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Water Resources and Environmental Management in Ghana

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Three principal river basins are found in Ghana and the Volta River Basin is the major one, covering about three-quarters of Ghana. The basin is shared with Mali, Burkina Faso, Cote d'Ivoire, Togo and Benin. Water from the Volta River Basin is used for drinking water supply, generating hydro-electric power, irrigation, inland fisheries and lake transport. The sustainable management of the Volta River Basin is thus of great importance. Land use activities in the basin are thus closely monitored not only in Ghana, but also in the other riparian countries as well. This paper presents information and data on the water resources and environmental management of the Volta River Basin in Ghana.

Key words: *water resources, environmental management, Volta River Basin, Ghana, water utilization*

1 INTRODUCTION

Ghana is covered by three main river basins. These are the Volta, South-Western and the Coastal Basins. The Volta River Basin (**Fig. 1**) covers about 70 % of the total surface area of the country and it is shared by six West Africa countries, namely; Ghana, Mali, Burkina Faso, Cote d'Ivoire, Togo and Benin. In Ghana, the Volta River has been dammed at Akosombo for hydro-electric power, creating the largest man-made lake in the world. The generated electricity is also supplied to the neighbouring countries of Cote d'Ivoire, Burkina Faso, Togo and Benin. Water from the lake is used for water supply (domestic and industrial) and irrigation. Also, the lake has become a major waterway for transport, linking the south of the country to the north. Due to its vast extent and national importance, the sustainable management of the Volta Basin is of very great importance in Ghana. It is for this reason that this basin is used as a case for the study of the hydrology, water resources and environmental management in Ghana.

1.1 Climate

The climate in the Volta Basin is mainly Tropical Continental or Interior Savannah. The rainfall distribution is principally unimodal. The rainfall season occurs from May to October, followed by a prolonged dry season between November and April. The mean annual rainfall ranges from 1,000 to 1,300 mm. The distributions of mean annual rainfall and evapotranspiration in Ghana are shown in **Fig. 2** and **3**, respectively. Rainfall studies in West Africa show that there has been a decline in the mean annual rainfalls for both the forest and savannah zones since the early 1970s (Opoku-Ankomah and Amisigo, 1998; Paturel, et al. 1997; Aka, et al. 1996). The mean annual temperatures vary between 24.4 °C and 28.1 °C. Gyau-Boakye and Tumbulto (2000) have observed that the mean annual temperature in the basin has increased by 1 °C between 1945 and 1993.

1.2 Geology, soil and vegetation

The Volta Basin in Ghana is mainly underlain by consolidated sedimentary formation, consisting of sandstones, shale, arkose, mudstone, sandy and pebbly beds and limestones. These rocks cover 45 % of the country (WARM, 1998; Kankam-Yeboah, et al. 2003). Other formations found in the basin consist of granites and associated granites. The soils of the basin are basically Savannah Ochrosols, groundwater laterites and laterite-ochrosols and acid gleisols. The basin is principally located in the interior wooded savannah ecological zone. The predominant vegetation is grass with trees such as baobab, dawadawa, nim and sheanut trees in the north and *Acacia sp.* and mangroves in the south.

2 WATER RESOURCES

2.1 Surface Water Resources

2.1.1 Coverage

The major tributaries of the Volta River (also called the Volta lake) are the Black, White and Oti rivers. Into these, minor rivers and streams empty their waters. The Black Volta has a total drainage area of 149,015 km^2, with only about a fifth (38,107 km^2) of this lying wholly in Ghana (WARM, 1998; Kankam-Yeboah, 1997). The Black Volta is shared by Ghana, Burkina Faso and Cote d'Ivoire. The main tributaries of the Black Volta are Benchi, Chuko, Laboni, Gbalon, Pale, Kamba and Tain rivers.

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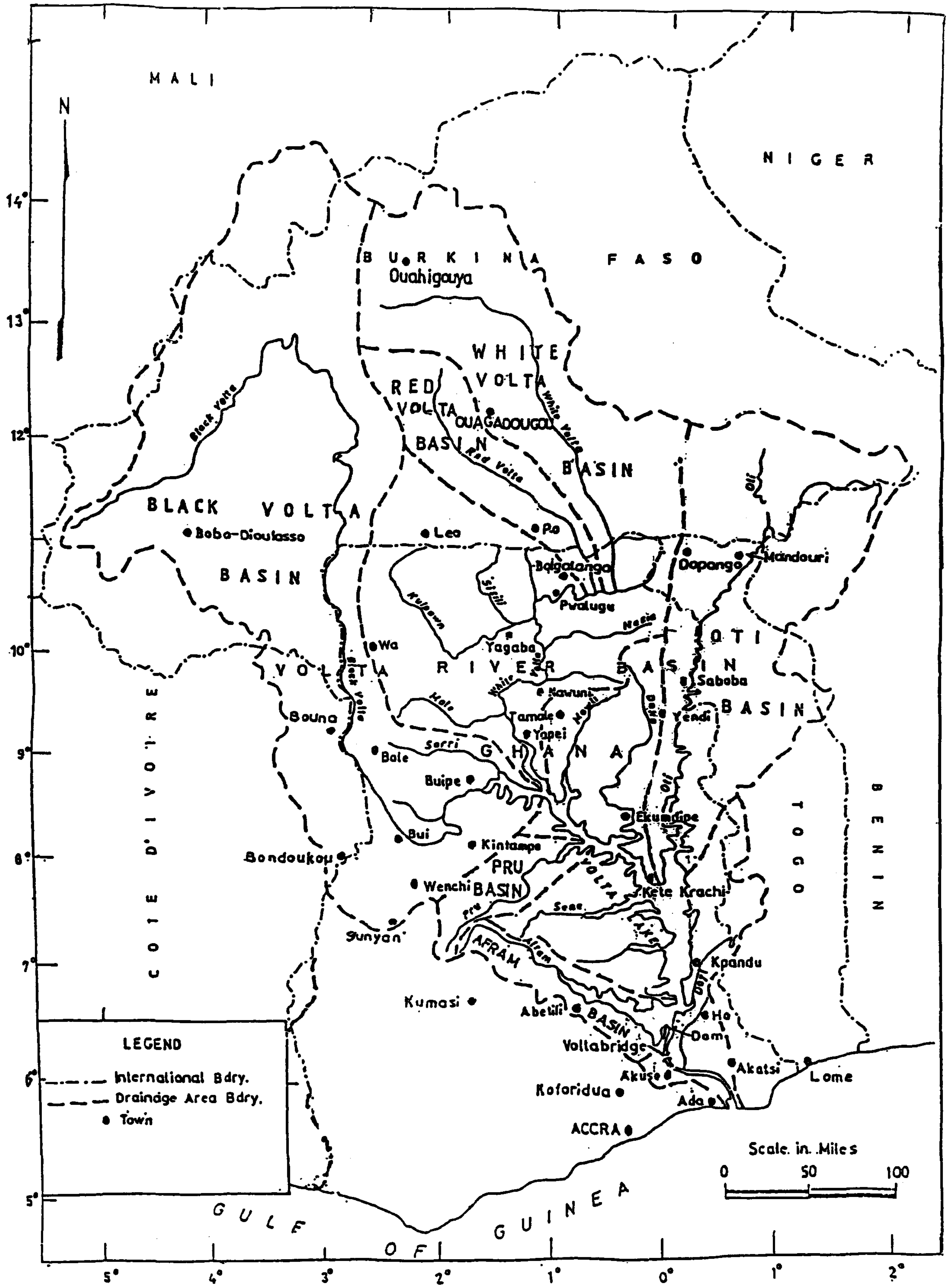

Fig. 1 The Volta River Basin (Modified after WARM, 1998)

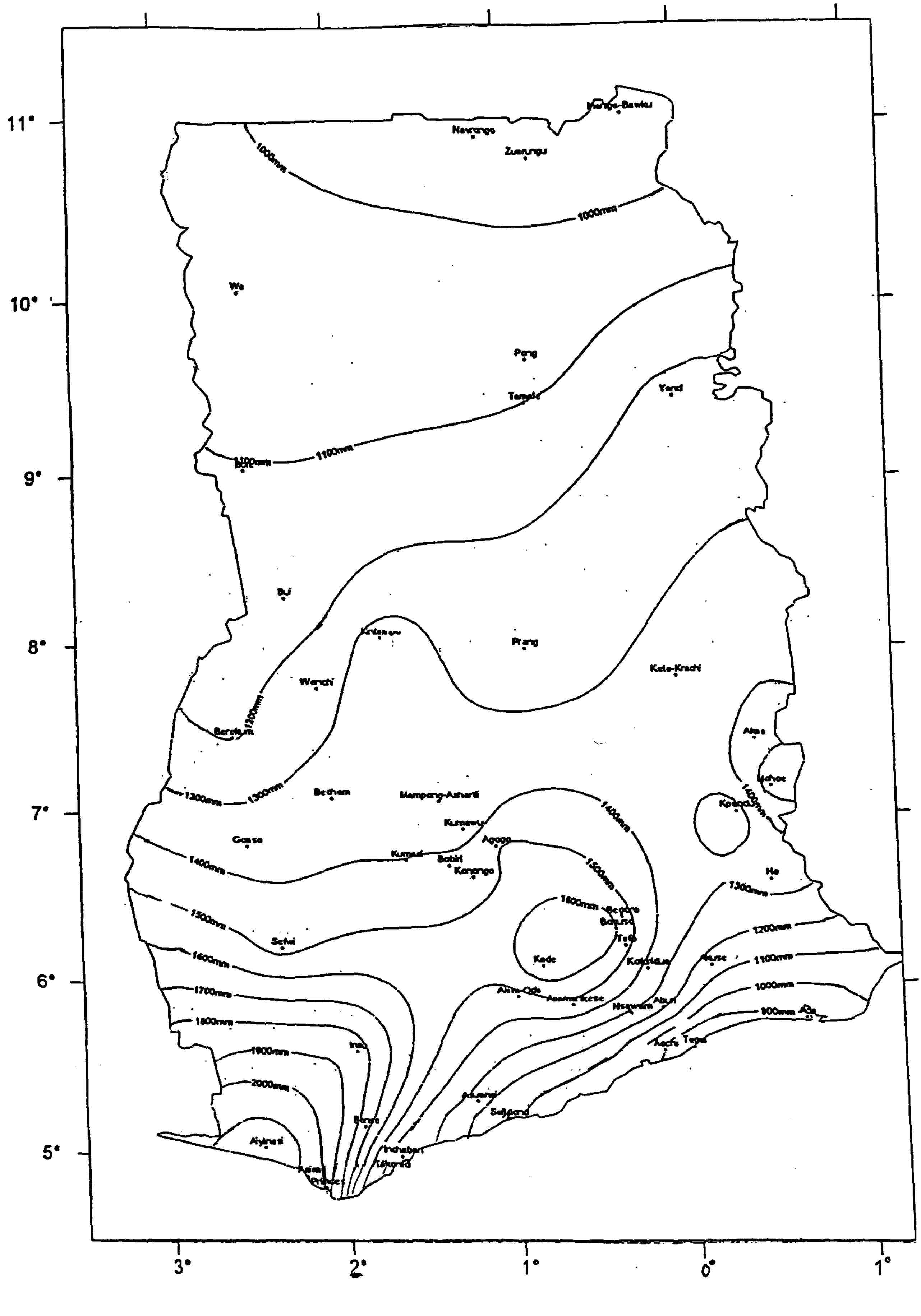

Fig. 2 Rainfall isohyets in Ghana (Modified after WARM, 1998)

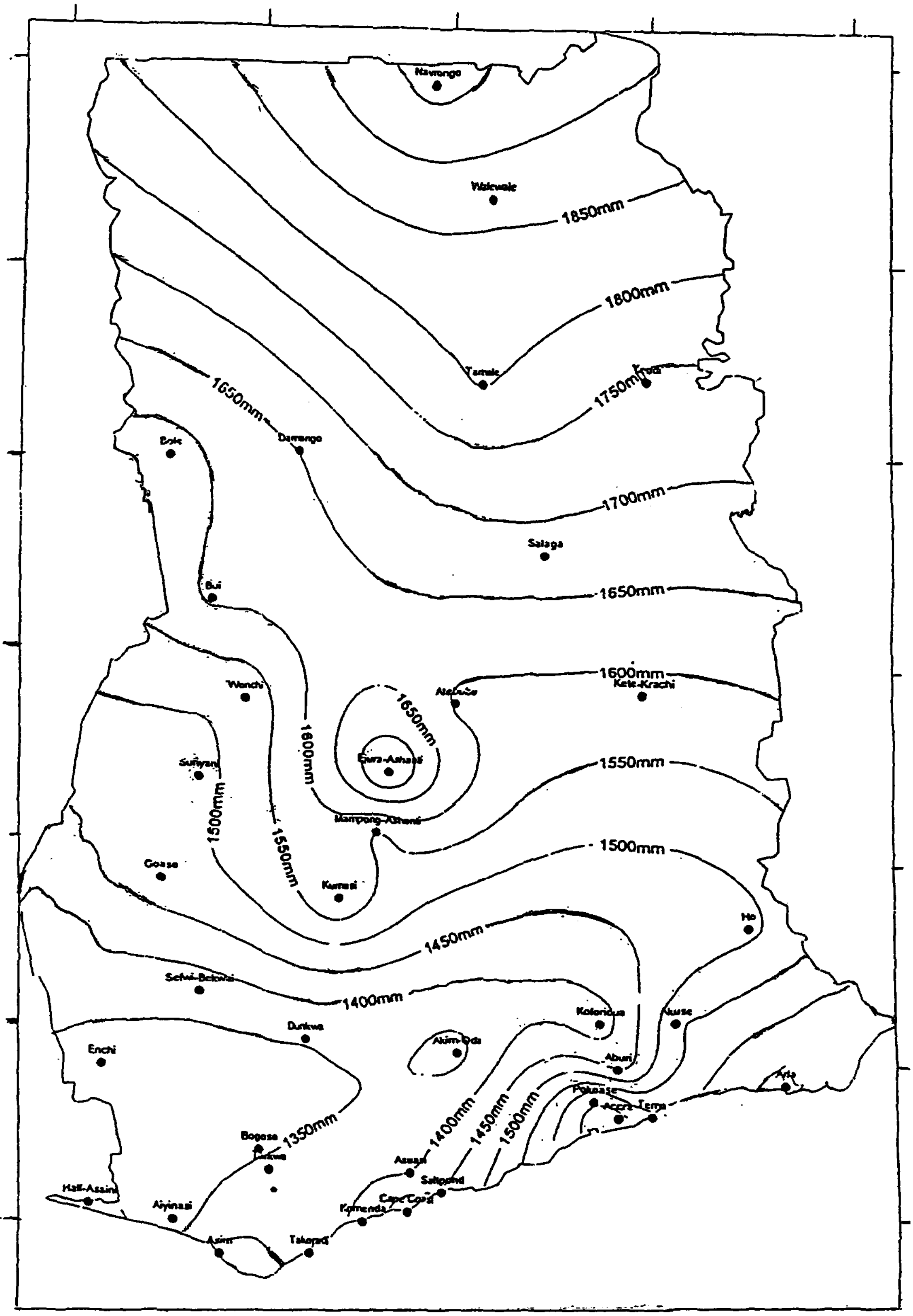

Fig. 3 Potential evapotranspiration in Ghana (Modified after WARM, 1998)

The White Volta Basin, which Ghana shares with Burkina Faso and Mali, covers an area of about 104,752km^2 with only 45,804 km^2 lying in Ghana. The main tributaries of the White Volta are Mole, Kulpawn, Sisili, Red Volta, Asibilika, Agrumatue, Nasia and Nabogo rivers.

The Oti Basin is shared by Ghana, Burkina Faso, Togo and Benin. It occupies an area of about 72,778 km^2 out of which only 16,213 km^2 lies in Ghana. The main tributaries of Oti are Afram, Obosom, Sene, Pru, Kulurakun, Daka, Asukawkaw and Mo rivers.

Beside the above–mentioned tributaries and south of Ghana is the Lower Volta River. It is shared between Ghana and Togo and it occupies an area of about 62,651 km^2 of which 59,414 km^2 lies in Ghana.

2.1.1 *Runoff*

The total annual runoff for Ghana is 54.45 billion m^3, of which 38.3 billion m^3 is accounted for by the Volta River System (WARM, 1998). The total annual runoff originating from Ghana alone is 39.4 billion m^3, which is 68.6 % of the total annual runoff. The Volta Rivers System contributes 64.7 % of the actual runoff from Ghana, nearly, 25.5 billion m^3.

The Oti basin, though only about 18 % of the total catchment of the Volta River System, contributes between 30 % and 40 % of the annual flow of the Volta Rivers System (Moxon, 1968). The reason for this is that the catchment of the Oti River is the most hilly and mountainous in the whole Volta basin.

Opoku-Ankomah (1998) estimated the total annual discharge of the White Volta basin to be 303.29 m^3/s, where the percentage of flow from outside the country to the total flow is estimated to be 36.5 %. The mean annual flow of the Black Volta at Bamboi is 218.97 m^3/s, out of which about 42.6% originate outside of Ghana. The total annual flow from the Oti catchment was estimated to be 365.5 m^3/s with 89.1 m ^{3}/s from within the country.

In general, there is a great variability between the wet and dry season flows in the river basins in Ghana, the Volta River Basin being no exception.

2.1.2 *Floods*

Periodic and temporary flooding occurs in many parts of the country, as a result of heavy rains and overflows from rivers and streams. To manage flood incidents, regional flood frequency curves have been approximately derived for the entire country based not only on limited data but also on data full of gaps (Ontoyin, 1985). In order to apply the Index-flood method, the country was divided into five provisional hydrological homogenous regions based on rainfall, topography and geology. The series of observed and estimated discharges for each station was ranked and corresponding periods computed from the plotting position formula:

$$T = (n + 1)/m \qquad (1)$$

where, **m** = 1 for the highest discharge and **m** = **n** for the lowest in a series of n discharges.

The observed discharges alone were plotted against their return periods on Gumbel (Extreme value type 1) graph paper to define station frequency curves. From these frequency curves, floods of return period 1.1, 1.5, 5, 10, 25, 50 years (**Q_T**) and the index flood, **Q_{ind}** (flood of return period of 2.33 years) were obtained. The corresponding regression equations derived for the Volta Rivers System are as follows (Ontoyin, 1985):

$$Q_T / Q_{ind} = 0.97 + 0.4y \text{ for Black and White Volta} \qquad (2)$$
$$Q_T / Q_{ind} = 1.00 + 0.94y \text{ for Oti} \qquad (3)$$
$$Q_T / Q_{ind} = 1.00 + 0.66y \text{ for Lower Volta} \qquad (4)$$

where, **y** = -ln [-ln(1-1/**T**)] and **T** = return period in years.

These derived equations for flood estimates in the Volta River Basin ought to be used with caution and the results should be treated as provisional since they are based mainly on limited data. Only very few hydro-stations have continuous records of 20 years and more, giving rise to many inter-station correlation estimates.

2.1.3 *Surface water quality*

The mean pH of the Volta Rivers System varies from 6.9 to 7.5 in the Oti River at Saboba and on the Black Volta at Bamboi, respectively. The range is not very wide and the waters appear mostly neutral (pH 7.0). The maximum level of dissolved salts, in terms of conductivity, was 280.0 μs/cm in the Oti River at Saboba (WARM, 1998).

The mean suspended solids concentrations are generally low, less than 200 mg/l; and the dissolved oxygen concentrations generally indicate low levels of pollution. The mean annual suspended yields in some of the rivers in the Volta Basin are as follows:

Black Volta	:	19.97 tons/km^2/year
White Volta	:	21.09 tons/km^2/year
Oti	:	53.58 tons/km^2/year

2.2 Groundwater resources

The Paleozoic sedimentary formations, locally referred to as the Voltaian Formation, which underlie the Volta Basin have little primary porosity. Groundwater occurrence is thus associated with the development of secondary porosity as a result of jointing, shearing, fracturing and weathering (WARM, 1998). This has given rise to aquifers which may be weathered or fractured. For the various subdivisions of the Voltaian Formation, average borehole yields range from 6.2-8.5m^3/h. **Figures 4 and 5** show the borehole and specific yield maps, respectively, of Ghana.

Recharge to the aquifers is mainly direct infiltration of precipitation through the fractures and fault zones along the highland fronts and also through the sandy portions of the weathered zone. Some amount of recharge also occurs through seepage from ephemeral stream channels during the rainy seasons.

2.2.1 *Groundwater quality*

The quality of groundwater in the Volta Basin is generally good for multipurpose use except for the presence of low pH (3.5 – 6.0), high levels of iron (1 – 64 mg/l), manganese, and fluoride (1.5-5.0 mg/l) in the

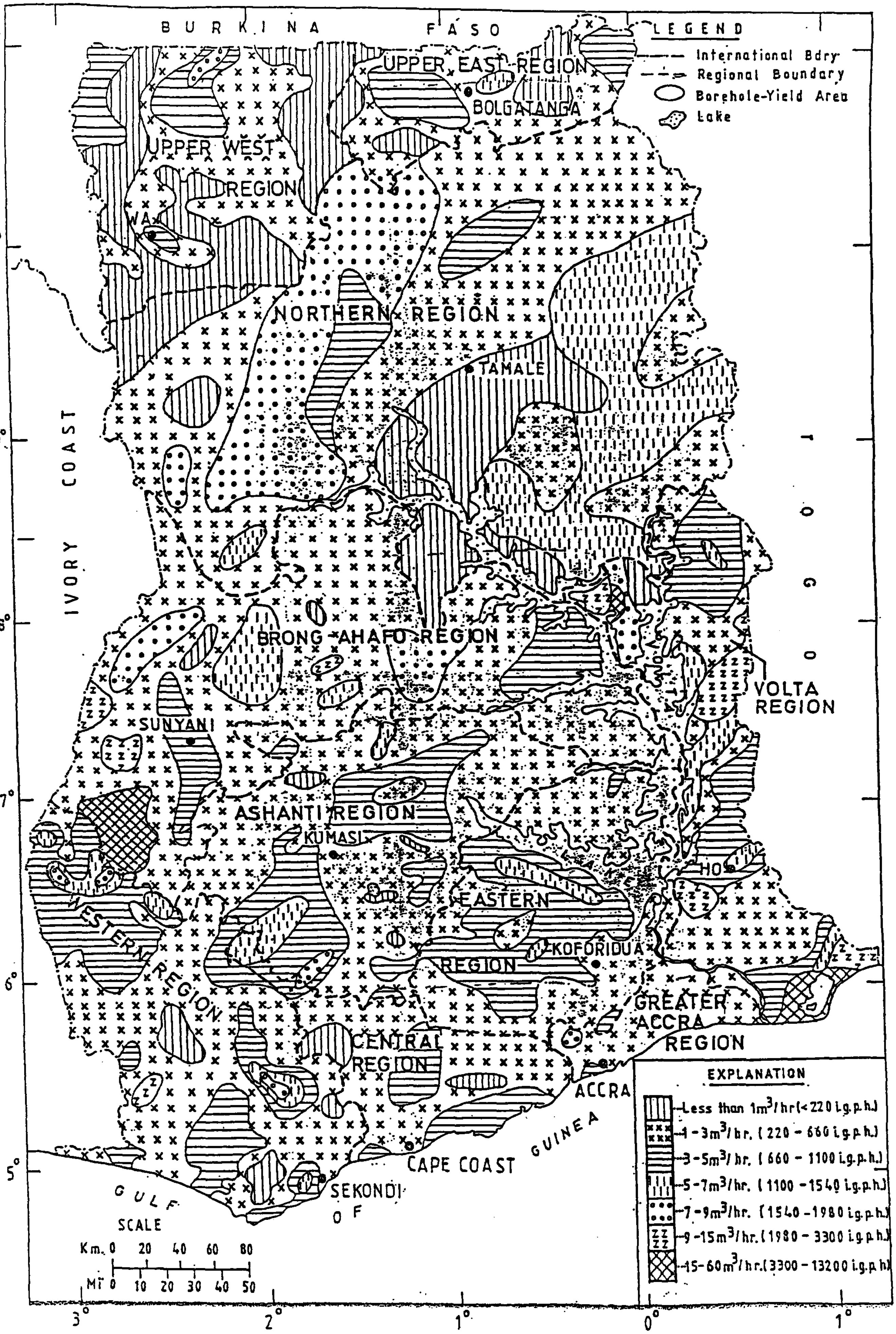

Fig. 4 Borehole yields in Ghana (WRI, Unpubl.)

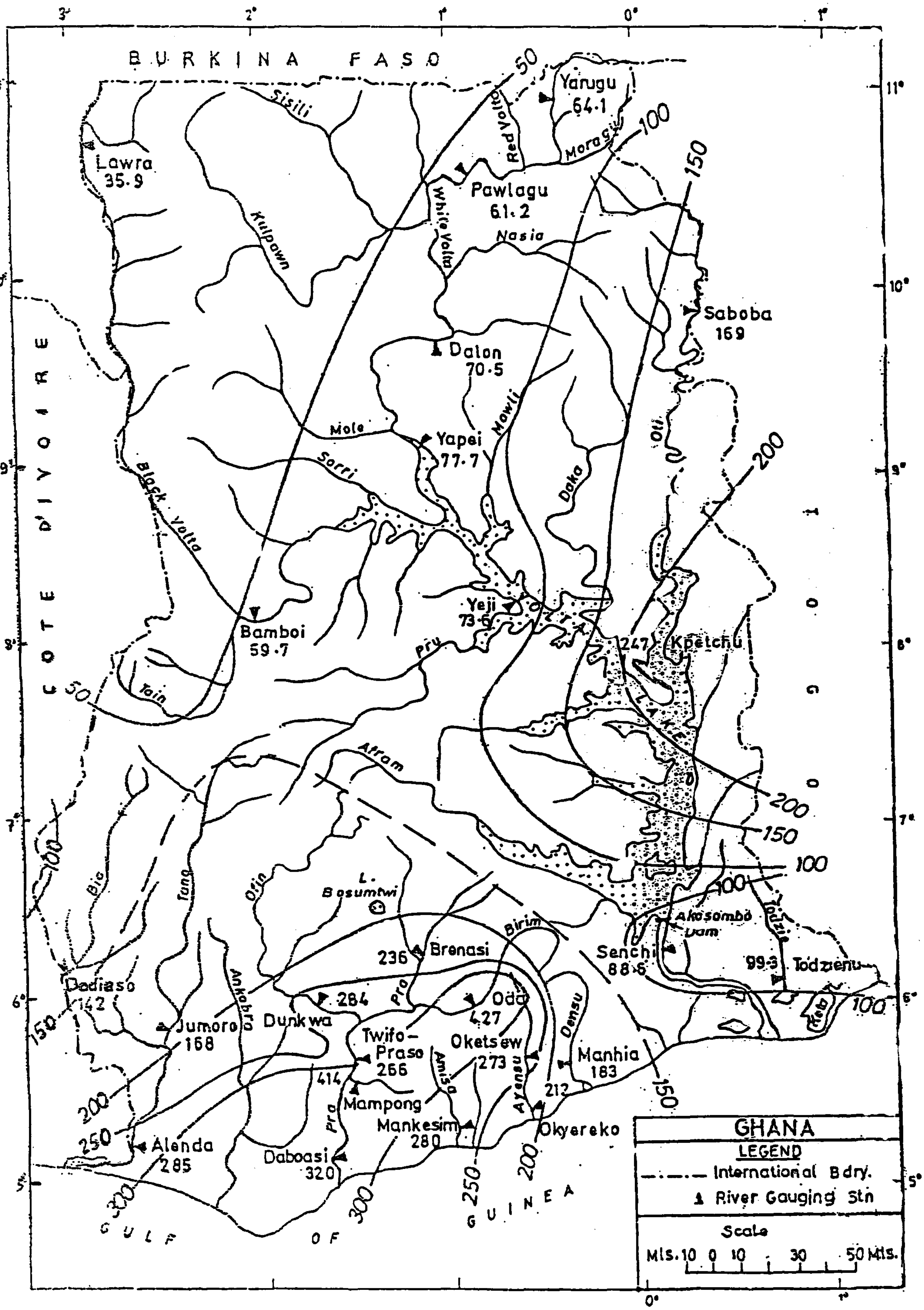

Fig. 5 Specific yields in Ghana (10^3 m^3/km^2, WRI, Unpubl.)

granite formations in the basin (WARM, 1998). About 30 % of boreholes in Ghana have iron problems. High mineralization, with Total Dissolved Solids (TDS) in excess of 1,500 mg/l, is also found in the Volta River Basin. The waters in many hand-dug wells are turbid and polluted as they contain high levels of nitrate (30 – 60 mg/l) and coliform.

2.3 Water Balance

The mean annual rainfall for the White Volta Basin ranges from 1,015 mm in the north to about 1,140 mm in the south, while the annual potential evapo-transpiration ranges from 1,700 mm in the south to 1,950 mm in the north. The northern parts of the Oti basin receive an annual rainfall of about 1,015 mm while the south experiences about 1,397 mm of rainfall on the average per year. The annual potential evapo-transpiration of the Oti basin ranges from 1,550 mm in the south to 1,900 mm in the north. The annual rainfall of the Black Volta basin ranges from 1200 mm in the south to 1,000 mm in north while annual potential evapo-transpiration ranges from 1,600 mm in the south to about 1800 mm in the north.

The estimation of direct recharge in the Volta Rivers System is based on the assumption that recharge occurs when actual evapo-transpiration and direct runoff are taken care of by the precipitation. This happens when the soil is saturated to the field capacity. The soil is likely to be saturated to the field capacity when precipitation exceeds the evapo-transpiration.

Analyses of rainfall data from various stations within the Volta Rivers System indicate that the months in which precipitation exceeds the evapo-transpiration are mostly June, July, August, and September. The annual recharge for the Volta Rivers System ranges from 13.4 % to 16.2% of the mean annual precipitation. On the average, the mean annual recharge of the Volta Rivers System is about 14.8 % of the mean annual precipitation. Thus, the annual recharge varies between 157.7 mm and 193.1 mm with an average of 175.4 mm (Ghana Country Report, 2001).

It must be pointed out that this mode of estimating recharge may result in over-estimation of recharge to aquifers in Ghana. Darko (Unpublished), in a study on the Pra River Basin of Ghana using the *Sacramento Soil Moisture Accounting Model*, found that the average recharge was only about 4 % of total catchment rainfall.

2.4 Water use

Water, in Ghana, has many uses. Its living and non-living resources range from minerals to food. Both surface and ground waters in the Volta Basin are in increasing demand for potable supplies and for irrigation, agriculture and industrial purposes. The estimated rural domestic and livestock water demands are presented in **Table 1**. The rural and urban per capita water demand (water consumption) for various population sizes are presented in **Table 2**. The annual groundwater demand and the current water abstraction data are also shown in **Tables 3** and **4**, respectively. Generally, the demand for water in the northern section of the Volta Basin outstrips abstraction. This calls for the judicious use of the available water resources. In fact, more water sources ought to be sought for in these areas.

Inland fisheries are major sources of livelihood to many communities along the Volta River, for fish provides about 60 % of the total protein requirements of Ghana. Inland fisheries and aquaculture together contribute about 20 % of Ghana's total production.

Ghana's energy requirements still heavily rely on hydroelectric power generation at Akosombo and Kpong which are both sited on the Volta and, together, have a current generating capacity of 1,072 or 92 % of the total installed electricity generation capacity of 1,160 Megawatts. The water systems serve for transportation of people and goods, especially in rural areas where there are fewer roads. The Volta Lake has thus become important for the transport of petroleum products from the seaport of Tema via Akosombo to the Northern and Upper Regions, which are located in the upper reaches of the Volta River Basin in Ghana.

Many urban areas are located close to major rivers and discharge wastes into them. Linked to this is the growing popularity of tourism and recreation in the inland waters of the Volta Lake which occupies and area of about 8,500 km^2 or 3 % of the surface area of Ghana.

In terms of potential, Ghana has a cultivable area of 10,000,000 ha and more than 1,140,000 ha under cultivation. The potential for irrigation is 1,900,000 ha, which is 19 % of the cultivable area. The area under full or partial control of irrigation was only 6,374 ha. The water withdrawal for agriculture (in 1970) was 52 %. With increasing population and industrialization, more land would be put under irrigated agriculture in the coming years.

3 ENVIRONMENTAL CONCERNS

In recent times, concern for the environment in and around the Volta Basin has increased. This concern is due to increasing human population and activities associated with this. With the ever-expanding population (**Table 5**), there is the urgency for proper conservation and efficient utilisation of our river basins, especially the Volta River Basin, for sustainable development. The population pressures cause (a) an increase in the demand, so that every year there is less and less water available for use; indeed, in some places there is already less water to meet demand than in the past; (b) an acceleration of the progressive deterioration of water quality because of increased domestic, municipal, agricultural, and industrial effluent being discharged into water bodies; and (c) an increase in environmental degradation resulting from urbanisation and deforestation. Increased population growth and increased demand for water in the various sectors of the economy (food and agriculture, health, industry including mining, energy, etc.), and the corresponding impact of these developments on land and water resources have made it imperative to take a holistic view of water resources management and integrate it with overall socio-economic development, the environment and the ecosystem.

Human activities also impact negatively on the quality of water bodies, thereby limiting the scope of its

Table 1 Rural domestic and livestock water demands (WARM, 1998)

River Basin	Rural domestic water supply ($10^6 m^3$)		Livestock water demand ($10^6 m^3$)	
	2000	2005	2000	2005
White Volta	23.4	27.4	13.4	18.3
Black Volta	11.5	14.1	3.8	4.2
Main Volta	30.1	35.8	4.9	5.5
Daka	2.4	2.9	1.26	1.39
Oti	7.1	8.5	2.6	2.9

Table 2 Rural and urban per capita water demand (WARM, 1998)

Population Size	Per capita water consumption (litres/day)				
	Year				
	1980	1990	2000	2010	2020
<2000	22.5	22.5	30.0	30.0	30.0
2000 –5000	50.0	55.0	60.0	65.0	65.0
5001-10000	60.0	65.0	70.0	70.0	70.0
>10000	70.0	80.0	85.0	90.0	90.0

Table 3 Estimated annual groundwater abstraction (WARM, 1998)

Basin	No. of boreholes	Yield (m^3h^{-1})		Current annual abstraction ($x10^6m^3$)
		Range	Mean	
White Volta Basin	3,007	0.3-24.0	2.1	18.2
Black Volta Basin	895	0.1-36.0	2.2	5.7
Main Volta	2,163	0.02-36.0	5.1	26.5
Daka	204	0.5-18.0	4.6	2.3
Oti	531	0.6-36.0	4.4	5.6

Table 4 Current annual water demand and abstraction (WARM, 1998)

Basin	Current water demand ($x10^6 m^3$)	Annual abstraction ($x10^6m^3$)	Excess demand over abstraction ($x10^6 m^3$)	% Excess demand over abstraction
White Volta Basin	29.0	22.7	6.3	27.8
Black Volta Basin	12.4	7.1	5.3	74.6
Main Volta	28.7	39.7	-11	-27.7
Daka	3.0	2.6	0.4	15.4
Oti	8.0	7.3	0.7	9.6

Table 5 Projected population of the sub-basins of the Volta River in Ghana

River Basin	2000	2005	2010
White Volta (Total)	2,041,690	2,360,310	2,732,615
Rural	1,735,223	1,971,865	2,235,930
Urban	306,467	388,445	496,685
Black Volta (Total)	1,034,067	1,230,088	1,468,405
Rural	851,762	1,012,565	1,208,242
Urban	182,305	217,523	260,163
Daka (Total)	230,416	267,942	312,438
Rural	175,962	206,394	242,843
Urban	54,454	61,548	69,595
Oti (Total)	600,223	698,615	826,793
Rural	532,297	615,071	722,841
Urban	67,926	83,544	103,952
Grand Total	3,897,396	4,556,955	5,340,251
Rural	3,295,244	3,805,895	4,409,856
Urban	611,152	751,060	930,395

usage. These human activities include farming and deforestation, mining, sand winning and quarrying, and liquid and solid waste disposal. The activities of the people living in the Volta River Basin are considered to be major causes of degrading water quality.

Deforestation is man-made – it arises out of unsustainable levels of timber extraction, poor agricultural practices (i.e. shifting cultivation), surface mining, use of fire for illegal hunting and cutting of trees for fuel wood and charcoal production. The removal of vegetation covers at headwaters of the watersheds and along water bodies have the effect of exposing the water bodies to the elements of weather and thereby precipitating the drying up of these water sources. Land degradation caused by extensive farming, deforestation and mining activities cause sedimentation of rivers and silting of natural and artificial reservoirs. These activities help to diminish the quantity and affect the quality of fresh water bodies. The Volta basin continues to have its fair share of these.

Poor farming activities and environmental degradation disturb the land and hence large amounts of sediments are washed into the water bodies during the rainy season. The use of chemicals, like fertilizers, pesticides, etc. for agricultural activities contribute to contamination of rivers in the Volta River Basin.

Due to improper solid and liquid waste disposal practices, the bacteriological quality of water is quite often affected. High faecal coliform counts have been recorded (Ampofo, 1997). Mining activities were responsible for the high turbidity levels and have contaminated some rivers with arsenic and mercury (Osafo and Paintsil, 1994). High cyanide concentrations have also been recorded in the lower Volta (Larmie, 1993). These are attributed to increased agricultural and industrial activities in the basin as a whole.

As the water demand is increasing, the rainfall amounts in many parts of the country have been observed to be declining and its spatial and temporal variabilities have been observed to be changing for the worst. Similarly, temperatures throughout the country have also been observed to be increasing. The reducing rainfall amounts and the increasing temperatures with corresponding increase in evaporation are said to be mainly responsible for the reduction in the river runoffs in the country.

4 WATER-RELATED INSTITUTIONS IN GHANA

Ghana has several public institutions that are relevant for the sustainable management of the water resources and the environment of the Volta Basin. They include the Water Resources Commission (WRC), the Water Research Institute of the Council for Scientific and Industrial Research (CSIR-WRI), Ghana Water and Sewerage Corporation (GWSC) currently known as Ghana Water Company Limited (GWCL), Irrigation Development Authority (IDA), the Environmental Protection Agency (EPA), The Meteorological Services Department (MSD), the Hydrological Division of the Ministry of Works and Housing and the Public Utility Regulatory Commission (PURC).

A review by the Ministry of Works and Housing (WARM, 1998) showed that Ghana has enough institutions for integrating water resources management at the sectoral level, but not at the macro or national level. For this reason, the setting up of the Water Resources Commission (WRC) in 1996 (Parliament of Ghana, 1996) to undertake water resources planning is expected to rectify the gap. Secondly, the Commission has been given the powers to grant water rights, and Ghana has enough laws for granting water rights for controlling pollution and for protecting catchments. The Commission will rationalize, coordinate and direct the activities of all water related institutions so that they are better integrated into the socio-economic development process. The Water Resources Commission is also developing a Ghana Water Policy. Within the framework of this Ghana Water Policy, there is an objective to 'promote an efficient management system and environmentally sound development of all water resources in Ghana'. In line with the main focus of the WRC to effectively manage the water resources of Ghana, a Water Resources Management Fund (WRMF) has been set up and would be disbursed for projects and activities that address the following:

(a) research activities;
(b) development of efficient water resources database;
(c) Co-operation with other riparian countries;
(d) assistance, where possible, to specific projects initiated by communities;
(e) watershed protection; and
(f) specific projects of concern to water resources utilization, e.g. eradication of noxious aquatic weeds.

The Council for Scientific and Industrial Research (CSIR), amongst its functions, is to encourage coordinated employment of scientific research for the management, utilisation and conservation of the natural resources of Ghana in the interest of development. Within this framework, the CSIR-Water Research Institute conducts research on the country's water resources to provide scientific and technological information and services for socio-economic development.

At present, the Ghana Water Company Limited (GWCL) formerly known as the Ghana Water and Sewerage Corporation (GWSC) which was set up in 1965 (Parliament of Ghana, 1965), is the national agency responsible for domestic and industrial water and sewerage in both urban and rural area. In 1994, a Community Water and Sanitation Division (CWSD) was formed to concentrate on accelerating water and sanitation delivery in the rural areas. This CWSD advocates community ownership and community management approach.

In the case of drinking water for both the urban and rural areas, the government is required, according to existing law, to approve tariffs so that the water supply utility can break even on its revenues and expenditure. Unfortunately, tariffs approved have over protected the consumers and never been adequate (to enable the utility meet its debt and other financial obligations) with the consequent negative impact on the economy. In order to arrest the situation, a Public Utilities Regulatory Commission (Parliament of Ghana, 1997) has been set up to ensure that tariffs are fair to the consumer and the service provider.

In the irrigation sector, the Ghana Irrigation Development Authority, set up in 1985 under SMCD 85 (1977), is responsible for the management of irrigation schemes. Farmers are now encouraged to form cooperatives and determine their own management with the authority only advising on technical aspects. The provision of credit, farm inputs, and availability of storage, processing facilities and marketing have been chosen as the best options for integrating agriculture into economic develop.

The Environmental Protection Council was set up in 1974 (NRCD 239, 1974) and has been transformed into an Environmental Protection Agency with executive powers to deal with environmental issues. The agency now demands the preparation, presentation and approval of Environmental Impact Assessment Statements for development projects prior to their implementation in any part of Ghana.

The Meteorological Services Department and the Hydrological Services Division of the Ministry of Works and Housing provide hydrometeorological and hydrometric data, respectively, to support the sustainable management of the water resources and the environment in Ghana.

In addition to the above-mentioned public institutions, several local and international Non-Governmental Organisations are involved in various water related activities in Ghana.

5 CONCLUSION RECOMMENDATIONS

The sustainable development of the entire Volta Basin calls for the promotion of mutually beneficial economic cooperation with riparian countries. The integrated water resources management of the Volta Basin must therefore have the aims to:

(a) manage the basin for sustainable development to increase food and agricultural production;
(b) introduce proper farming practices to reduce erosion and sedimentation; introduce regulations and legislation to reduce pollution;
(c) have a coordinated plan of action to reduce flooding; and
(d) improve health and meet basic energy needs for present and future socio-economic development.

It will be appropriate to encourage the sharing of benefits of the water resources of the Volta Basin and aquifers by extending hydropower and potable water to other co-riparian states, where feasible. In this way riparian communities of the Volta Basin will be obliged to put in conservation and management policies which will enhance the overall sustainable integrated water resources management of the basin.

Since the demand for water, i.e. for domestic and industrial usage, irrigation and hydropower generation keeps on increasing in response to the ever-expanding population and the changing lifestyles of society, there is the urgent need to properly conserve and efficiently manage the water resources in the Volta River Basin, which forms the bulk of the country's water resources. Apart from the fact that the water resources are both temporally and spatially distributed, there are other threats from increasing evaporation, reducing rainfall amounts, pollution and seawater intrusion into the fresh waters. To this end, the following are recommended for the management and protection of all river basins in Ghana including the Volta:

(a) all river basins in Ghana should be properly delineated and protected through afforestation and reforestation to save some streams from drying up and to avoid decreasing runoff from the rivers. This should be backed by proper and enforceable legislation;
(b) extensive deforestation should be discouraged, and reafforestation programmes be introduced through proper planning;
(c) communities living close to streams and rivers should be educated through mass education, mobile cinema vans, etc., not to foul the streams or rivers by disposing waste into rivers. Environmental education should be placed in the curricula of first-and second-cycle institutions in the country;
(d) sand winning activities close to rivers or on riverbeds should be halted, as these introduce turbidity and create ponds that impede the smooth flow of rivers, especially in the dry season. Equally, the removal of stones close to rivers or from river beds for quarrying should be discouraged, as these activities expose river bottoms to faults and cracks that induce excessive seepage;
(e) improper fishing methods of damming rivers and using chemicals should be stopped through education as this introduces turbidity, pollution and also creates ponds;
(f) education on proper land use practices should be done. For example, people should be educated on the negative effects of farming on hill slopes as sediments are likely to be washed into water bodies. Ecologically sound land use systems should be adopted;
(g) all effluents from major industries, including the mining and agricultural sector, should be treated before being discharged into natural water bodies. This is to check pollution and conserve the fresh water quality, and this should be backed by legislation and strictly enforced;
(h) there should be efficient management of water quality. Public and private sectors should be required to undertake proper Environmental Impact Assessment (EIA) of their activities. The laws of Ghana should be re-evaluated and amended to make them consistent with modern trends. The laws should be simple, easy to implement, and should be enforced;

(i) the quality of well water could be improved, through proper construction and adequate protection of well sites from surface runoff and wastes. There should be education and the provision of proper liquid and solid waste disposal facilities to avoid bacteriological contamination of water bodies;

(j) there should be proper education on how to handle pesticides and how to use the right quantities for better application to avoid or minimise the contamination of water bodies;

(k) development of water supply or irrigation schemes should be kept reasonably away from the sea to avoid saline waters during low river flows and/or the high tide;

(l) there should be adequate collaboration or coordination between the water agencies to avoid conflicting interest of water use; and

(m) adequate resources should be made available for research in hydrology and water resources of the Volta River Basin in particular and the river basins of Ghana in general; Scientific research is especially needed to determine the effect of water use and climate change on the hydrology and water resources of Ghana and to determine the groundwater recharge and groundwater-surface water interactions.

It is hoped that the Water Resources Commission (WRC) will get all the co-operation it needs and, in collaboration with the other public institutions, civil authorities and Non-Governmental Organisations, manage the water resources and the environment of the Volta River and all other river basins in Ghana on a sustainable basis.

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