	R11		10	313	484	21.12.68		60.00	19.35		
2123	MADINA SEY KUNDA	KOMBO NORTH	W E D	GUC	EX4		10	318	480	17.05.77		67.50	15.50		
2123	MADINA SEY KUNDA	KOMBO NORTH	W E D	GUC	OB1		10	316	480	21.05.77		71.50	14.96		
2126	MARIAMA KUNDA	KOMBO NORTH	W E D	GUC	OB2		10	313	478	31.05.77		83.50	10.35		
2129	OLD YUNDUM	KOMBO NORTH	W E D	GUC	EX3		10	318	477	22.04.77		82.50	14.45		
2129	OLD YUNDUM	KOMBO NORTH	W E D	RWS	R19		10	320	476	1.06.89		*******			
2132	SINCHU DULA BALIA	KOMBO NORTH	W E D	SSP	2/2	D		318	479	1.06.87	PRAK			1	1.06.87
2134	SUKUTA	KOMBO NORTH	W E D	GUC	A11		10	317	483	21.08.84		55.30	12.01		
2134	SUKUTA	KOMBO NORTH	W E D	GUC	A12		10	318	483	10.07.84		53.00	10.52		
2134	SUKUTA	KOMBO NORTH	W E D	GUC	EX2		10	315	481	7.04.77		59.50	13.61		
2134	SUKUTA	KOMBO NORTH	W E D	GUC	OB8		10	316	479	18.03.88		67.00	15.17		
2134	SUKUTA	KOMBO NORTH	W E D	GUC	PN7		10	315	483	11.10.77		36.15	4.75		
2134	SUKUTA	KOMBO NORTH	W E D	GUC	SS1		10	315	481	30.05.88		60.00	18.28		
2134	SUKUTA	KOMBO NORTH	W E D	GUC	SS2		10	315	480	19.05.88		65.00	19.60		
2134	SUKUTA	KOMBO NORTH	W E D	GUC	SS3		10	315	478	20.06.88		76.00	21.46		
2134	SUKUTA	KOMBO NORTH	W E D	GUC	SS4		10	314	481	20.06.88		60.00	18.61		
2134	SUKUTA	KOMBO NORTH	W E D	GUC	SS5		10	314	479	23.06.88		60.00	16.24		
2138	WELLINGARA	KOMBO NORTH	W E D	GUC	EX1		10	320	481	21.03.77		80.50	12.75		
2138	WELLINGARA	KOMBO NORTH	W E D	GUC	EX5		10	319	482	23.07.77		64.50	9.66		
2138	WELLINGARA	KOMBO NORTH	W E D	GUC	PN2		10	318	482	18.06.77		64.24	15.19		
2138	WELLINGARA	KOMBO NORTH	W E D	GUC	PN3		10	319	481	13.07.77		57.29	12.81		
2138	WELLINGARA	KOMBO NORTH	W E D	GUC	PN4		10	319	481	31.07.77		57.00	13.86		
2138	WELLINGARA	KOMBO NORTH	W E D	GUC	PN5		10	319	481	24.08.77		48.00	10.02		
2138	WELLINGARA	KOMBO NORTH	W E D	GUC	PN6		10	318	481	12.09.77		53.50	9.01		
2213	FARATO	KOMBO SOUTH	W E D	GUC	2		10			19.11.77		76.00	13.80		
2213	FARATO	KOMBO SOUTH	W E D	SSP	2/3	D		320	472	1.06.87	PRAK			1	1.06.87
2218	GUNJUR	KOMBO SOUTH	W E D	RWS	P2		10	320	469	31.03.86		63.00			
2221	JAMBUR	KOMBO SOUTH	W E D	GUC	OB3		10	315	474	8.06.77		84.50	11.25		
2221	JAMBUR	KOMBO SOUTH	W E D	SSP	2/4	D		315	473	1.06.87	PRAK			1	1.06.87
2233	NIMSAT	KOMBO SOUTH	W E D	SSP	2/7	D		310	468	1.06.87	PRAK			1	1.06.87
2234	NJOFELLEH	KOMBO SOUTH	W E D	SSP	2/6	D		314	462	1.06.87	PRAK			1	1.06.87
2246	SANYANG NDING	KOMBO SOUTH	W E D	RWS	R1		10	305	468	7.01.88		55.00	5.78		
2246	SANYANG NDING	KOMBO SOUTH	W E D	RWS	R2		10	305	468	19.01.88		29.00	6.02		
2246	SANYANG NDING	KOMBO SOUTH	W E D	RWS	R3		10	305	468	20.01.88		53.00	2.01		
2253	TUJERENG	KOMBO SOUTH	W E D	SSP	2/5	D		306	473	1.06.87	PRAK			1	1.06.87
2307	BRIKAMA	KOMBO CENTR	W E D	GUC	RS11		10	322	469	17.05.78		88.00	15.00		
2307	BRIKAMA	KOMBO CENTR	W E D	RWS	P1		10	320	469	24.10.85		59.20	17.34		
2322	KEMBUJAE	KOMBO CENTR	W E D	RWS	R5		10	325	469	2.07.88		51.00	15.64		
2322	KEMBUJAE	KOMBO CENTR	W E D	RWS	R6		10	325	469	8.07.88		52.00	14.40		
2322	KEMBUJAE	KOMBO CENTR	W E D	SSP	2/9	D		324	469	1.06.87	PRAK			1	1.06.87
2323	KITTI	KOMBO CENTR	W E D	SSP	2/8	D		319	463	1.06.87	PRAK			1	1.06.87
2338	PENJEM	KOMBO CENTR	W E D	RWS	R16		22	324	462	26.04.89		70.00	7.87		
2404	BONTO	KOMBO EAST	W E D	RWS	R10		10	331	470	6.12.88		67.00	6.40		
2404	BONTO	KOMBO EAST	W E D	RWS	R9		10	331	470	29.11.88		77.00	10.12		
2415	JIBORO KUTA	KOMBO EAST	W E D	RWS	R12		10	329	458	14.04.89		64.00	13.20		
2425	OMORTOH	KOMBO EAST	W E D	RWS	R17		22	335	457	28.04.89		94.00	15.46		
2428	SOHM	KOMBO EAST	W E D	RWS	R18		23	338	458	30.04.89		94.00	19.60		
2505	BREFET	FONI BREFET	W E D	SSP	2/10	D		350	464	1.06.87	PRAK			1	1.06.87
2603	BAJAKARR JOLA	FONI BIN. K	W E D	SSP	2/17	D		378	459	1.06.87	PRAK			1	1.06.87
2606	BATENDING KAJARA	FONI BIN. K	W E D	SSP	2/11	D		357	466	1.06.87	PRAK			1	1.06.87
2609	BINTANG	FONI BIN. K	W E D	SSP	2/14	D		368	465	1.06.87	PRAK			1	1.06.87
2610	BUKAFNEH	FONI BIN. K	W E D	SSP	2/12	D		360	458	1.06.87	PRAK			1	1.06.87
2633	KASSAGNE	FONI BIN. K	W E D	SSP	2/13	D		367	463	1.06.87	PRAK			1	1.06.87
2636	KAYIMU BINTANG	FONI BIN. K	W E D	UNSO	2	L	24	372	457	10.12.78	POLS	60.00	5.30		

Vcode	Vname	District	Division	WPcode	Nr.	Use	Map	X	Y	Cnst.date	Firm	T.D.	D.T.W.	Pumps	Inst.date
2644	SIBANOR	FONI BIN. K	W E D	UNSO	2		24	372	457	10.12.78		68.00	5.30		
2645	SIKON	FONI BIN. K	W E D	SSP	2/15	D		371	456	1.06.87	PRAK			1	1.06.87
2640	TAMBA KUNDA	FONI BIN. K	W E D	SSP	2/16	D		377	456	1.06.87	PRAK			1	1.06.87
2711	BWIAM	FONI KANSAL	W E D	GUC	7	DH	24	383	463	22.03.78	GUC	60.00	12.00	1	
2737	MONOM	FONI KANSAL	W E D	UNSO	3	L	24	382	463	2.01.79	POLS	55.00	21.54		
2740	SANAJORR JIRAMBA	FONI KANSAL	W E D	SSP	2/10	D		390	465	1.06.87	PRAK			1	1.06.87
2904	JARROL	FONI JARROL	W E D	SSP	2/20	D		400	464	1.06.87	PRAK			1	1.06.87
2904	JARROL	FONI JARROL	W E D	UNSO	4	L	25	409	462	16.01.79	POLS	56.00	25.60		
2907	KABOMBO	FONI JARROL	W E D	SSP	2/22	D		412	464	1.06.87	PRAK			1	1.06.87
2914	NEMA KUNKU	FONI JARROL	W E D	GUC	A17		10					60.00	14.00		
2914	NEMA KUNKU	FONI JARROL	W E D	RWS	R4		10			31.01.88		39.00	16.00		
2917	SANTANG KOTO /KEW	FONI JARROL	W E D	SSP	2/21	D		412	457	1.06.87	PRAK			1	1.06.87
2922	WASSADUNG	FONI JARROL	W E D	SSP	2/19	D		406	451	1.06.87	PRAK			1	1.06.87
3005	BURONG	KIANG WEST	L R D	SSP	2/25	D		372	473	1.06.87	PRAK			1	1.06.87
3006	DUMBUTU	KIANG WEST	L R D	SSP	2/33	D		409	476	1.06.87	PRAK			1	1.06.87
3007	JALI	KIANG WEST	L R D	SSP	2/29	D		395	476	1.06.87	PRAK			1	1.06.87
3010	JANNEH KUNDA	KIANG WEST	L R D	CARIT	BH12	DG		377	479	17.06.87	PRAK	64.00	8.50	1	17.06.87
3012	JIFFARONG	KIANG WEST	L R D	CARIT	BH10	DG		406	480	14.06.87	PRAK	98.00	23.00	1	15.06.87
3013	JISSAY	KIANG WEST	L R D	SSP	2/28	D		382	472	1.06.87	PRAK			1	1.06.87
3014	JOLI	KIANG WEST	L R D	SSP	2/27	D		381	481	1.06.87	PRAK			1	1.06.87
3016	KANTONG KUNDA	KIANG WEST	L R D	SSP	2/30	D		396	474	1.06.87	PRAK			1	1.06.87
3017	KARANTABA	KIANG WEST	L R D	GUC	8	DH	12	375	476	30.04.78	HHS	55.00	15.30	1	
3017	KARANTABA	KIANG WEST	L R D	HHS			12	375	476	30.04.78		55.00	15.30		
3019	KENEBA	KIANG WEST	L R D	ITC	2	L	12	390	474	30.11.84		90.00	21.00		
3019	KENEBA	KIANG WEST	L R D	UNSO	6	L	12	418	480	30.01.79	POLS	45.50	16.60		
3021	KULLI KUNDA	KIANG WEST	L R D	SSP	2/31	D		400	475	1.06.87	PRAK			1	1.06.87
3023	MANDINA	KIANG WEST	L R D	SSP	2/26	D		373	477	1.06.87	PRAK			1	1.06.87
3024	MANDOUR	KIANG WEST	L R D	CARIT	BH11	DG		384	476	16.06.87	PRAK	82.00	20.60	1	16.06.87
3025	MISSERA TENDA /KU	KIANG WEST	L R D	SSP	2/24	D		371	471	1.06.87	PRAK			1	1.06.87
3026	NIORO JATTABA	KIANG WEST	L R D	SSP	1/7	D	12	410	469	4.06.85	PRAK	95.00	16.60	1	4.06.85
3028	SANDENG	KIANG WEST	L R D	SSP	2/23	D		412	466	1.06.87	PRAK			1	1.06.87
3031	TABORANG KOTO	KIANG WEST	L R D	SSP	2/32	D		372	473	1.06.87	PRAK			1	1.06.87
3108	KWINALLA NYAKUNDA	KIANG CENTR	L R D	UNSO	5	L	13	418	480	31.01.79	POLS	45.50	16.60		
3109	KWINELLA SANSANKO	KIANG CENTR	L R D	SSP	2/34	D		413	481	1.06.87	PRAK			1	1.06.87
3109	KWINELLA SANSANKO	KIANG CENTR	L R D	UNSO	5	L	13	418	480	31.01.79	POLS	45.50	16.60		
3110	MADINA	KIANG CENTR	L R D	SSP	2/35	D		424	483	1.06.87	PRAK			1	1.06.87
3204	JOMARR	KIANG EAST	L R D	SSP	2/37	D		427	485	1.06.87	PRAK			1	1.06.87
3207	KOLIOR SULAH	KIANG EAST	L R D	SSP	2/36	D		427	482	1.06.87	PRAK			1	1.06.87
3211	NJOLFEN	KIANG EAST	L R D	SSP	2/38	D		429	477	1.06.87	PRAK			1	1.06.87
3302	DIGANTEH	JARRA WEST	L R D	SSP	2/40	D		442	479	1.06.87	PRAK			1	1.06.87
3304	JABISA	JARRA WEST	L R D	SSP	2/42	D		449	489	1.06.87	PRAK			1	1.06.87
3305	JINOI	JARRA WEST	L R D	SSP	2/39	D		439	491	1.06.87	PRAK			1	1.06.87
3306	JENOI AGRIC	JARRA WEST	L R D	HHS	8		14	439	490	30.04.78		81.00	13.80		
3308	KANI KUNDA	JARRA WEST	L R D	UNSO	19	L	14	443	485	30.06.79	POLS	98.00	24.80		
3311	MANSA KONKO	JARRA WEST	L R D	GUC	9	H					GUC			1	
3314	SANKWIA	JARRA WEST	L R D	HHS			14	443	488	30.10.86		*******	6.14		
3314	SANKWIA	JARRA WEST	L R D	SSP	2/61	D		443	488	1.06.87	PRAK			1	1.06.87
3318	SOMA	JARRA WEST	L R D	SSP	1/6	D	14	442	486	31.03.85	PRAK	66.00	12.70	1	7.07.85
3319	SUMBUNDU	JARRA WEST	L R D	SSP	2/41	D		442	480	1.06.87	PRAK			1	1.06.87
3413	JAPPINE TEMBETO	JARRA CENTR	L R D	SSP	2/43	D		454	484	1.06.87	PRAK			1	1.06.87
3504	BURENG	JARRA EAST	L R D	SSP	2/44	D		470	484	1.06.87	PRAK			1	1.06.87
3507	DASILAMI	JARRA EAST	L R D	UNSO	17	L	16	474	491	30.05.79	POLS	72.00	3.00		
4022	KANUMA	LOWER NUIMI	N B D	GUC	13		1	338	493	19.07.78		72.00	10.80		
4107	BAKALAR	UPPER NUIMI	N B D	UNSO	27		11	348	482	26.11.79		71.50	19.00		
4114	FASS CHAHO /FASS	UPPER NUIMI	N B D	RWS	P10		11								
4114	FASS CHAHO /FASS	UPPER NUIMI	N B D	RWS	R15		11	350	488	24.04.89		87.00	22.50		
4118	JUFUREH	UPPER NUIMI	N B D	GUC	12		11	350	475	7.07.78		74.00	16.30		
4135	MEDINA BAFULOTO /	UPPER NUIMI	N B D	RWS	R13		11	355	488	17.04.89		71.00	24.55		
4141	PAKAU NJOGU	UPPER NUIMI	N B D	UNSO	27	L	11	348	482	26.11.79	POLS	71.50	19.00		
4149	SARE MAMA	UPPER NUIMI	N B D	RWS	R14		11	353	484	10.04.89		45.65	24.81		
4203	BALLI MANDINKA	JOKADU	N B D	RWS	R7		3	379	500	3.08.88		40.00	9.40		
4203	BALLI MANDINKA	JOKADU	N B D	RWS	R8		3	379	500	1.08.88		42.00	10.21		
4210	DASILAMI	JOKADU	N B D	SSP	1/3	D	3	377	475	16.03.85	PRAK	42.00	13.90	1	5.08.85
4233	MUNYAGEN	JOKADU	N B D	UNSO	28	L	3	372	497	1.12.79	POLS	73.00	23.75		
4307	KEREWAN	LOWER BADDI	N B D	GUC	6		12	382	492	27.07.78		90.00	15.00		

Vcode	Vname	Pop1983	District	Division	WPcode	Dia	Use	X	Y	Cnst.date	T.D.	D.T.W.	Pumps
3001	BAJANA	321	KIANG WEST	L R D	SSP	2	D	404	471	9.02.86	24.20	19.60	2
3004	BATTENDING	293	KIANG WEST	L R D	SSP	2	D	408	482	27.05.85	26.70	23.50	2
3009	JAMARO	227	KIANG WEST	L R D	SSP	2	D	389	470	24.05.86	23.00	18.50	2
3010	JANNEH KUNDA	603	KIANG WEST	L R D	SSP	2	D	377	479	24.02.86	14.50	8.67	2
3011	JATTABA	261	KIANG WEST	L R D	SSP	2	D	410	467	1.04.85	16.50	10.50	2
3012	JIFFARONG	953	KIANG WEST	L R D	SSP	2	D	406	470	23.11.85	23.60	20.30	2
3015	JULA KUNDA	253	KIANG WEST	L R D	SSP	2	D	372	474	7.12.86	16.90	9.89	2
3024	MANDOUR	553	KIANG WEST	L R D	SSP	2	D	384	476	22.01.85	30.70	27.39	2
3032	TANKULARR	649	KIANG WEST	L R D	SSP	2	D	398	483	10.01.86	11.30	5.76	2
3101	BAMBAKO	275	KIANG CENTRA	L R D	SSP	2	D	417	482	31.07.85	17.00	11.59	2
3102	BUMARR	104	KIANG CENTRA	L R D	SSP	2	D	416	481	18.07.85	19.75	14.35	2
3104	JIROFF	588	KIANG CENTRA	L R D	SSP	2	D	423	483	20.09.85	20.00	16.60	2
3107	KUNDON NUMU KUNDA	147	KIANG CENTRA	L R D	SSP	2	D	422	484	20.08.85	21.40	17.10	2
3108	KWINALLA NYAKUNDA	759	KIANG CENTRA	L R D	SSP	2	D	413	481	15.08.85	30.60	25.60	2
3110	MADINA	471	KIANG CENTRA	L R D	SSP	2	D	417	476	26.12.85	27.60	22.72	2
3112	NEMA	894	KIANG CENTRA	L R D	SSP	2	D	418	483	13.08.85	21.80	16.50	2
3113	NEMA KUTA	319	KIANG CENTRA	L R D	SSP	2	D	425	483	6.11.85	20.50	15.60	2
3114	NIORO ANGALLEH	48	KIANG CENTRA	L R D	SSP	2	D	410	469	7.01.86	34.30	29.76	2
3116	SARE SAJO	128	KIANG CENTRA	L R D	SSP	2	D	425	478	13.01.86	31.90	27.15	2
3119	TABANANI	123	KIANG CENTRA	L R D	SSP	2	D	418	477	19.12.85	25.50	20.58	2
3120	TENDABA CAMP	132	KIANG CENTRA	L R D	SSP	2	D	412	486	19.06.85	17.80	7.45	2
3123	WUROKANG	301	KIANG CENTRA	L R D	SSP	2	D	412	478	11.07.85	19.00	14.70	2
3201	GENIERE	657	KIANG EAST	L R D	SSP	2	D	433	483	31.08.85	19.00	13.50	2
3203	JASOBO	212	KIANG EAST	L R D	SSP	2	D	427	488	15.11.85	9.60	4.50	2
3206	KOLIOR NYAMALA	717	KIANG EAST	L R D	SSP	2	D	427	484	1.09.85	14.75	7.20	2
3208	MADINA	328	KIANG EAST	L R D	SSP	2	D	418	473	8.02.86	43.20	40.01	2
3209	MASSENBEH	951	KIANG EAST	L R D	SSP	2	D	436	484	7.11.85	20.60	15.90	2
3214	SARE PATEH	83	KIANG EAST	L R D	SSP	2	D	428	482	14.11.85	21.00	18.20	2
3218	SARE ALKALI		KIANG EAST	L R D	SSP	2	D	435	478	13.11.85	45.80	40.83	2
3307	JIFFIN	541	JARRA WEST	L R D	SSP	2	D	436	484	11.12.85	13.80	10.00	2
3308	KANI KUNDA	991	JARRA WEST	L R D	SSP	2	D	443	487	25.10.85	14.80	10.25	2
3309	KARANTABA	1067	JARRA WEST	L R D	SSP	2	D	444	486	11.09.85	19.40	14.53	2
3310	KOHEL	48	JARRA WEST	L R D	SSP	2	D	439	482	20.11.85	26.60	21.75	2
3313	PAKALINDING	1816	JARRA WEST	L R D	SSP	2	D	440	488	24.10.85	16.75	3.60	2
3315	SARE SAIDY /DEMBA JE	91	JARRA WEST	L R D	SSP	2	D	438	478	19.11.85	31.40	26.41	2
3320	TONIATABA	1542	JARRA WEST	L R D	SSP	2	D	437	485	5.09.85	13.75	8.95	2
3401	BADUME KOTO	276	JARRA CENTRA	L R D	SSP	2	D	459	482	20.10.85	16.50	10.12	2
3403	BUIBA JALLOW KUNDA	88	JARRA CENTRA	L R D	SSP	2	D	450	484	1.11.85	14.70	10.57	2
3404	BUIBA MANDINKA	540	JARRA CENTRA	L R D	SSP	2	D	451	485	24.10.85	14.20	9.60	2
3415	KANUMA	190	JARRA CENTRA	L R D	SSP	2	D	456	484	22.10.85	15.00	10.97	2
3417	NANEKO	202	JARRA CENTRA	L R D	SSP	2	D	460	480	15.10.85	14.75	10.52	2
3420	SASITA	143	JARRA CENTRA	L R D	SSP	2	D	451	480	19.01.86	25.50	20.91	2
3501	BANTAN NYIMA	131	JARRA EAST	L R D	SSP	2	D	476	489	20.01.85	18.35	13.01	2
3502	BARO KUNDA	1846	JARRA EAST	L R D	SSP	2	D	471	491	20.09.85	9.80	5.23	2
3503	BUDAYEL	161	JARRA EAST	L R D	SSP	2	D	470	479	6.10.85	15.75	10.50	2
3509	DEMATI	179	JARRA EAST	L R D	SSP	2	D	471	480	27.09.85	23.80	19.65	2
3511	DONGOROBA	494	JARRA EAST	L R D	SSP	2	D	468	479	10.10.85	18.45	14.00	2
3512	DONGORONDING	46	JARRA EAST	L R D	SSP	2	D	476	488	25.01.86	21.90	16.15	2
3516	JASSONG	820	JARRA EAST	L R D	SSP	2	D	466	472	15.10.85	13.50	9.04	2
3517	MADINA	207	JARRA EAST	L R D	SSP	2	D	473	492	19.09.85	18.20	12.16	2
3521	PAKALIBA	1129	JARRA EAST	L R D	SSP	2	D	473	495	12.09.85	14.70	10.00	2
3522	SIBINDING	132	JARRA EAST	L R D	SSP	2	D	466	479	13.10.85	27.90	23.32	2
3525	SUTUKUNG	1110	JARRA EAST	L R D	SSP	2	D	471	489	5.10.85	13.00	7.90	2
3526	WELLINGARA /JUTA KD	19	JARRA EAST	L R D	SSP	2	D	470	481	23.09.85	17.70	13.30	2

D = Domestic

NB The table is like that of Boreholes

MONITORING.

NO.	Village Name	District	Division	Type	Elevation (masl)	Level/date 3/91	Level/date 6/91
1	BURENG (P1)	JARRA EAST	LRD	RWS	7.63		
2	DONGORO BA (P1)	JARRA EAST	LRD	A/AID	15.62		
3	FAKALI BA (P1)	JARRA EAST	LRD	RWS	12.89		
4	DIGANTEH (P1)	JARRA WEST	LRD	RWS	37.75	32.20	
5	JAPPENI (P1)	JARRA WEST	LRD	A/C	20.60	17.07	
6	JENOI (U60)	JARRA WEST	LRD	A/C	8.23	7.11	
7	JIFFIN (P1)	JARRA WEST	LRD	A/C	13.71	11.84	
8	JIFFIN (U55)	JARRA WEST	LRD	TRAD		12.15	
9	KANI KUNDA (U63)	JARRA WEST	LRD	A/C	15.78	12.24	
10	KARANTABA (U64)	JARRA WEST	LRD	RWS	16.11	14.11	
11	MANSAKONKO (U61)	JARRA WEST	LRD	RWS	25.61	24.06	
12	NANAKO (P1)	JARRA WEST	LRD	A/AID	12.04	7.89	
13	SANKWIA (U62)	JARRA WEST	LRD	A/C	12.73	10.02	
14	SOMA (U59)	JARRA WEST	LRD	TRAD	14.49	13.63	
15	TONIATABA (U56)	JARRA WEST	LRD	TRAD	8.93	7.98	
16	BAMBAKO (U34)	KIANG CENTRAL	LRD	TRAD	11.06	10.55	
17	BUMARI (U33)	KIANG CENTRAL	LRD	TRAD	17.48	16.53	
18	JIROFF (P1)	KIANG CENTRAL	LRD	A/AID	22.88	19.74	
19	JIROFF (U39)	KIANG CENTRAL	LRD	TRAD	20.51	17.66	
20	KWINELLA (P1)	KIANG CENTRAL	LRD	RWS	27.11	17.73	
21	MUNKUTALLA (U44)	KIANG EAST	LRD	RWS	37.55	36.12	
22	DUMBUTU (P1)	KIANG WEST	LRD	RWS	25.78	24.31	
23	FONKOI KUNDA (U45)	KIANG WEST	LRD	TRAD	24.58	22.87	
24	FULA KUNDA (U37)	KIANG WEST	LRD	A/C	16.91	15.30	
25	GENIERI (U53)	KIANG WEST	LRD	TRAD	18.69	12.90	
26	KARANTABA (P1)	KIANG WEST	LRD	RWS	12.12	12.09	
27	KENEBA (P1)	KIANG WEST	LRD	RWS	26.38	23.67	
28	KOLIOR (U47)	KIANG WEST	LRD	TRAD	11.87	11.10	
29	MANSASANSANG (U36)	KIANG WEST	LRD	A/C	11.23	9.61	
30	MASSEMBE (U52)	KIANG WEST	LRD	TRAD	21.85	19.97	
31	NUMU KUNDA (U38)	KIANG WEST	LRD	TRAD	18.43	16.32	
32	GALLEH MANDA (P1)	FULLADU WEST	MID	RWS	41.44		
33	JALLUBEH (P1)	FULLADU WEST	MID	A/C	40.60		
34	KAOLONG (P1)	FULLADU WEST	MID	RWS	24.73		
35	MAMUT FANA (P1)	FULLADU WEST	MID	RWS	14.78		
36	NJOBEN (P1)	FULLADU WEST	MID	RWS	21.58		
37	SANKULI KUNDA (P1)	FULLADU WEST	MID	GITEC	5.61		
38	SANTANTO BUBU (P1)	FULLADU WEST	MID	TRAD	30.50		
39	SARA MALANG (P1)	FULLADU WEST	MID	A/C	27.38		
40	SARA NGAI (P1)	FULLADU WEST	MID	GITEC	24.21		
41	SARA YORO GOLOBI (P1)	FULLADU WEST	MID	GITEC	26.65		
42	SARE SOFI (P1)	FULLADU WEST	MID	RWS	14.90		
43	SARUJA (P1)	FULLADU WEST	MID	GITEC	10.24		
44	SOLOLO FULLA (P1)	FULLADU WEST	MID	GITEC	16.15		
45	TABANANI (P1)	FULLADU WEST	MID	GITEC	9.72		
46	DANKUNKU (P1)	NIAMINA DANKUN.	MID	RWS	20.71		
47	JARRENG (P1)	NIAMINA EAST	MID	RWS	6.92		
48	KUDANG (P1)	NIAMINA EAST	MID	A/C	10.30		
49	KAI HAI (P1)	NIANI	MID	RWS	12.16		
50	KER JABEL (P1)	NIANI	MID	GITEC	13.08		
51	KER MAKA WOLLOF (P1)	NIANI	MID	RWS	20.21		
52	NIAKOI (P1)	NIANI	MID	GITEC	40.11		
53	SANDA (P1)	NIANI	MID	GITEC	13.33		
54	SUKUTA (P1)	NIANI	MID	GITEC	11.27		
55	WASSU (P1)	NIANI	MID	RWS	8.75		

NO.	Village Name	District	Division	Type	Elevation (masl)	Level/date 3/91	Level/date 6/91
56	CHANGAI (P1)	SAMI	MID	RWS	48.20		
57	JAMALI TAMSIR SECKA (P1)	SAMI	MID	GITEC	18.92		
58	KIBERI (P1)	SAMI	MID	RWS	39.27		
59	KUNTING (P1)	SAMI	MID	RWS	6.85		
60	SAMI PANCHONKI (P1)	SAMI	MID	RWS	31.64		
61	TABANANI (P1)	SAMI	MID	GITEC	33.36		
62	PANCHANG (P1)	UPPER SALOUM	MID	GITEC	9.10		
63	KER PATEH KORE (P1)	CENTRAL BADDIBU	NBD	GITEC	25.98		
64	NJABA KUNDA (P1)	CENTRAL BADDIBU	NBD	GITEC	25.30		
65	SALIKENE (P1)	CENTRAL BADDIBU	NBD	A/C	12.21		
66	BALI HALI HAWA (P1)	JOKADU	NBD	GITEC	14.20		
67	BANTANDING TORANKA (P1)	JOKADU	NBD	A/C	38.41		
68	JURUNKU (P1)	JOKADU	NBD	GITEC	32.22		
69	MUNYAGEN (P1)	JOKADU	NBD	GITEC	32.90		
70	BANI (P1)	LOWER BADDIBU	NBD	GITEC	15.51		
71	FASS NJAGA CHOI (P1)	LOWER NUIMI	NBD	GITEC	34.58		
72	FASS OMAR SAHOR (P1)	LOWER NUIMI	NBD	GITEC	36.92	24.58	
73	KANUMA (P1)	LOWER NUIMI	NBD	RWS	8.84	7.06	
74	KER WALLY (P1)	LOWER NUIMI	NBD	GITEC	35.07	21.18	
75	BALANGHAR (163) (P1)	LOWER SALOUM	NBD	GITEC	10.76		
76	BALANGHAR (164) (P1)	LOWER SALOUM	NBD	GITEC	15.46		
77	GIMBALA KER MALICK (P1)	LOWER SALOUM	NBD	GITEC	20.62		
78	CHAMEN (P1)	NIANIJA	NBD	RWS	13.29		
79	BALINGHO (P1)	UPPER BADDIBU	NBD	GITEC	7.02		
80	BAMBALI (P1)	UPPER BADDIBU	NBD	RWS	13.04		
81	BASSIK (P1)	UPPER BADDIBU	NBD	GITEC	8.44		
82	ILLIASSA (P1)	UPPER BADDIBU	NBD	GITEC	11.38		
83	JAMAL MBALLO (P1)	UPPER BADDIBU	NBD	GITEC	39.53		
84	KATCHANG (P1)	UPPER BADDIBU	NBD	GITEC	14.09		
85	KEUR AYIP (P1)	UPPER BADDIBU	NBD	GITEC	34.55		
86	NEMA (P1)	UPPER BADDIBU	NBD	BH	42.90		
87	NGAYEN SANJAL (P1)	UPPER BADDIBU	NBD	A/C	29.66		
88	NO KUNDA (P1)	UPPER BADDIBU	NBD	RWS	14.65		
89	SINCHU PALLEN (P1)	UPPER BADDIBU	NBD	GITEC	11.12		
90	KILLA (P1)	UPPER NUIMI	NBD	GITEC	17.47		
91	LAMIN (P1)	UPPER NUIMI	NBD	GITEC	17.89		
92	NDUGU KEBBEH (P1)	UPPER NUIMI	NBD	GITEC	26.32		
93	SARE MAMA (P1)	UPPER NUIMI	NBD	GITEC	36.21		
94	SIKA (P1)	UPPER NUIMI	NBD	GITEC	13.56		
95	JAGLE (P1)	UPPER SALOUM	NBD	GITEC	34.05		
96	BAKADAGI (P1)	FULLADU EAST	URD	A/C	12.76		
97	GAMBISSARA (P1)	FULLADU EAST	URD	RWS	23.03		
98	KANUBE (P1)	FULLADU EAST	URD	TRAD	12.08		
99	KULARI (P1)	FULLADU EAST	URD	A/C	14.38		
100	MANSAJANG (P1)	FULLADU EAST	URD	RWS	16.85		
101	NDIMBO (P1)	FULLADU EAST	URD	TRAD	27.88		
102	SABI (P1)	FULLADU EAST	URD	TRAD	34.87		
103	SANUNDING (P1)	FULLADU EAST	URD	A/C			
104	GAMBISSARA LAMOI (P1)	KANTORA	URD	TRAD	17.22		
105	GARAWOL (P1)	KANTORA	URD	RWS	13.90		
106	GARAWOL (P1)	KANTORA	URD	BH	19.95		
107	KANTALE KUNDA (P1)	KANTORA	URD	A/C	18.50		
108	KOINA (P1)	KANTORA	URD	RWS	14.31		
109	NYAMANARRI (P1)	KANTORA	URD	RWS	44.20		
110	DASILAMI (P1)	SANDU	URD	RWS	16.58		
111	KURAU KUTO (P1)	SANDU	URD	RWS	18.69		

NO.	Village Name	District	Division	Type	Elevation (masl)	Level/date 3/91	Level/date 6/91
112	MISSIRA (P1)	SANDU	URD	RWS	14.30		
113	BRIFU (P1)	WULI	URD	RWS	20.00		
114	CHAMOI BUNDA (P1)	WULI	URD	RWS	16.11		
115	FADIA KUNDA (P1)	WULI	URD	RWS	47.20		
116	KANAPE (P1)	WULI	URD	A/C	24.13		
117	NJRE KUNDA (P1)	WULI	URD	RWS	40.19		
118	PASSAMASI FULA (P1)	WULI	URD	RWS	19.23		
119	SUTUKOBER (P1)	WULI	URD	RWS	26.96		
120	SUTUKONDING (P1)	WULI	URD	RWS	18.11		
121	YOROBAWOL (P1)	WULI	URD	RWS	34.37		
122	SIBANOR (P1)	FONI BINTANG	WED	RWS	26.66	18.63	
123	ALLA KUNDA (P1)	FONI BONDALI	WED	RWS	37.33	21.75	
124	BREFET (P1)	FONI BREFET	WED	CARIT	16.59	14.60	
125	BULOCK (P1)	FONI BREFET	WED	CARIT	15.23	9.10	
126	KANJABINA (P1)	FONI BREFET	WED	RWS	33.12	21.30	
127	ARANKOLI KUNDA (P1)	FONI JARROL	WED	RWS	13.05	8.95	
128	KAMAMUDU (P1)	FONI JARROL	WED	RWS	14.84	9.45	
129	BEBANGHAR (P1)	FONI KANSALA	WED	RWS	18.41	10.46	
130	BRIKAMA METHODIST MISSION	KOMBO CENTRAL	WED	A/C	18.47	7.66	
131	JIBOROH KUTA (P1)	KOMBO CENTRAL	WED	RWS	24.64	17.25	
132	KITI MANJAGO (U)	KOMBO CENTRAL	WED	RWS			
133	MANDINA BA (U26)	KOMBO CENTRAL	WED	RWS	17.36	12.07	
134	MANDUAR (U19)	KOMBO CENTRAL	WED	RWS	21.44	12.03	
135	MARAKISSA (U18)	KOMBO CENTRAL	WED	RWS	17.76	11.75	
136	SIFOE (U)	KOMBO CENTRAL	WED	A/C	11.13	8.04	
137	SIFOE (UN)	KOMBO CENTRAL	WED	RWS	12.80	9.04	
138	KOLORO SCHOOL (U29)	KOMBO EAST	WED	RWS	26.07	17.91	
139	SOTOKOI (P1)	KOMBO EAST	WED	A/C	9.59	6.18	
140	TUNJINA (P1)	KOMBO EAST	WED	RWS	23.66	18.40	
141	BRUFUT (P1)	KOMBO NORTH	WED	RWS		9.04	
142	GUNJUR (P1)	KOMBO SOUTH	WED	RWS	16.69		
143	GUNJUR (U)	KOMBO SOUTH	WED	A/C	14.77	8.37	
144	KARTUNG (P1)	KOMBO SOUTH	WED	A/C	6.39	4.45	
145	KOLUKOCH (U)	KOMBO SOUTH	WED	TRAD	16.45	12.62	
146	TANJI (P1)	KOMBO SOUTH	WED	RWS	13.80	11.62	

Vcode	Vname	District	Division	WPcode	Nr.	Use	Map	X	Y	Cnst.date	Firm	T.D.	D.T.W.	Pumps	Inst.date
4429	NJABA KUNDA	CENTRAL BAD	N B D	RWS	P11		4								
4429	NJABA KUNDA	CENTRAL BAD	N B D	UNSO	26	L	4	401	500	31.10.79	POLS	76.00	32.08		
4525	DIPPA KUNDA NGOOR	UPPER BADDI	N B D	UNSO	24	L	6	447	499	26.09.79	POLS	82.00	26.10		
4529	FARAFENNI	UPPER BADDI	N B D	GUC	5		5	436	500	22.02.78		90.00	14.00		
4583	NGEYEN SANJAL	UPPER BADDI	N B D	SSP	1/4	D	6	452	503	11.02.85	PRAK	45.00	31.00	1	10.07.85
4618	YALLAL	UPPER BADDI	N B D	UNSO	25	L	5	424	499	26.10.79	POLS	72.00	32.60		
5028	KAUR WHARF TOWN	LOWER SALOU	M I D	GUC	10	H					CHIN			1	
5028	KAUR WHARF TOWN	LOWER SALOU	M I D	RWS	P4		6	465	514	30.11.86		67.00	2.32		
5159	NIORO EBRIMA WURI	UPPER SALOU	M I D	UNSO	22	L	7	494	525	30.06.79	POLS	74.00	14.16		
5304	BARAJALI TENDA	NIANI	M I D	UNSO	23	L	8	506	502	30.06.79	POLS	74.00	11.67		
5328	KASS WOLLOF	NIANI	M I D	SSP	8	D	8	507	523	28.02.85	PRAK	92.00	37.60	1	11.07.85
5339	KUNTAUR WHARF TOW	NIANI	M I D	RWS	P3		8	512	511	31.12.85		62.00	3.70		
5359	NJOBEN TUKULORR	NIANI	M I D	UNSO	21	L	8	504	524	30.06.79	POLS	64.00	31.36		
5401	BANNI	SAMI	M I D	SSP	1/5	D	9	528	498	28.02.85	PRAK	*******	14.56	1	14.07.85
5468	WELLINGARA OMAR J	SAMI	M I D	UNSO	20	L	9	544	506	30.06.79	POLS	78.00	34.68		
6503	BARO KUNDA	NIAMINA DAN	M I D	UNSC	17		16	474	491	30.05.79		72.00	3.00		
6506	DANKUNKU	NIAMINA DAN	M I D	UNSO	18	L	6	465	501	30.05.79	POLS	86.00	10.30		
6509	JAKOTO	NIAMINA DAN	M I D	RWS	P8		6	465	501	31.10.87		64.00	13.75		
6621	PINIA FULA KUNDA	NIAMINA WES	M I D	RWS	P7		6	470	498	30.09.87		63.00	35.04		
6621	PINIA FULA KUNDA	NIAMINA WES	M I D	RWS	P9		6	469	498	30.11.87		69.40	14.81		
6719	KUDANG	NIAMINA EAS	M I D	GUC	11	H					CHIN			1	
6724	MAMUD FANA	NIAMINA EAS	M I D	RWS	P5			487	503	30.08.86		81.00	18.16		
6727	MEDINA	NIAMINA EAS	M I D	UNSO	7										
6729	MISSRA TOBEN /SAR	NIAMINA EAS	M I D	UNSO	16	L		493	506	30.05.79	POLS	80.00	14.15		
6731	NJAI KUNDA	NIAMINA EAS	M I D	CARIT	BH6	DE		521	491	23.04.87	PRAK	66.20	19.20	1	23.04.87
6734	PATEH SAK	NIAMINA EAS	M I D	UNSO	16			493	506	30.05.79		80.00	14.15		
7227	JAR KUNDA	WULI	U R D	UNSO	14	L	20	587	490	7.05.79	POLS	80.00	29.72		
7241	MADINA NIANTANBA	WULI	U R D	UNSO	15	L	21	611	496	26.05.79	POLS	*******	39.50		
7256	SARE DEMBA	WULI	U R D	UNSO	13		19	572	486	6.04.79		96.00	19.70		
7261	SARE GUBU	WULI	U R D	UNSO	12		19	565	487	12.06.79		90.00	33.00		
7276	SUTUKOBA	WULI	U R D	SSP	1/1	D	20	606	493	6.03.85	PRAK	54.00	14.90	1	2.07.85
7280	TAIBATU	WULI	U R D	GUC	14		20	586	485	1.12.77		*******	26.70		
7336	SARE GUBU BASIRU	SANDU	U R D	UNSO	12	L	19	565	487	12.06.79	POLS	90.00	33.00		
7408	BANSANG HOSPITAL	FULLADU WES	M I D	GUC	15		17								
7456	KONKO FULA /SANKU	FULLADU WES	M I D	CARIT	BH9	DG		521	496	2.06.87	PRAK	67.00	18.00	1	2.06.87
7477	MURTABEH /JAMAGEN	FULLADU WES	M I D	CARIT	BH5	DG		520	491	22.04.87	PRAK	34.60	16.82	1	22.04.87
7486	NJOBEN	FULLADU WES	M I D	UNSO	21		8	504	524	30.06.79		64.00	31.36		
7502	SARE BABOU /TAIFA	FULLADU WES	M I D	CARIT	BH4	DG		511	489	21.04.67	PRAK	34.80	15.30	1	21.04.87
7508	SARE DEMBARU	FULLADU WES	M I D	CARIT	BH2	DG		560	471	15.04.87	PRAK	76.00	24.16	1	15.04.87
7509	SARE FALLY /KHAHC	FULLADU WES	M I D	CARIT	BH7	DG		519	491	23.04.87	PRAK	47.00	15.00	1	23.04.87
7514	SARE JABEL	FULLADU WES	M I D	UNSO	10	L		533	480	30.04.79	POLS	74.00	27.30		
7527	SARE NSAI	FULLADU WES	M I D	CARIT	BH1	DG		518	489	13.04.87	PRAK	35.00	17.90	1	13.04.87
7539	SARE WURING /CHEW	FULLADU WES	M I D	CARIT	BH8	DG		519	493	24.04.87	PRAK	59.00	8.30	1	24.04.87
7542	SARE YORRO TAKKO	FULLADU WES	M I D	CARIT	BH3	DG		515	487	16.04.87	PRAK	64.00	8.73	1	16.04.87
7544	SAPU AGRIC STATIO	FULLADU WES	M I D	SAPU	1		8								
7544	SAPU AGRIC STATIO	FULLADU WES	M I D	SAPU	2		8								
7544	SAPU AGRIC STATIO	FULLADU WES	M I D	SAPU	3		8								
7574	SOLOLO MANDINKA	FULLADU WES	M I D	ITC	3		17	537	485	28.02.85		85.00	10.70		
7596	Y.B.K AGRIC STATI	FULLADU WES	M I D	UNSO	11			526	492	30.04.79		83.00	16.53		
7597	YORO BERI KUNDA F	FULLADU WES	M I D	UNSO	11	L		526	492	30.04.79	POLS	83.00	16.53		
7608	BANICO KEKORD	FULLADU EAS	U R D	SSP	2/54	D		593	466	1.06.87	PRAK			1	1.06.87
7611	BASSE SANTO SU	FULLADU EAS	U R D	GUC	4		20	485	471	4.02.78		85.00	11.71		
7617	DAMPHA KUNDA	FULLADU EAS	U R D	EDF		D	20			30.10.90	DWR	84.10	8.55		
7621	DEMBA KUNDA KUTA	FULLADU EAS	U R D	SSP	2/48	D		579	465	1.06.87	PRAK			1	1.06.87
7625	DIABUGU ALPHA /SA	FULLADU EAS	U R D	SSP	2/57	D		610	477	1.06.87	PRAK			1	1.06.87
7627	DINGIRI	FULLADU EAS	U R D	SSP	2/67	D		602	470	1.06.87	PRAK			1	1.06.87
7628	FASS BAJON	FULLADU EAS	U R D	SSP	2/53	D		593	463	1.06.87	PRAK			1	1.06.87
7632	GAMBISSARA	FULLADU EAS	U R D	RWS	P6		19	475	463	30.11.86		76.00	16.62		
7635	GIROBA KUNDA	FULLADU EAS	U R D	SSP	2/49	D		588	470	1.06.87	PRAK			1	1.06.87
7645	KANUBE	FULLADU EAS	U R D	SSP	2/47	D		577	473	1.06.87	PRAK			1	1.06.87
7658	KULARI	FULLADU EAS	U R D	SSP	2/55	D		599	482	1.06.87	PRAK			1	1.06.87
7660	KULINTO YEL	FULLADU EAS	U R D	SSP	2/68	D		596	469	1.06.87	PRAK			1	1.06.87
7662	KUMBIJA	FULLADU EAS	U R D	SSP	2/50	D		589	466	1.06.87	PRAK			1	1.06.87
7671	MADINA SAMAKO	FULLADU EAS	U R D	SSP	2/65	D		607	471	1.06.87	PRAK			1	1.06.87
7676	MANKAMANG KUNDA /	FULLADU EAS	U R D	SSP	2/45	D		460	473	1.06.87	PRAK			1	1.06.87

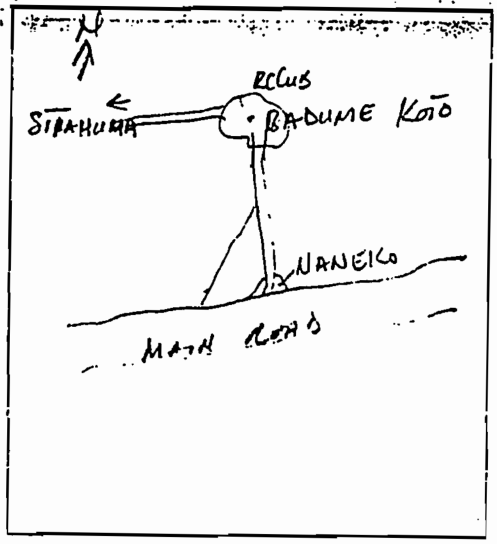
Vcode	Vname	District	Division	WPcode	Nr.	Use	Map	X	Y	Cnst.date	Firm	T.D.	D.T.W.	Pumps	Inst.date
7688	NUMUYEL	FULLADU EAS	U R D	EDF		D	20			3.11.90	DWR	86.10	9.10		
7690	PERAI	FULLADU EAS	U R D	SSP	2/56	D		605	479	1.06.87	PRAK			1	1.06.87
7692	SABI	FULLADU EAS	U R D	SSP	1/2	D	20	587	463	3.04.85	PRAK	31.31	14.97	1	5.07.85
7711	SARE DEMBA DARDOH	FULLADU EAS	U R D	UNSO	13	L	19	572	486	6.04.79	POLS	96.00	19.70		
7727	SARE PIRASU	FULLADU EAS	U R D	SSP	2/52	D		593	463	1.06.87	PRAK			1	1.06.87
7734	SARE TALATA	FULLADU EAS	U R D	SSP	2/46	D		570	471	1.06.87	PRAK			1	1.06.87
7762	TUBA TAFSIRU	FULLADU EAS	U R D	SSP	2/51	D		592	469	1.06.87	PRAK			1	1.06.87
7767	WELLINGARA KUBEH	FULLADU EAS	U R D	SSP	2/60	D		581	475	1.06.87	PRAK			1	1.06.87
7806	DAMPHA KUNDA	KANTORA	U R D	EDF		D	21			5.11.92	DWR	60.08	9.65		
7808	FATOTO	KANTORA	U R D	GUC	3		21	628	451	1.01.78		73.50	15.50		
7809	BADAFARO	KANTORA	U R D	SSP	2/63	D		628	481	1.06.87	PRAK			1	1.06.87
7811	BARAWOL	KANTORA	U R D	EDF		D	21			8.11.90	DWR	67.97	15.84		
7811	BARAWOL	KANTORA	U R D	HHS	2		21	615	482	12.01.86		*******	6.40		
7817	JAWO KUNDA	KANTORA	U R D	SSP	2/59	D		623	484	1.06.87	PRAK			1	1.06.87
7817	JAWO KUNDA	KANTORA	U R D	UNSO	6	L	21	624	485	3.08.79	POLS	80.00	7.68		
7821	KEBBEH KUNDA	KANTORA	U R D	UNSO	9	L	21	613	486	3.01.79	POLS	79.00	22.15		
7823	KOINA	KANTORA	U R D	EDF		D	21			11.11.90	DWR	53.70	15.84		
7823	KOINA	KANTORA	U R D	SSP	2/64	D		623	490	1.06.87	PRAK			1	1.06.87
7830	MADINA KUTA /LAIB	KANTORA	U R D	UNSO	15		21	611	496	26.05.79		*******	39.50		
7833	NYAMANARI	KANTORA	U R D	SSP	2/66	D		622	474	1.06.87	PRAK			1	1.06.87
7842	SONS KUNDA	KANTORA	U R D	SSP	2/62	D		625	479	1.06.87	PRAK			1	1.06.87
7844	SUDUWOL	KANTORA	U R D	SSP	2/58	D		611	478	1.06.87	PRAK			1	1.06.87

G1 DWR Site Appraisal and Well Completion Report

1 LOCATION

MAP 1:50,000

VILLAGE NAME: BADUME KOTO
LONGITUDE: 4593
DISTRICT: JARRA CENTRAL
LATITUDE: 4821
DIVISION: L.R.D.
ALTITUDE: APR. 8 M
DATE: 26/4/91



2 SOCIO ECONOMIC DATA

POPULATION
Census 1983 ..276..
Revised 1991 ....
Estimate ..500..
Nr of Compounds ..32..

LIVESTOCK
Cattle ..50..
Small livestock ..400..
Donkey ..25..
Horse ..2..

CULTURES (crops)
Rice yes
Groundnuts yes
Millet yes
Sorghum yes
Cotton No

VILLAGE AMENITIES
Hospital yes/no
Dispensary yes/no
School (type) No
Others No

ETHNICS
Mandingo 96 %
Wollof %
Fula %
Sarahuleh %
Jola %
Sere' %
+ Manjago 4 %

CRAFTSMEN
Byke mechanic None
Motor mechanic None
Blacksmith yes
Others None

PARTICIPATION : Not yet

ORGANISATION
Women committee y
Water committee
Social committee
Other committee y
VDC, Action A

GARDENING : yes
OTHER ACT.: No

3 WATER RESOURCES UNDER EXPLIOTATION

TRADITIONAL WELLS : 4
AREA COUNCIL WELLS : –

MODERN WELLS		Nr	USE	PUMP	PUMP TYPE
	RWS	None			
	SSP	None			
	GITEC	None			
	CARITAS	None			
Two wells Contaminated with Salt.	ACTION AID	4	Garden		
	ROTARY CLUB	1	Domestic	1	Moyle II

EQUIPPED BOREHOLES ..None
SPRINGS ..None

	SOURCE	EST.Y
IRRIGATION:	None	

ADDITIONAL WATER RESOURCES : River yes/no Y.K.
Brook yes/no Y.K.

4 SANITATION

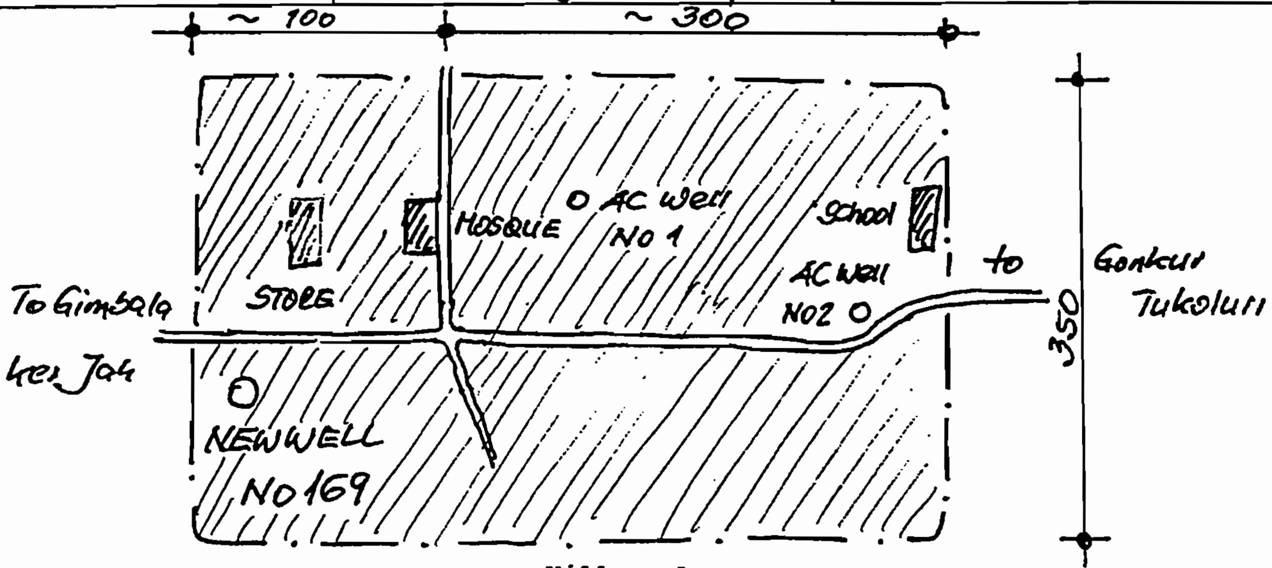
LATRINISATION (% of compounds) TYPE : VIP, PIT LINING, UNLINED PIT
Nr : 10

DATA COLLECTED BY : Kinteh Ceesay

GAMBIA: HAND DUG WELL CONSTRUCTION PROGRAMME

Village/Well Identification and Monitoring Record

Well No.: 169	Village: Genji Wollof	District: Lower Saloum



Village Layout

Village Area: ~ 14.0 ha

No of Compounds:	72	No of Inhabitants:	523

Planned No. of Handpumps: 2

Data of Existing Wells:

Well No.	Type/Constr. Date	Dia	Head Constr.	Shaft Constr.	Performance
1	AC/ 1973	1.20	conc. parap. 0.55	conc. lined	

Remarks:

two Nos of public wells
Area Council
two Nos of private wells

Monitoring of Existing Wells (Measured from Ground Level)

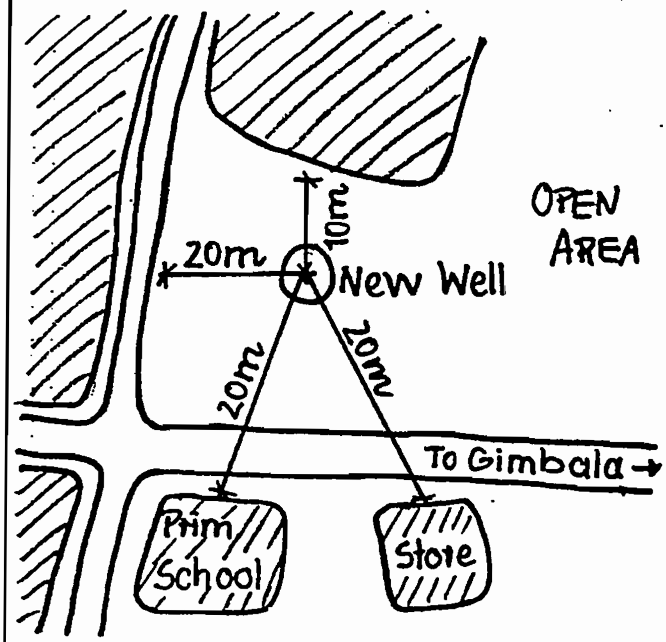
Well No.: 1				Well No.:				Well No.:			
Date	Depth	GWL	Column	Date	Depth	GWL	Column	Date	Depth	GWL	Column
12.2.85	20.60	19.93	0.67								

GAMBIA: HAND-DUG WELL CONSTRUCTION PROGRAMME

Well Construction and Acceptance Sheet

Well No.: 169	Village: GENJI WOLLOF	District: LOW. SALOUM

Layout of Well Surrounding



Elevation: .... masl

Commencement of Work: 18.04.1985

Dry Digging Completed: 26.06.1985

Wet Digging Completed: 11.09.1985

Well Head Completed: 16.01.1986

Handpump Installed: 06.02.1986

Yield: m^3/d

Reference Point of GWL Measurement

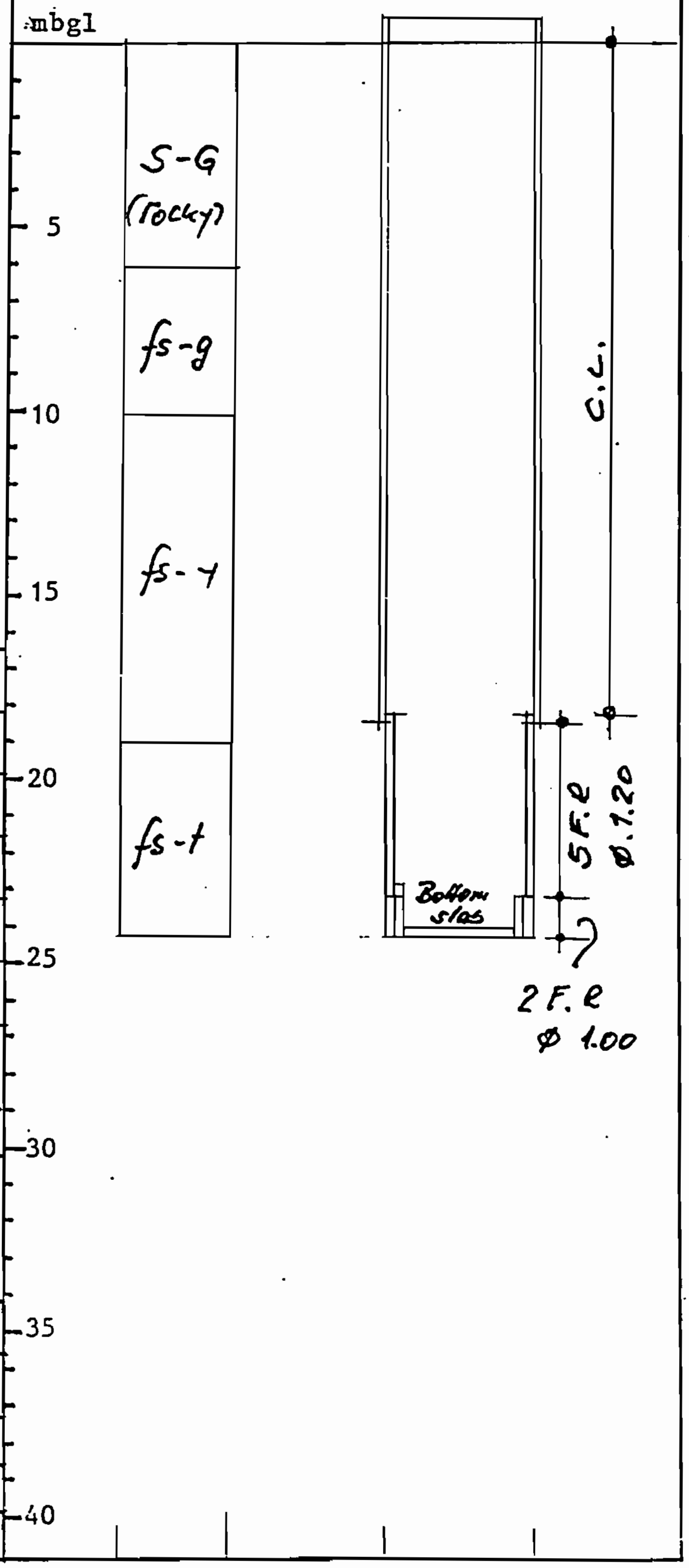
Description: TOP OF WELL COVER

Height: 0.62 magl

Groundwater Level Records (mbgl)

Date	Time	Depth	GWL	Column
11.9.85	–	24.28	20.42	3.86
14.11.85	–	24.31	20.41	3.90

Well Log Well Construction



G2 GITEC Data Base Output

GAMBIA-GERMAN HAND-DUG WELL PROGRAMME

L I S T O F W E L L S

WELL CONSTRUCTION DATA - DISTRICT: FW/A Printed on: 17.02.91 Page: 2

WELL CODE	VILLAGE NAME	STARTING DATE	COMPLETION DATE	TOTAL DEPTH (M)	DEPTH GWL (M)	WATER COLUMN (M)	PUMPS	INSTALLATION DATE (Left)	INSTALLATION DATE (Right)	CYLINDER (Left)	CYLINDER (Right)	WELL COVER	FENCI
GITEC-062	JAHALLY	03.04.84	21.05.84	11.40	6.70	4.70	1	20.06.84	. .	A373		Basalt	Wire
GITEC-063	MEDINA UMFALLY	03.04.84	31.05.84	12.10	8.06	4.04	2	20.06.84	20.06.84	A373	Pb 2.5	Basalt	Wire
GITEC-064	BRIKAMA BA	03.04.84	16.06.84	15.32	11.58	3.74	2	20.06.84	20.06.84	A373	A373	Basalt	Wire
GITEC-067	BRIKAMA N'DING	24.04.84	29.06.84	15.80	12.00	3.80	2	10.10.84	10.10.84	A373	A373	Basalt	Wire
GITEC-068	SARUJA	24.04.84	26.09.84	13.40	9.01	4.39	2	11.10.84	11.10.84	A373	A373	Basalt	Wire
GITEC-077	N'JOBEN	22.05.84	24.08.84	21.85	17.62	4.23	2	13.10.84	13.10.84	A373	A373	Basalt	Wire
GITEC-079	DENTON BOYRAM	04.06.84	28.08.84	20.50	16.59	3.91	2	11.10.84	11.10.84	A373	A373	Basalt	Wire
GITEC-080	SINCHU MADADO	18.06.84	05.09.84	18.05	14.30	3.75	1	16.10.84	. .	A373		Basalt	Wire
GITEC-082	KEREWAN FULA	28.06.84	05.09.84	14.25	10.55	3.70	2	15.10.84	15.10.84	A373	A373	Laterite	Wire
GITEC-083	TAIFA	04.07.84	03.09.84	13.50	9.26	4.24	2	15.10.84	15.10.84	A373	A373	Basalt	Wire
GITEC-096	SINCHU DAMBEL	27.08.84	17.10.84	13.08	7.88	5.20	1	21.12.84	. .	A373		Basalt	Wire
GITEC-097	SINCHU MAGAI	25.08.84	26.10.84	17.80	10.61	7.19	1	20.03.85	. .	A373		Laterite	Wire
GITEC-098	DRAGAS	31.08.84	27.10.84	12.40	8.49	3.91	1	21.12.84	. .	A373		Basalt	Wire
GITEC-099	SABU SIRAY	10.09.84	19.11.84	14.18	8.81	5.37	1	20.12.84	. .	A373		Laterite	Wire
GITEC-103	JAMWELL (SIBANOR)	13.09.84	06.01.85	21.35	17.34	4.01	1	20.03.85	. .	A373		Laterite	Wire
GITEC-104	PACHARR	11.09.84	16.11.84	12.95	9.07	3.88	2	21.12.84	21.12.84	A373	A373	Laterite	Wire
GITEC-117	FULA BANTANG	18.10.84	22.01.85	18.22	7.05	11.17	2	19.03.85	19.03.85	A373	A373	Laterite	Wire
GITEC-118	SUKURR	24.10.84	25.11.84	13.30	9.42	3.88	1	23.03.85	. .	A373		Basalt	Wire
GITEC-119	DASILAMI	30.10.84	25.11.84	17.00	14.20	2.80	2	22.03.85	22.03.85	A373	A373	Basalt	Wire
GITEC-124	SINCHU YORO	20.11.84	09.02.86	13.82	8.42	5.40	1	21.03.85	. .	A373		Laterite	Wire
GITEC-125	SINCHU BAMBA	22.11.84	09.02.85	16.90	13.00	3.90	1	21.03.85	. .	A373		Laterite	Wire
GITEC-128	SARE N'GAI	04.12.84	21.03.85	22.40	18.00	4.40	2	30.04.85	30.04.85	A373	A373	Laterite	Wire
GITEC-129	SARE FUTA	04.12.84	28.02.85	18.25	11.71	6.54	1	22.03.85	. .	A373		Laterite	Wire
GITEC-139	FASS ABDOU	03.01.85	22.04.85	17.58	13.60	3.98	2	25.04.85	25.04.85	A373	A373	Laterite	Wire
GITEC-145	TABA N'DING	25.01.85	20.02.85	18.90	15.00	3.90	2	19.03.85	19.03.85	A373	A373	Laterite	Wire
GITEC-150	MEDINA N'DING	11.02.85	04.04.85	13.37	9.40	3.97	1	26.04.85	. .	A373		Laterite	Wire
GITEC-151	FARABA	14.02.85	04.04.85	14.78	9.82	4.96	1	26.04.85	. .	A373		Laterite	Wire
GITEC-152	NEMA	23.03.85	18.04.85	20.92	17.60	3.32	1	27.04.85	. .	A373		Basalt	Wire
GITEC-153	TABANANI	21.02.85	04.04.85	13.65	9.56	4.09	2	24.04.87	24.04.87	A373	A373	Laterite	Wire
GITEC-271	WELLINGARA ADAMA	01.09.86	24.12.86	26.12	21.93	4.19	1	17.05.87	. .	Pb 2.5		Basalt	Wire
GITEC-272	TAIFA AMADOU	08.09.86	16.11.86	16.55	11.05	5.50	1	17.05.87	. .	Pb 2.5		Basalt	Wire
GITEC-278	KEREWAN MANDINKA	06.10.86	20.01.87	16.70	12.79	3.91	2	17.05.87	17.05.87	Pb 2.5	Pb 2.5	Basalt	Wire
TOTAL:	32			526.39	380.42	145.97	48						
AVERAGE:				16.45	11.89	4.56							

GAMBIA-GERMAN HAND-DUG WELL PROGRAMME

MAINTENANCE MONITORING: PAYMENTS FOR MAINTENANCE

Time Period: 22.05.1989 - 30.04.1991

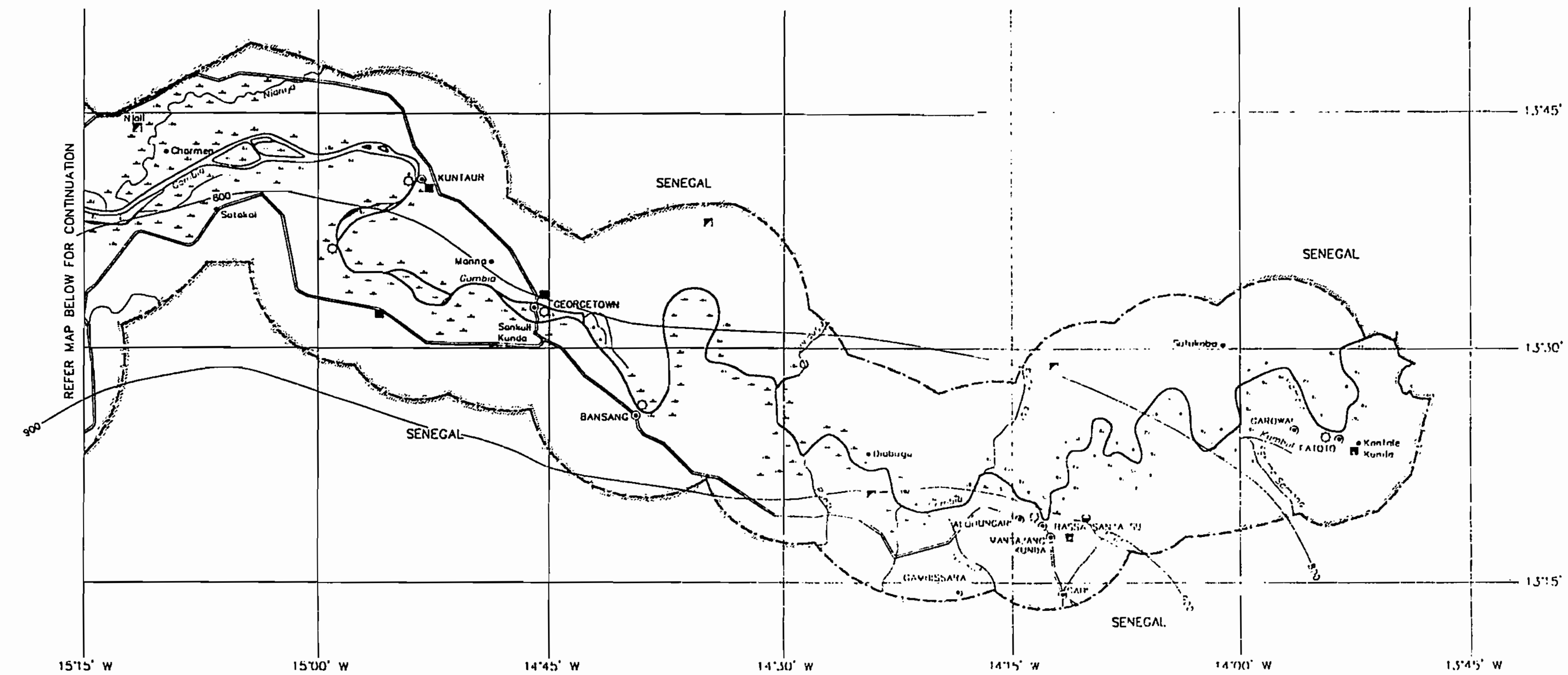
Printed on: 17/06/91

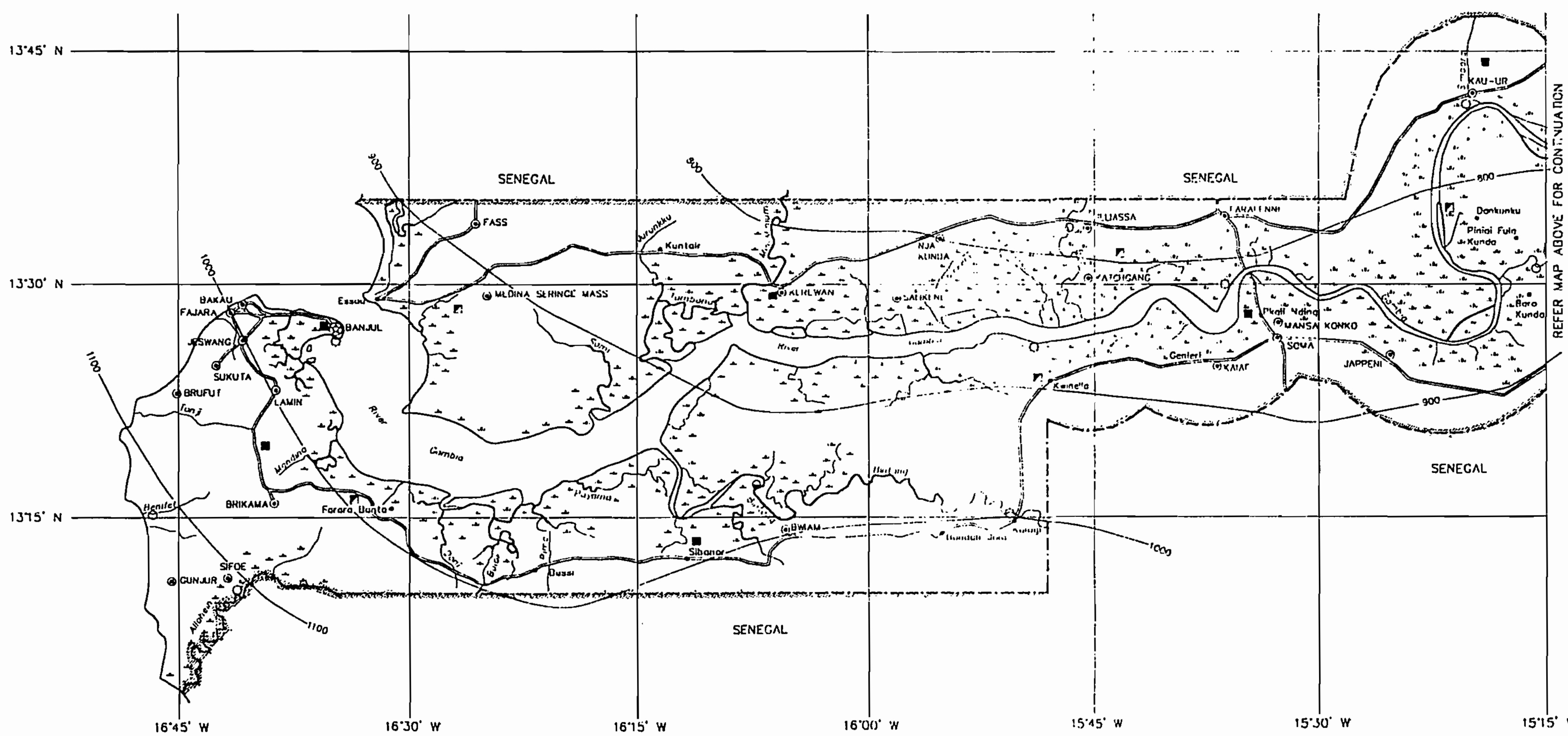
DIVISION: NBD DISTRICT: UN

DATE	WELL NO.	VILLAGE NAME	TRANSPORT TO VILLAGE	TRANSPORT TO D-SHOP	MAINT. CASES	WORK MAINT.TEAM	SPARES PROJECT	WORK AREA MECH	D-SHOP	SPARES D-SHOP	INCOME PROJECT	INCOME AREA MECH./D-SHOP	TOTAL	FUND
27/07/89	GITEC-021	M'BANTA KELLING	25.00	15.00	1	0.00	0.00	40.00	BA	245.00	40.00	285.00	325.00	Y
13/11/89	GITEC-021	M'BANTA KELLING	25.00	0.00	1	0.00	0.00	0.00		0.00	25.00	0.00	25.00	N
22/11/89	GITEC-021	M'BANTA KELLING	25.00	0.00	1	0.00	455.00	20.00		0.00	480.00	20.00	500.00	Y
06/06/90	GITEC-021	M'BANTA KELLING	0.00	0.00	1	0.00	0.00	55.00	BA	410.00	0.00	465.00	465.00	Y
25/08/90	GITEC-021	M'BANTA KELLING	0.00	0.00	1	0.00	0.00	70.00	BA	412.50	0.00	482.50	482.50	Y
28/07/89	GITEC-027	PAKAU N'JOKU	25.00	15.00	1	0.00	0.00	20.00		0.00	40.00	20.00	60.00	N
08/08/89	GITEC-027	PAKAU N'JOKU	25.00	0.00	1	0.00	1042.00	15.00		0.00	1067.00	15.00	1082.00	Y
23/11/89	GITEC-027	PAKAU N'JOKU	25.00	0.00	1	0.00	0.00	0.00		0.00	25.00	0.00	25.00	N
29/01/90	GITEC-027	PAKAU N'JOKU	25.00	15.00	2	0.00	314.00	55.00	BA	1927.00	354.00	1982.00	2336.00	Y
11/12/90	GITEC-027	PAKAU N'JOKU	0.00	0.00	1	0.00	0.00	13.25	BA	109.75	0.00	123.00	123.00	Y
10/04/91	GITEC-027	PAKAU N'JOKU	0.00	0.00	1	0.00	0.00	50.00	BA	415.00	0.00	465.00	465.00	Y
08/06/89	GITEC-024	PAKAU SALOUM	25.00	0.00	1	0.00	253.00	20.00		0.00	278.00	20.00	298.00	Y
12/01/90	GITEC-024	PAKAU SALOUM	25.00	15.00	1	0.00	319.00	50.00	BA	492.00	359.00	542.00	901.00	Y
14/05/90	GITEC-032	SAMI KOTO	0.00	0.00	1	0.00	0.00	90.00	BA	1645.00	0.00	1735.00	1735.00	Y
05/10/90	GITEC-022	SIKA	0.00	0.00	2	0.00	0.00	65.00	BA	1994.00	0.00	2059.00	2059.00	Y
21/11/89	GITEC-074	SITTA NUNKU	25.00	15.00	1	0.00	310.00	30.00	BA	174.00	350.00	204.00	554.00	Y
20/11/90	GITEC-074	SITTA NUNKU	0.00	0.00	1	0.00	0.00	25.00	BA	20.00	0.00	45.00	45.00	Y
23/04/91	GITEC-074	SITTA NUNKU	0.00	0.00	1	0.00	0.00	25.00	BA	217.50	0.00	242.50	242.50	Y
08/06/89	GITEC-013	TUBA KOLONG	25.00	0.00	1	0.00	269.00	25.00		0.00	294.00	25.00	319.00	Y
21/11/89	GITEC-013	TUBA KOLONG	25.00	15.00	1	0.00	569.00	40.00	BA	278.00	609.00	318.00	927.00	Y
13/05/90	GITEC-013	TUBA KOLONG	0.00	0.00	1	0.00	0.00	60.00	BA	502.00	0.00	562.00	562.00	Y
16/10/90	GITEC-013	TUBA KOLONG	0.00	0.00	1	0.00	0.00	15.00		0.00	0.00	15.00	15.00	N
26/12/90	GITEC-013	TUBA KOLONG	0.00	0.00	1	0.00	0.00	40.00	BA	67.50	0.00	107.50	107.50	Y
15/03/91	GITEC-013	TUBA KOLONG	0.00	0.00	1	0.00	0.00	40.00	BA	289.50	0.00	329.50	329.50	Y
DISTRICT TOTAL:			500.00	150.00	54	0.00	4807.00	1848.25				19881.25	25338.25	

G3 UN Groundwater Resources Planning and Development Project Data Base Output

HYDROMETEOROLOGICAL MAP OF THE GAMBIA





SUB-SAHARAN AFRICA HYDROLOGICAL ASSESSMENT
(WEST AFRICAN COUNTRIES)
THE WORLD BANK
THE UNITED NATIONS DEVELOPMENT PROGRAMME
AFRICAN DEVELOPMENT BANK

prepared by
Mott MacDonald International
Cambridge, U.K.
in association with
BCEOM
Montferrier-sur-Lez, France
and
SOGREAH
Grenoble, France

Precipitation

1000 Isohyets of mean annual precipitation (mm)

Meteorology

Synoptic station

Agro-meteorological station

River Gauging Stations

Staff gauge

Staff gauge and discharge measurements

Water level recorder

Surface Water

River

Lake

Swamp

Topographic Features

Paved road

Railway

Town, village with airstrip

City/Larger Town

Scale 1:500 000

0 5 10 15 20 25 km