WATER RESOURCES COMMISSION, GHANA

ANKOBRA RIVER BASIN -

Integrated Water Resources Management Plan

March 2009

PREAMBLE

Right from the establishment of the Water Resources Commission (WRC) a priority task has been to introduce the basic principles of Integrated Water Resources Management (IWRM) at local level in selected river basins. Towards this aim, WRC is elaborating IWRM plans for priority basins, and so far two plans have been prepared, i.e. for the Densu River Basin and for the White Volta River Basin during the period 2007-08.

Hence, the present Ankobra River Basin IWRM Plan is the third of its kind, and this basin was chosen due to the trends witnessed here, including detrimental land and water quality degradation, caused, among other factors, by what otherwise is the hallmark of the Ankobra Basin, namely the many, large-scale gold and other metal mining operations in the basin.

The Ankobra River Basin is a classic case of an area in need of a basin-wide planning approach involving stakeholder participation, awareness raising, capacity building and training, and environmental engineering. It is believed that this approach could lead to the sustainable implementation of effective measures to improve land use practices and management of liquid and solid wastes from the mining activities as well as from the towns and communities within the basin. Other initiatives have already been undertaken towards the goal of reviving the threatened riverine environment, prominently through the recent Mining Sector Support Programme, which included activities in the Ankobra Basin.

WRC has of recently assisted in creating a basin-based IWRM structure for the Ankobra River Basin. The decentralised IWRM structure, which has evolved through a targeted participatory and consultative process, combines the following partners: a broadly anchored stakeholder-oriented coordinating body, soon to be established as the Ankobra Basin Board, planning and executive units of the District Assemblies and WRC's Ankobra Basin office in Tarkwa (serving as secretariat for the Board).

In parallel to the organisational arrangements, activities of a more technical nature have been ongoing, which eventually resulted in the present IWRM Plan. This plan should also be viewed as an integral part of the stipulations in the WRC Act 522 of 1996 to "propose comprehensive plans for utilisation, conservation, development and improvement of water resources" in adherence with the overall National Water Policy of June 2007.

Inasmuch as IWRM is a cyclic and long-term process, the document can be seen as a milestone in this process, in which the status of the water resources situation is documented – a process that should be subject to continuation and updates as the need arises in the future.

It is WRC's sincere hope that this plan can be a useful catalyst towards accelerating concrete water management activities in the Ankobra Basin, and importantly, may also serve as a source of inspiration to advance collaboration among the stakeholders, namely the riparian communities and the mining operations – who all in one way or another depend on the bountiful resources of the basin.

Ben Ampomah
Ag. Executive Secretary
Water Resources Commission
Accra, March 2009

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ABBREVIATIONS

ABB	Ankobra Basin Board
CBO	Community-Based Organisation
CWSA	Community Water and Sanitation Agency
DA	District Assembly
Danida	Danish International Development Assistance
EIS	Environmental Impact Study
EPA	Environmental Protection Agency
GIS	Geographic Information System
GWCL	Ghana Water Company Limited
ha	hectare
HSD	Hydrological Services Department
IWRM	Integrated Water Resources Management
km^2	square kilometre
mg	milligram
mm	millimetre
m^3	cubic metre
MDAs	ministries/departments/agencies
MOFA	Ministry of Food and Agriculture
MSSP	Mining Sector Support Programme
MWRWH	Ministry of Water Resources, Works and Housing
NGO	Non-Governmental Organisation
pop	population
SEA	Strategic Environmental Assessment
sec	second
WEAP	Water Evaluation and Planning Model
WHO	World Health Organisation
WRC	Water Resources Commission
WRI	CSIR-Water Research Institute
WSSD	World Summit on Sustainable Development (August 2002)
WQI	Water Quality Index

1. INTRODUCTION

1.1 IWRM in an international context

At the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002, the international community took an important step towards more sustainable patterns of water management by including, in the WSSD Plan of Implementation, a call for all countries to develop "*integrated water resources management and water efficiency plans*". Activities aimed at enhancing "water efficiency" are considered important components of IWRM, and hence should be included as an integral part of an IWRM plan.

The term integrated water resources management (IWRM) has been subject to various interpretations, but the following definition by the Global Water Partnership[1] has been adopted in the Ghanaian context:

> *"... a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems ..."*

Due to competing demands for the water resource (in the worst case resulting in limiting economic development, decreasing food production, or basic environment and human health and hygiene services), the process is intended to facilitate broad stakeholder input in order to build compromise and equitable access. This is particularly the case for developing countries like Ghana, which allocates much effort in addressing poverty reduction and in implementing the UN Millennium Development Goals.

IWRM is a broad based approach to the development of water, addressing its management both as a resource and within the framework of providing water services.

The Global Water Partnership models the IWRM process as a cycle of the following activities:

- establishing the status and overall goals;
- building commitment to the reform process;
- analysing gaps;
- preparing a strategy and action plan;
- improving the legal and institutional management framework; and
- monitoring and evaluating progress.

The goal of preparing IWRM plans as called for at the WSSD has set the tone for a world wide initiative, which Ghana has adopted with the purpose "to promote an ef-

[1] *Global Water Partnership (GWP): Integrated Water Resources Management, Technical Advisory Committee, TAC Background Paper No. 4 (2000)*

ficient and effective management system and environmentally sound development of all its water resources”[2] based on IWRM principles.

1.2 IWRM planning in the Ghanaian context

In Ghana, IWRM plans are thought initially to be prepared at the river basin level starting with the most “water stressed” basins of the country. At a later stage, this exercise can provide input to preparation of an IWRM strategy/plan at national level incorporating trans-boundary water resource related issues. The IWRM plans and strategies shall be prepared with the overall purpose of addressing major problems at a river basin level related to:

- water resource availability;
- water quality; and
- environmental/ecosystem sustainability.

Due account shall be taken to water use, and the social and economic implications of implementing an IWRM plan. Actions to be taken as a consequence of planning shall be prepared based on scenarios describing different approaches for solving major management problems (that might be described with natural resources, socio-cultural, economic and regulatory, administrative and institutional indicators) within a defined time period.

As such the prime outcome to be provided are prioritised and ranked sets of programmes/actions, which from a political, legal, technical, sociological and economic point of view are considered as the most sustainable and efficient solutions. Political (democratic) aspects of IWRM planning in this regard require, that plans shall be elaborated with a participatory approach guided by principles which are imbedded in the concept of Strategic Environmental Assessment (SEA).

Generally, SEA is applied with two purposes:

- to evaluate environmental impacts and to rank the environmental effects of plans and programmes; and
- to evaluate conformity and/or conflicting stipulations between various related plans and programmes.

SEA tools have in Ghana been applied in assessing the first Ghana Poverty Reduction Strategy and during formulation of the National Water Policy. As a continuation of these approaches, a SEA Practical Guide[3] has been prepared, which presents a number of SEA tools applicable to the water and sanitation sector, including water resource planning, development and management.

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[2] *National Water Policy - Government of Ghana, Ministry of Water Resources, Works and Housing (June 2007).*

[3] *SEA of Water and Environmental Sanitation – a Practical Guide. Ministry of Water Resources, Works and Housing; Ministry of Local Government, Rural Development and Environment; and Environmental Protection Agency (April 2007).*

Key aspects, therefore, in the IWRM-SEA process is a participatory approach involving users, planners and policy makers to build commitment; a holistic view that calls for cross-cutting interaction within basins; an integration in terms of upstream-downstream catchment implications; and recognition to the fact that water is an economic good.

As part of a process, the basin-based IWRM plan shall form a widely accepted and easily understood document describing the current state of the water resources and outlining strategies that enable basin-based water management, which adheres to stipulations in the National Water Policy. Thus, the IWRM plan can be considered a "blueprint", that describes steps to be taken towards realising the visions.

1.3 Purpose and institutional setting of the IWRM plan

The target group of the basin-based IWRM plans is planners and decision-makers operating in the water sector, including the river basin boards, who are provided with a tool for "what to do" and for detailing activities and programmes concerning specific interventions. More specifically, the purpose of the IWRM plan is to:

- contribute to the provision of sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use;
- prevent further deterioration and protect the status of aquatic ecosystems with regard to their water needs;
- protect terrestrial ecosystems directly depending on the aquatic ecosystems;
- contribute to mitigating the effects of floods and droughts; and
- provide appropriate water management with efficient and transparent governance in the sector whether at local, district or basin-based level.

IWRM is a cyclic and long-term process. Hence, the IWRM plan can be seen as a milestone in this process, where the status of the process is documented, and the plan inevitably will need to be kept up-to-date when new knowledge surfaces, e.g. related to changes in the hydrological regime and projections of future water requirements.

For the IWRM plan to be successfully implemented, it is imparative that the WRC collaborates with institutions and major water abstractors affected by the plan. This is because the plan impacts on a variety of societal aspects, viz. utilisation and protection of natural resources, social and cultural situations, economics and production, and the legal, administrative and institutional frameworks. It is evident that there must be effective collaboration with planning efforts in these areas.

For instance, WRC has to collaborate with –

- MDAs, CWSA and GWCL in water demand projections;
- MDAs, Lands Commission, Minerals Commission, EPA, MOFA and traditional authorities in catchment management;
- MDAs, EPA, Minerals Commission and mining companies in controlling various wastes into water bodies; and
- EPA, Forestry Commission, Fisheries Department, Water Research Institute and HSD in assessing environmental flow requirements.

The overall institutional setting as it relates to the further planning and implementation of activities and measures outlined in the IWRM plan is depicted in Figure 1.1.

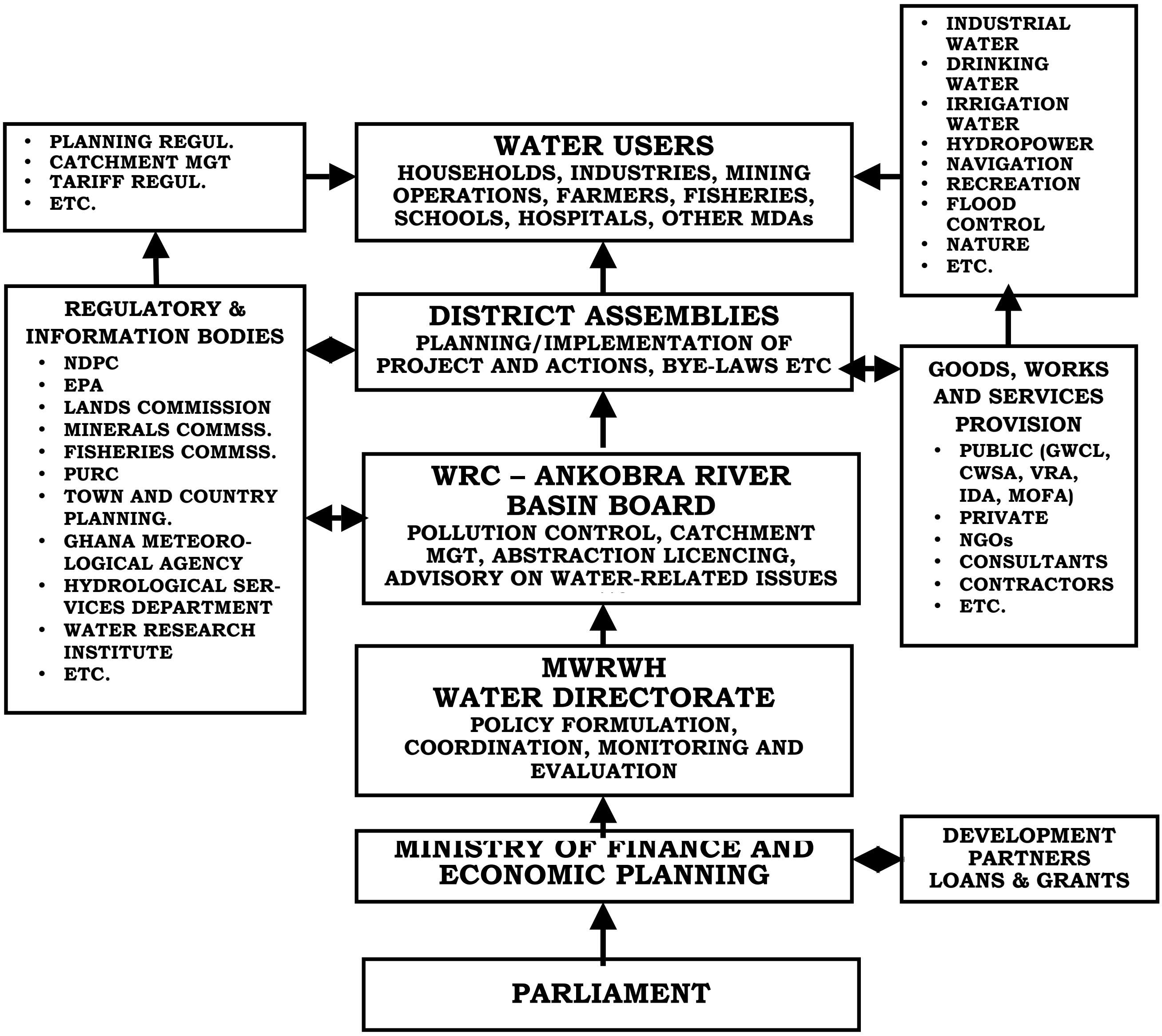


Figure 1.1: Overall institutional setting

1.4 Status of IWRM activities in the Ankobra River Basin

For quite many years Ghana has been planning for and engaged in the introduction of IWRM at various levels of society, and as such has advanced in the IWRM process resulting in a new national water policy and legislation facilitating water resources management and development based on IWRM principles. Furthermore, an enabling institutional framework has been introduced at national level, i.e. establishment of the Water Resources Commission (WRC) and the Water Directorate under the Ministry of Water Resources, Works and Housing, and at local river basin level in the form of creation of river basin boards.

The Ankobra Basin Board (ABB) is the third river basin management set-up to be established. The Board has a consultative and advisory role as it relates to the management of the the Ankobra Basin's water resources and represents a wide sphere of interest groups within the Basin, including the traditional authorities. Its work is facilitated by a secretariat as a decentralised entity of the WRC. The ABB membership combines the following:

(a) A chairperson appointed by the WRC,

(b) A representative of the WRC,

(c) One person representing each of the following within the basin.

- Bibiani-Anhwiaso-Bekwai District Assembly
- Wassa Amenfi West District Assembly
- Wassa Amenfi East District Assembly
- Prestea-Huni Valley District Assembly
- Tarkwa-Nsueam Municipal Assembly
- Nzema East Municipal Assembly
- Western Regional Coordinating Council
- Ministry of Women and Children Affairs
- Ministry of Food and Agriculture
- Environmental Protection Agency
- Minerals Commission
- Ghana Water Company Limited
- Regional House of Chiefs
- Western Regional Association of NGOs
- Chamber of Mines
- Association of Small-scale Mining

(d) The Basin Officer as ex-officio member appointed by the WRC in charge of the Board's Secretariat.

Over the past few years quite many specifically targeted studies and related activities have been completed aimed at providing data and new information of relevance for the IWRM planning. Furthermore, as part of the Mining Sector Support Programme (MSSP) a comprehensive strategic environmental assessment study was carried out in 2007, including the Ankobra River, which specifically looked at the physical and social environment prevailing in the basin. In the following chapter "Baseline Description" these various sources of information and reports are acknowledged as and when used.

1.5 Preparation and structure of the IWRM plan

The WRC has elaborated the present IWRM plan for the Ankobra River Basin as part of WRC's mandate to "*propose comprehensive plans for utilisation, conservation, development and improvement of water resources*" [4] with due consideration to stipulations in the National Water Policy.

The IWRM plan is based on a number of dedicated assessment studies and information reviews all unveiling implications relevant for decisions made during the process of prioritising measures forming the IWRM plan. Guided by SEA procedures and application of "tools", consultative meetings and workshops have taken place during the course of preparation, specifically targeting the Ankobra Basin Board members as well as District Assemblies and their planning officers.

Following the present introductory chapter, Chapter 2 presents the baseline description, which provides the background against which the planning and identification of actions can be made. In Chapter 3 water demand projections are presented based on district development plans and other information notably the 2000 census results. Furthermore, in this chapter a number of scenario analyses are presented comprising different development options and strategies for the utilisation of the basin's water resources, including likely climate change impacts on the water resources.

Chapter 4 describes the consultative process followed towards identification and ranking of water resource management problems and issues as perceived by local stakeholders and planners of the basin. As result of this process the chapter further presents an action plan comprising of a number of prioritised activities and measures for implementation required to meet the water resource management challenges of the basin. The final Chapter 5 concludes the IWRM Plan by outlining the steps to be initiated to move forward towards implementation of the action programme.

[4] *Water Resources Commission (WRC) Act No. 522 of 1996*

2. BASELINE DESCRIPTION

2.1 Physical, demographic and socio-economic features

The Ankobra River flows through the tropical, evergreen, wet forest in the south-western portion of Ghana. Because of the increasing destruction of vegetative cover and large-scale mining activities, the degradation of the environment has become an important concern in the basin.

Although droughts rarely occur, the increasing degradation of the surface water resources within the basin is likely to precipitate shortages for production of potable water in the future. Groundwater-based water supplies, therefore, are likely to continue to be exploited as the principal resource for provision of potable water to the riparian communities.

2.1.1 Location and topography

The Ankobra River Basin is located between latitude 4° 50' N and 6° 30' N and longitude 1° 50' W and 2° 30' W. The basin is bounded to the east by the Pra Basin, to the north and west by the Tano Basin and in the south-east by the small coastal Butre Basin.

The basin belongs to the physiographic region called the Forest-dissected Plateau. Many years of intensive erosion have reduced the area to a rather uniformly appearing plateau generally at an elevation of 250-300 metres above sea level. The heavy rainfall in the basin and subsequent forest vegetation, which prevents sheet erosion, explains the pronounced dissected nature of the plateau.

The topography of the basin is characterised in the southern half of relatively flat land, which gives way in the mid to northern sections of the basin to characteristic rounded hills, which occasionally are also steep-sided. The hilly terrain is prominent around Wassa Akropong, a chain of hillocks forming the north-eastern rim of the basin, south of Dunkwa and north of Awaso in the upstream north-western corner of the basin. The hilly terrain reaches an altitude of close to 500 m above sea level. The topography of the basin is depicted in Map 1 (inserted at the end of the chapter).

The Ankobra River Basin belongs to the Western River System and covers an area of about 8,460 km^2. The river takes its source from the hills north of Basindare (near Bibiani) and flows for about 260 km mostly due south before it enters the Gulf of Guinea at Asanta a few kilometres west of Axim.

2.1.2 Administrative structure, population and settlement pattern

Some 94% of the Ankobra River Basin area is located within the Western Region. Following the basin's eastern boundary some 5% of its area is within the Central Region, and a mere 1% in the Ashanti Region around the northern fringe.

A total of 11 districts are represented within the basin as follows:

Western Region:

- Bibiani-Anhwiaso-Bekwai,
- Wassa Amenfi West,
- Wassa Amenfi East,
- Tarkwa-Nsueam (up to 2007 part of Wassa West),
- Prestea-Huni Valley (up to 2007 part of Wassa West),
- Mpohor Wassa East,
- Nzema East, and
- Ahanta West.

Central Region:

- Upper Denkyira,
- Twifo-Heman/Lower Denkyira.

Ashanti Region:

- Atwima Mponua,

The land area contributed by the portions within the basin of the four districts Wassa Amenfi West, Wassa Amenfi East, Wassa West and Nzema East constitutes more than 80% of the entire basin area. In contrast, the portions of the two districts Ahanta West and Twifo-Heman/Lower Denkyira constitute an insignificant part of the basin area amounting to less than 1% combined. The administrative set-up with district demarcations in the basin are depicted in Map 2 (inserted at the end of the chapter).

Based on the 2000 Population Census[5], Table 2.1 presents the population size and distribution within the basin. The settlement categories is based on the population threshold of 5,000 people for urban and less than 5,000 for rural settlements. The portion of a district's rural population living within the basin is estimated by matching the proportion of the area of the respective district, which is located in the basin, and using the percentages to calculate the rural population. The location of a number of the major settlements/towns within the basin is also indicated on Map 2.

The population increases recorded in the latest inter-censal period (i.e. between the censuses of 1984 and 2000) showed in average for the Western Region an annual growth rate of 3.2 % as compared to the national average of 2.7 %. However, more locally within the basin, much higher growth rates were realised particularly in certain parts of the Wassa West District in vicinity of the gold mining areas, which showed growth rates of above 10% during that period.

Internal migration is the most important determinant of this marked population growth in these parts of the Ankobra Basin. As the localities are becoming relatively attractive for migrants, new settlers are likely to gravitate to the localities to swell up the existing population. The driving force behind this phenomenon is mining – both large-scale and "galamsey" operations – but also the cocoa and rubber plantations, and the timber industry in general, can explain this trend.

[5] *Ghana Statistical Service (2002) : 2000 Population and Housing Census (official results on CD- ROM)*

As an average for the whole Ankobra Basin, the population density (year 2000) was given as 80 pop/km^2 as compared to the overall national average figure of 77 pop/km^2. The total population (year 2000) residing within the basin was 680,000 of which the urban population constituted a little less than 20%. These demographic features specified at district level are also presented in Table 2.1.

Table 2.1: Population in the Ankobra River Basin (2000 Census)

Region	District	Settlement category	Population (2000)	Area in basin (km^2)	Area in basin (%)	Density (pop/km^2)
Western	Bibiani-Anhwiaso-Bekwai	rural	60,800	646	7.6	118
		urban	15,200			
	Wassa Amenfi West	rural	104,500	1,575	18.6	66
		urban	0			
	Wassa Amenfi East	rural	108,900	1,640	19.4	71
		urban	7,400			
	Wassa West	rural	149,700	2,325	27.5	100
		urban	82,600			
	Mpohor Wassa East	rural	25,000	384	4.5	65
		urban	0			
	Nzema East	rural	67,500	1,343	15.9	66
		urban	21,800			
	Ahanta West	rural	2,000	35	0.5	57
		urban	0			
Central	Upper Denkyira	rural	24,800	402	4.8	62
		urban	0			
	Twifo-Heman / Lower Denkyira	rural	800	15	0.2	53
		urban	0			
Ashanti	Atwima Mponua	rural	9,000	95	1.0	95
		urban	0			
Ankobra Basin, total		rural	553,000	8,460	100.0	80
		urban	127,000			

2.1.3 Socio-economic profile

The water resources of the Ankobra Basin contribute significantly to the livelihood of the people living in the basin. Water is used for domestic and industrial purposes, especially, in the metal extraction industries, but insignificantly in the agriculture sector because of the abundance of rainfall in the basin throughout the year.

The main occupation within the basin is agriculture, which employs about 65% of the entire population. The majority of the people live in rural communities and indulge in slash and burn or shifting cultivation on a subsistence scale. They grow staples such as plantain, cassava and cocoyam. However, many companies as well as individuals in the basin own cocoa, citrus, oil palm, coconut and rubber plantations.

There is little fishing in the basin. Commercial fishing activities are confined to the coast zone in the south. Other fishing activities take place in the streams and rivers on a subsistence scale.

Logging is an important industry within the basin and harvesting of timber is carried out in concessions granted to timber companies by the Forestry Commission. Fuel wood, harvested mainly from the forests, is the main source of energy for the residents within the basin.

The hallmark of the Ankobra Basin is the intensive mining operations, which are of utmost importance in context of the national economy. More than ten large-scale surface gold and other metal mining companies are hosted in the basin. In addition, many small-scale ventures and illegal mining (galamsey) operations are also found in the basin.

Other major industries in the basin are the manufacture of lorry tyres at Bonsaso (on divestiture), the manufacture of latex rubber in the Ahanta West District and the manufacture of glass bottles at Abosso (on divestiture/idle).

In the urban areas, the economic activities are more diversified and the prominent occupations include wholesale and retailing, manufacturing and other commercial activities. The small-scale industries include saw milling, block making, local soap manufacturing, black-smith and metal work. Many large markets, such as those at Tarkwa and Sefwi Bekwai form points of contact between rural and urban residents.

The above socio-economic pattern is highlighted in Table 2.2. The figures in the table are derived from the 2000 Census data, and are given as percentages of the economically active population (above 15 years of age). In spite of the important status in a national economic context, it is worthwhile noting that the mining sector only occupies a relatively small portion of the basin's population.

Table 2.2: Occupation (in %) of the economically active population [(a)]

Economic activity (industry)	District					
	Bibiani-Anhwiaso-Bekwai	Wassa Amenfi East and West	Wassa West	Mpohor Wassa East	Nzema East	Upper Denkyira
Agriculture and forestry	67.0	75.6	45.8	70.8	54.2	65.3
Fishing	0.2	0.3	0.5	1.0	9.6	0.9
Mining and quarrying	5.1	1.6	12.4	3.3	1.2	2.9
Manufacturing	6.7	6.6	9.7	9.9	10.2	7.4
Wholesale and retail sale	4.2	2.7	14.5	3.9	9.1	8.9
Construction	5.0	1.7	2.5	1.8	1.4	1.9
Hotel and restaurants	0.5	0.3	2.4	0.6	2.9	1.3
Transport and communication	3.2	1.6	2.7	2.2	2.3	2.2
Education	3.6	3.0	3.3	3.2	3.2	3.7
Other (unspecified) activity	4.5	6.6	6.2	3.3	5.9	5.5
	100.0	100.0	100.0	100.0	100.0	100.0

[(a)] *Only districts with a sizeable population within the basin are included in this table*

2.1.4 Land use pattern and ecological trends

The high rainforest zone of southern Ghana is the richest and most diverse of the terrestrial ecological zones of Ghana both in terms of flora and fauna. The three-tier structure of trees with closed canopy of branches and little or patchy undergrowth as well as a preponderance of lianes (large woody climbers) are characteristic features of the original rainforest vegetation. The ecology of the basin has been greatly altered by human activities through time. The basin, which hitherto, was poorly developed and thinly populated, is now opened-up due to the location of the extractive industries. Within the past 10-20 years, the ecological perspective of the Ankobra Basin has changed profoundly. There is a rapid decline in forest cover as a result of marked shifts in land use caused by increased agriculture and mineral extraction.

At present, the Ankobra Basin traverses three sub-types of the high rainforest zone viz. (i) the moist semi-deciduous, (ii) the moist evergreen and (iii) the wet evergreen forests. Most of the north-western upstream part of the Ankobra Basin lies in sub-zone (i) which is characterized by very tall trees (up to 60 m). It is the most productive of the forest sub-types and has seen significant conversion of land to agricultural purposes. Cocoa and food crop farms have replaced most of the off-reserve forest lands, the main food crops being plantain and cassava. The mid-section of the Ankobra Basin lies mostly in sub-zone (ii) with trees being shorter in stature compared to the moist semi-deciduous sub-zone (tallest trees up to 43 m). Sub-zone (ii) is rich in economic species and thus has been heavily logged, making way for farmers to expand their farmlands.

The wet evergreen forest sub-zone covers most of the southern downstream section of the Ankobra Basin. It has relatively poor soils and therefore is not attractive to cocoa farmers. However, plantations of rubber trees, oil palm and coconut palm dominate the zone.

The Ankobra Basin contains deposits of all the minerals produced and exported from Ghana. Hence, much investment has gone into mining prospecting and mineral exploitation with a steady increase in the operations at the expense of an accelerated rate of deforestation and pollution. The mining concessions are located mostly in the mid-eastern portions of the basin.

From various perspectives, the Ankobra Basin and it water resources are under siege. The main factors at play are mining, logging and farming along the length and breadth of the basin. Map 3 (inserted at end of chapter) provides a simplified overview of the land use/cover situation as derived from satellite image maps produced in the year 2000. From similar image maps representing year 1990, Table 2.3 summarizes the development in area coverage of the forested and arable lands as it has occurred during this ten-year period.

Table 2.3: Development in land use/cover of the Ankobra Basin (1990-2000)

Year	Forest reserves	Forested areas with dense tree cover	Arable land	Settlements and unclassified areas
1990	25%	55%	15%	5%
2000	15%	35%	40%	10%

2.1.5 Protected areas

Forest reserves

The Ankobra Basin has 19 forest reserves under the management of the Forest Service Division of the Forestry Commission. Some of the reserves provide the head waters of tributaries of the Ankobra River, e.g. the Fure and Bonsa rivers have their sources in the Fure and Bonsaben Forest Reserves, respectively. The forest reserves are indicated on Map 4 (inserted at the end of chapter).

Ankasa Conservation Area

Part of the Ankasa conservation area that adjoins the Draw River Forest Reserve, lies in the Ankobra Basin. The Ankasa Conservation Area is under the management of the Wildlife Division of the Forestry Commission, and is home to a wide variety of globally endangered fauna and flora. Some of the endangered fauna found in Ankasa are the Diana monkey (*cercopithecus diana*), Western Black and White colobus (*procolobus vellerosus*), Chimpanzee (*pan troglodytes*), Giant Forest hog (*hylochoerus meinertzhageni*) and the African elephant (*loxodonta africana*). The Ankasa Conservation Area has been developed into a major tourist attraction.

2.2 Water resources

2.2.1 Meteorological characteristics and impact of climate change

Data concerning the meteorological conditions are obtained from the Ghana Meteorological Agency, which operates a number of rainfall stations in the Basin. The location of the meteorological stations is indicated on Map 5 (inserted at the end of chapter).

The Ankobra Basin lies in the southern forest and transitional climatic zones characterised by a bi-modal rainfall regime with two rainy seasons, which extend from April to June and again from September to November. These features can be observed in Table 2.4, which is a summary of monthly rainfall data at the Tarkwa meteorological station.

Table 2.4: Mean monthly rainfall (mm), Tarkwa (1970-2007)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
34	79	141	166	252	291	143	68	153	225	153	71	1,776

Both the spatial and temporal distributions of rainfall in the basin are high. The meteorological statistics show that the mean annual number of rainy days is between 90 and 140 days. The annual rainfall increases southwards and ranges between 1,450 and 1,950 mm. The mean annual rainfall distribution is also shown on Map 5.

The mean annual relative air humidity in the basin ranges from a minimum of 64-79% to a maximum of 92-95% with an average of 77-86%. The mean annual potential evapo-transpiration varies from about 1,300 mm in the south-eastern part of the basin to about 1,550 mm in the most northern part[6].

The meteorological data also shows that the Ankobra Basin is characterised by uniformly high temperatures throughout the year with a mean annual temperature of about 26°C. March is the hottest month in the basin with a mean monthly temperature of about 27-29°C. August is the coolest month with a mean temperature of 24-25°C. Diurnal variation of 3^o-5^oC from the mean is observed in the basin.

In a study by the Environmental Protection Agency[7] the impacts of likely climatic changes on river discharges (runoffs) were analysed for the country. One of the basins included in the study was the neighbouring Pra Basin. The results obtained for this basin are assumed to be applicable also to the Ankobra Basin due to the similarity in climatic and hydrological characteristics of the two basins. It is important

[6] *Ministry of Works and Housing: Water Resources Management (WARM) Study, Information "Building Block" Study, Part II, Vol.3: Information on the South-Western Basin System. Nii Consult (May 1998).*

[7] *Environmental Protection Agency (EPA): Climate Change Vulnerability and Adaptation Assessment on Water Resources in Ghana (February 2000)*

that the impacts and consequences cited in that study report is duly recognised in future water resources planning activities for the Ankobra Basin. The main findings of relevance for the IWRM plan are:

- There was an observed increase in temperatures of about 1°C over a 30-year period, and reductions in rainfall and runoff in the historical data sets.
- Simulations using realistic climate change scenarios (10-20% change in rainfall and a 1-2°C rise in temperature over the respective values for the base period 1961-1990) indicated reduction in runoffs of 10%-20% over the next 30-year period.
- The climate change scenarios also showed a reduction in groundwater recharge at a rate of nearly 20% during the same period.
- Irrigation water demand would be affected by the simulated climate change adding some 40% to the base period water demand.

2.2.2 Surface water availability

The Ankobra River and its tributaries constitute a well watered and perennial surface water system, which only rarely realises prolonged drought occurrences. The main tributaries are the Mansi, Bonsa, Fure/Ankasa and Hwene rivers.

Water (hydrological) balance

Taking the Ankobra Basin as a whole, the water (hydrological) balance representing a full year has been estimated based on criteria derived at from the previous cited WARM study and earlier work by Opoku-Ankomah and Forson[8]:

- average basin rainfall based on the rainfall distribution (Map 5) set at 1,700 mm annually;
- average groundwater recharge rate set at 20% of rainfall;
- basin runoff set as 16% of rainfall;
- actual evapo-transpiration estimated as the unknown water balance element; and
- contribution from groundwater to river flow (base-flow) and vice-versa not known and, therefore, not included in the calculation.

Table 2.5 below provides a summary of the water balance elements. The results depend to a large extent on the estimated percentages, which determine the amount of the rainfall that ends up as surface water runoff and as groundwater recharge. Since the Ankobra is a perennial river, the groundwater baseflow could be significant. This would result in a decrease of net groundwater recharge and a higher value for the estimated evapo-transpiration.

From the table, it can be seen, that on an annual basis the average "yield" of the Ankobra Basin (surface water availability) amounts to 2,300 million m^3. By using this basin runoff, the annual flow volume at various points along the Ankobra River and for some of the main tributaries has been estimated (calculated on the basis of sub-basin area) as listed in Table 2.6.

[8] *Opuku-Ankomah, Y. and M.A. Forson: Assessing surface water resources of the South-Western and Coastal Basin Systems of Ghana. Hydrological Sciences Journal 43(5), 1998.*

Table 2.5: Annual water balance for Ankobra Basin

Water balance component	Annual amount	In percent of rainfall
Rainfall	1,700 mm	
Actual evapo-transpiration	1,088 mm	
Ankobra basin area	8,460 km^2	
Rainfall over basin (volume)	14,380 million m^3	100 %
Actual evapo-transpiration (volume)	9,200 million m^3	64 %
Recharge to groundwater (volume)	2,880 million m^3	20 %
Surface water runoff (total for basin)	2,300 million m^3	16 %

Table 2.6: Mean annual flow volume, Ankobra River system

River/locality	Area of sub-basin (km^2)	Mean annual runoff (million m^3)
Ankobra at Ankwaso	670	182
Ankobra at Prestea	4,270	1,160
Ankobra at Dominase	8,120	2,207
Bonsaso sub-basin	1,200	326
Bepo sub-basin	1,100	299
Total Ankobra Basin	8,460	2,300

It must be emphasised, that this water balance presentation reflects a highly simplified situation incorporating assumptions which can be refined, but nevertheless, is judged to provide a realistic measure as to the relative size of the elements of the basin's hydrological cycle.

Runoff statistics

Recorded flow data and information on runoffs are obtained from the Hydrological Services Department, which operates a number of river gauging stations in the Basin. The locations of these monitoring stations are indicated on Map 5 (inserted at the end of chapter). It is noted that the available data records comprise in general broken time series with many gaps over the years. Missing flows of more than a year are common in the data records, although it can be noted that from year 2000/01 and onward the recorded runoff at the Prestea and Dwokwa gauging sites on the Ankobra river, and at the Bepo site on the Mansi and at Bonsaso on Bonsa tributaries, are almost complete with only a relatively small number of missing data. However, through scrutiny of the flow records, inconsistencies are found to such an extent that the available flow records are to be regarded as unreliable.

The flow regime of the Ankobra River exhibits a marked variability in the seasonal runoff within the year as well as in the annual flows. These features are highlighted in Table 2.7 for the seasonal flows and Figure 2.1 for the annual flow volumes, respectively, using the 2001-2007 stream flow data at the Prestea gauging site as an example.

Table 2.7: Ankobra River mean monthly flow (2001-2007), Prestea (m^3/sec)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave-rage
Mean	2.3	3.4	4.2	8.6	23.9	27.9	21.3	11.5	19.2	35.9	19.3	5.5	15.3
Max.	3.0	16.5	10.7	12.3	52.0	57.5	35.5	27.3	43.6	65.5	55.0	7.8	32.2
Min.	1.0	0.5	1.1	5.1	2.7	8.7	10.5	3.7	3.4	8.0	3.1	1.9	4.1

As stated above, it is difficult to compute long-term mean annual flows for the Ankobra basin from recorded stream flow series because of the many long gaps and inconsistencies in the data. However, at Prestea time series of (a) 38 months representing the period 1961-64, (b) 67 months representing the period 1970-76, and (c) 35 months representing the period 1989-92, are available and provide some further insight into the mean annual runoff of the Ankobra River. The three periods recorded mean flows of 59.5 m^3/sec, 36.0 m^3/sec and 25.1 m^3/sec, respectively, which is to be compared to the 2001-2007 mean flow of 15.3 m^3/sec given in Table 2.7. This apparent significant drop in annual flow volumes is hard to explain when considering the annual rainfall amounts over the past 30-40 years, which show only a modest decreasing trend. Therefore, it must be concluded - as also touched on above - that the available flow data must be used with extreme caution, and the results arrived at from using the data must be judged accordingly.

Nevertheless, if the older data are used, an average value of these four "discrete" mean annual flows (weighted based on the time span they represent) is found to be 30.5 m^3/sec, equivalent to an annual flow volume of 962 million m^3. If this figure is compared to the value of 1,160 million m^3 given in Table 2.6 (for the Prestea catchment), obtained from the basin's hydrological water balance computations, it can be observed that the two values are relatively close within a margin of ±10%.

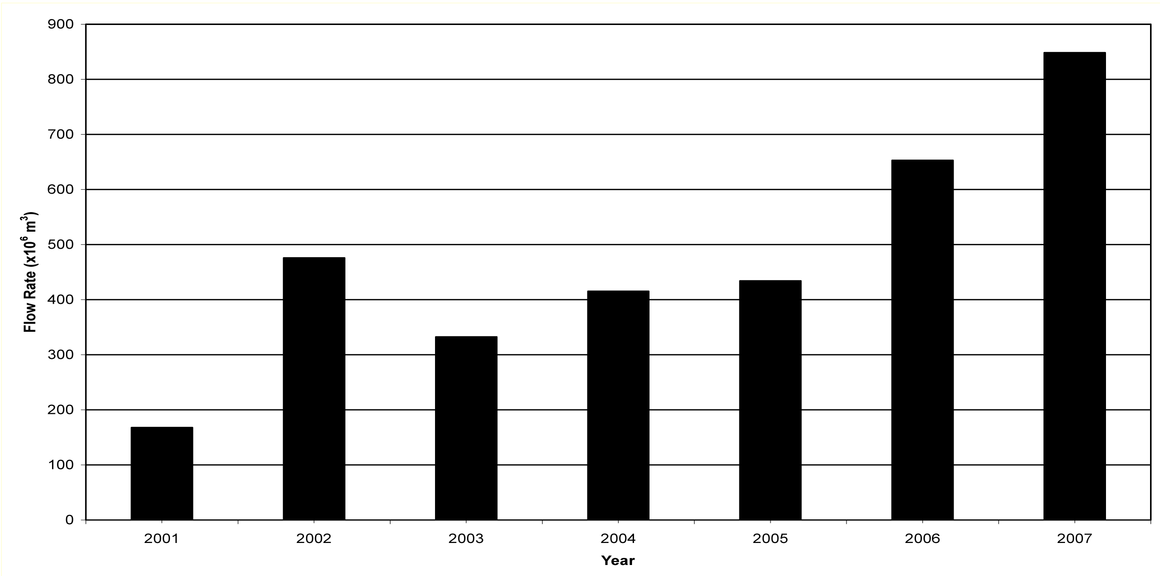


Figure 2.1: Ankobra River annual runoff (2001-2007), Prestea

The erratic flow pattern of the daily flows is clearly illustrated in Figure 2.2, which as an example depicts the hydrograph as recorded at the Prestea gauging site for year 2005.

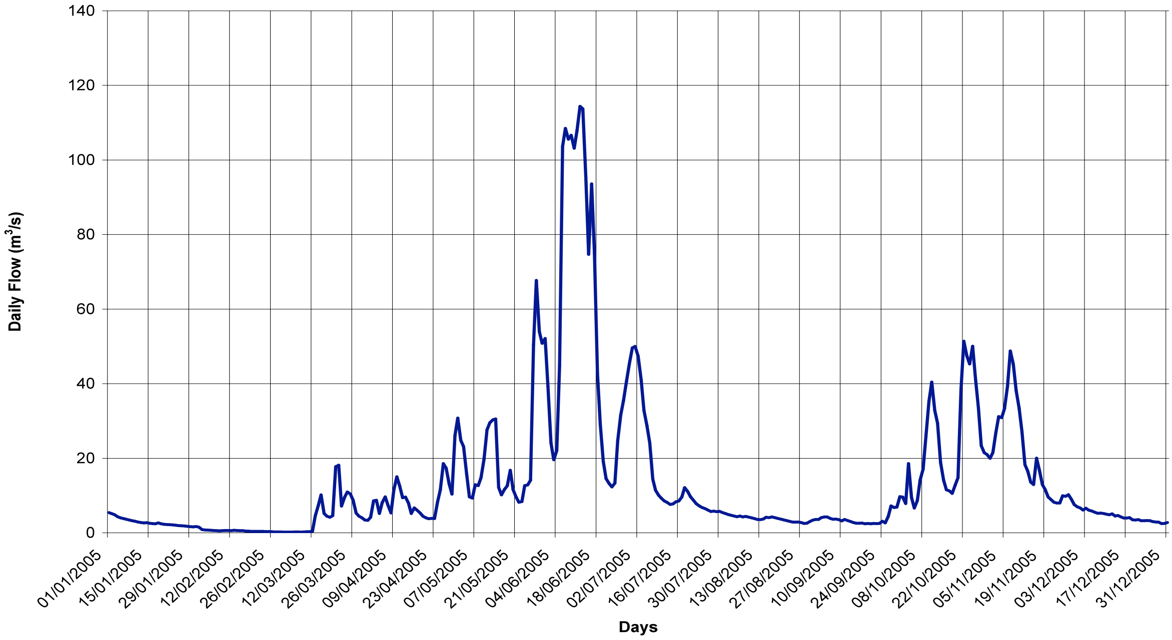


Figure 2.2: Ankobra River daily flows (2005), Prestea

Minimum/environmental flow considerations

Generally, it is the low flow characteristics of the river that determine its suitability as source for a year-round water supply, i.e. direct abstraction without a storage reservoir. Furthermore, the flow of the Ankobra River and its tributaries particularly during the dry season has a significant impact on the flora and fauna associated with the prevailing aquatic system.

Undoubtedly, the aquatic ecosystems of the Ankobra Basin are under a significant pressure due to the poor surface water quality as a result of mining activities, poor solid waste infrastructure and lack of environmental awareness. Therefore, in defining the minimum amount of flow required to maintain the aquatic ecosystems of the basin, a certain acceptable water quality level for the sustenance of these ecosystems must be specified and maintained. This should be done under an overall IWRM framework for the basin.

2.2.3 Groundwater resources

Geology and aquifer systems

The Ankobra Basin is underlain by four geological formations comprising granitic and metamorphic rocks of the Middle Precambrian namely, the Tarkwaian, Upper Birimian, Lower Birimian, and the Granitic rocks. These features are depicted in Map 6 (inserted at the end of chapter). About 50% of the Basin's total area is underlain by the Lower Birimian formation, which consists of phyllites, schists, tuffs and greywackes. The Upper Birimian formation makes about 18% of the total basin area and comprises metamorphosed lavas and pyroclastic rocks. Tarkwaian rocks within the Basin are also made up of quartzites, phyllites, grit and conglomerates. These also constitute percentage coverage of about 18% of the total basin area. The granitic rocks are made up of granites, granodiorites and granite-gneisses of the Cape Coast and Dixcove suites; and they make up the remaining 14% coverage of the total basin area[9].

Hydrogeological data from existing boreholes

Based on data and other information available in the above cited CSIR-WRI report, Table 2.8 summarises the statistical evidence from existing boreholes related to the occurrence and rate of groundwater abstraction in the Basin.

Table 2.8: Borehole characteristics in the Ankobra Basin

Geological zone	Depth of borehole (m)	Depth to aquifer top (m)	Static water level (m)	Borehole yield (l/min)
Tarkwaian	22 - 61	9-40	0-25	8-120
Upper Birimian	18 - 48	13-52	2-12	0-300
Lower Birimian	23-75	10-60	1-25	10-300
Granites	18-65	6-52	1-24	10-500

For the four geological zones, the average yield has been recorded as follows:

- Tarkwaian rocks: 2.6 m^3/hour;
- Upper Birimian rocks: 6.6 m^3/hour;
- Lower Birimian rocks: 4.5 m^3/hour; and
- Granites: 3.9 m^3/hour.

In general it can be stated that the groundwater potential is high and more wide-spread in the Ankobra Basin in comparison with other basins in Ghana. In particular many areas within the Wassa West, Wassa Amenfi East and Nzema East districts have groundwater occurrences to such an extent that they can sustain sizeable abstractions for industrial and domestic water supply schemes. These areas are associated with extensive fracturing and weathering that favour the formation of thick overburden. The yield of boreholes in these areas can be expected to be in the range of 20-30 m^3/hour.

To obtain optimal utilization of the basin's groundwater resources, it is imperative that groundwater schemes are based on state-of-the-art hydrogeological assessment methods, efficient borehole siting techniques as well as proper design, construction and development of the boreholes.

[9] *CSIR-Water Research Institute: Evaluation of existing Hydrogeological and Groundwater Abstraction Data in the Ankobra Basin. Submitted to Water Resources Commission (May 2008).*

2.3 Utilisation of water resources

2.3.1 General overview of water supply situation

Although the surface water is abundant in the Ankobra River system, it is not used that much as a source for production of potable water for the communities in the basin. This is because of the perception held by many that the surface waters, especially in the heavily industrialised zone of Tarkwa-Nsuta-Prestea-Abosso-Bogoso is polluted. Thus, only some tributaries of the Ankobra, e.g. Bonsa river, is used for the supply of pipe-borne water in the basin. Groundwater as a source, therefore, plays a more prominent role in this basin in comparison with other areas in Ghana, and is used in a number of pipe-borne water supply schemes for urban settlements and for the many mining compounds whether for mineral processing or domestic use.

Table 2.9 provides an overview of the water supply situation published as part of the 2000 Census results. The percentages represent the sources of water within the districts of the basin with the quoted percentages representing the entire district. On this basis, to assess the existing water supply situation for the Ankobra Basin as a unit, a weighted average for each water source category was calculated using the proportions of the respective district populations within the basin boundary.

Table 2.9: Main source of drinking water (in % of households)

District	Pipe-borne supply	Borehole and well	Tanker supply	Spring and rain water harvesting	River, stream, pond and dugout
Bibiani-Anhwiaso-Bekwai	11.9	60.2	1.2	7.1	19.3
Ahanta West	17.3	57.1	2.2	16.0	1.5
Nzema East	12.8	46.6	0.3	3.4	36.9
Mpohor Wassa East	11.3	45.2	0.2	4.1	39.2
Wassa West	40.4	25.5	0.6	5.3	27.2
Wassa Amenfi East/West	12.8	42.6	0.6	4.6	39.2
Twifo-Heman / Lower Denkyira	10.0	56.7	0.2	6.3	26.8
Upper Denkyira	29.5	51.7	0.3	3.8	14.0
Atwima Mponua	37.1	35.8	0.6	24.9	1.6
Ankobra Basin (average)	**24**	**40**	**1**	**5**	**30**

The figures in Table 2.9 reveal the prevalent differences between predominantly rural and more urbanised districts concerning pipe-borne water supply versus the traditional sources (borehole/well and stream/pond). Taken in its entirety, it is apparent that only about a quarter of all households in the Ankobra Basin receive water from a piped source – either in form of direct house connections or from public stand-pipes. The prominence of groundwater is also detected clearly from the table values.

2.3.2 Pipe-borne water supply schemes

In the Ankobra Basin, a total of 12 pipe-borne water supply schemes with a total abstraction of 6,265 m^3/day are in operation serving both urban and rural communities. This number does not include supply schemes for the mining operations. Of the 12 schemes, 5 with a total abstraction of 4,125 m^3/day rely on surface water as their source, while the remaining 7 with an extraction 2,140 m^3/day are based on groundwater. The schemes are listed in Table 2.10 (top part) including information about source, intake, treatment capacity and abstraction rates as obtained from the individual water plant statistics. The table shows that about half of the total abstractions are for the Tarkwa water supply scheme.

Table 2.10: Piped water supply schemes in the Ankobra Basin (2007)

Water supply scheme	Source	Intake	Treatment capacity m^3/day	Abstraction	
				m^3/day	million m^3/year
Abosso	groundwater	2 boreholes		380	0.14
Anhwiaso**	surface water	weir	180	153*	0.06
Asawinso***	surface water	weir	180	153*	0.06
Awaso	surface water	weir	180	153*	0.06
Axim	surface water	weir	600	510*	0.18
Diaso**	groundwater	1 borehole		320	0.12
Bogoso***	groundwater	1 borehole		160	0.06
Wassa Akropong**	groundwater	1 borehole		100	0.04
Prestea	groundwater	3 boreholes		620	0.22
Tarkwa	surface water	weir	n/a	3,156	1.15
Christ the King W.W. **	groundwater	1 borehole		410	0.15
Huni Valley**	groundwater	1 borehole		150	0.05
Total for the basin				**6,265**	**2.29**
Pra basin-based schemes also serving populations in the Ankobra Basin					
Bekwai	surface water	weir	180	153*	0.06
Anyanfuri**	groundwater	1 borehole		120	0.04
Dunkwa-on-Offin	groundwater	3 boreholes		720	0.26
Total Pra schemes				**993**	**0.36**

* *abstraction assumed to be 85% of the treatment capacity.*
** *serving rural communities*
*** *schemes serving populations outside the basin*

Furthermore, it can be noted (lower part of the table) that an additional 3 piped water supply schemes, which draw water from sources in the neighbouring Pra River Basin, also serve communities within the basin in the Upper Denkyira and Bibiani-Anwhiaso districts with a total abstraction of 993 m^3/day.

Population served by pipe-borne schemes

Two of the schemes (Asawinso and Bogoso) indicated in Table 2.10 with total abstraction of 313 m^3/day, also serve populations outside the basin. For calculation purposes, it is assumed that half of the supply goes outside the basin. Likewise, the three schemes which draw water from the Pra Basin have been included with an amount of water delivered within the Ankobra Basin estimated at about half the given abstraction rates. Against this background, the present total abstraction serving communities within the Ankobra Basin is estimated at 6,448 m^3/day of which 5,255 m^3/day are for urban settlements and 1,193 m^3/day for rural communities.

Given the fact that most of the pipe-borne supply is provided through standpipes scattered over wider areas, it is assumed that the unit consumption rate (daily consumption per person) is low and in this coverage estimation set at 35 l/capita/day. This implies that the current abstractions serve a population of about 184,200, equivalent to 27% of the basin's total population – a percentage which harmonises well with the similar figure given in Table 2.9, which used the 2000 Census results.

It should be noted, though, that in the above estimation of the number of people being served, the un-accounted water, i.e. leakage and other distribution losses, has not been duly incorporated in the figures. This would imply that the proportion of the population served as given here is somewhat over-estimated.

It is evident that a sizeable "unmet" demand exists within the areas already served by pipe-borne supplies. This "unmet" demand combines the part of the population living in settlements not yet provided with piped water and people living within existing supply areas, but not reached by the water scheme's supply. The reasons for not being able to cater for this "unmet" demand are attributed to various factors, e.g. technical-economic and financial aspects in expanding the systems' treatment capacity as well as the distribution network (the outreach) of the scheme. Water availability (both surface and groundwater) is not a problem as the current abstractions are just tiny fractions of the available water resources.

2.3.3 Point source water supplies

Rural water supply in the Ankobra Basin is derived mainly from boreholes and hand-dug wells. The numbers of these groundwater extraction points have been estimated from the available numbers in the districts spanned by the basin, as provided by the CWSA for the year 2006. These estimates are 420 for boreholes and 140 for hand-dug wells making a total of 560 extraction points in the basin. Most of the boreholes are for domestic purposes and are fitted with hand pumps. However, there are also communities where boreholes are mechanised with motor-driven pumps.

Based on the CWSA borehole design of 200 persons per water point and an average abstraction rate of 4.8 m^3/day (i.e. 8 hours pumping per day at 10 l/min), it can be found that utilisation of the 560 water points translates into a total groundwater abstraction of 2,688 m^3/day serving 112,000 people. This calculation indicates that about 17% of the basin's total population is served through improved water points.

2.3.4 Water for agriculture

Irrigation

Due to the favourable rainfall conditions of the basin irrigated agriculture is not practiced much in the basin. The previously cited WARM study reports only one system, the Kikam irrigation scheme, with a total irrigable area of 30 ha for rice and vegetable produce. The annual water requirement for this system is 0.75 million m^3.

Livestock

As generally done for the purpose of estimating livestock water demand, a percentage figure of the rural population water demand is applied. It can be estimated from the WARM study that livestock water demand is about 10% of the rural demand. This translates into a present livestock water usage in the Ankobra Basin of about 500 m^3/day.

2.3.5 Water for industrial/mining activities

Within the supply areas of urban pipe-borne schemes the water demand by small-scale industries, manufacturing and other commercial activities is included in the schemes production figures.

Most of the mining compounds and a few other larger industries, however, rely on their own water supply abstracting water from both surface water and groundwater sources. Table 2.11 lists these industries and mining operations, including information about water source and supply rate as obtained from WRC's register of granted water abstraction rights (licences).

In total, the licensed abstractions for the larger industrial complexes and mining operations within Ankobra Basin amount to 21.9 million m^3, equivalent to 60,000 m^3/day. Of this amount about 60% is from surface water sources and 40% from groundwater abstractions.

Table 2.11: Water abstractions for mining operations (2007), Ankobra Basin

Company	Source	Licensed abstractions (million m^3/year)	
		surface water	groundwater
Golden Star Bogoso Ltd.	groundwater	-	2.4
Abosso Goldfields Ltd.	surface water and groundwater	0.3	0.4
AngloGold Ashanti (Iduapriem)	surface water and groundwater	1.9	0.1
Ghana Manganese Company Ltd.	surface water and groundwater	3.9	0.1
Ghana Bauxite company Ltd.	surface water and groundwater	0.8	1.0
Ghana Rubber Estates Ltd.	surface water and groundwater	0.6	0.4
Golden Star Wassa Ltd.	surface water and groundwater	4.2	2.9
Goldfields Ghana Ltd.	surface water and groundwater	1.4	1.5
Total for Ankobra Basin		13.1	8.8

2.3.6 Summary of water resources utilisation

Table 2.12 provides an overview of the existing utilisation (abstraction) of the water resources located within the Ankobra Basin as derived from the above description.

Table 2.12: Water resources utilisation (2007), Ankobra Basin

Category	Present (actual) Abstraction		Source
	m^3/day	million m^3/year	
Potable:			
- urban water supply	5,255	1.9	surface and groundwater
- rural water supply	3,880	1.4	largely groundwater
Agriculture (irrigation and livestock)	2,550	0.9	surface water
Mining operations	60,000	21.9	surface and groundwater
Total for Ankobra Basin	71,685	26.1	

2.4 Water quality and pollution

Water pollution has been identified as the number one water management problem in the basin (WRC, 2000[10]). This is due mainly to disposal of untreated mining effluents from locations such as Tarkwa, Beposo, Prestea, Nsuta and Awaso. According to the Mining Sector Support Programme (MSSP) Report[11], the largest source of arsenic seems to be along the Ankobra River from Prestea downstream to Dominase. The report indicates that the amount of arsenic transported by the river in 2006 were 18,000 kg/year. High levels of cyanide in the river were reported in the WRC report cited above. Therefore, the main challenge in the Ankobra River Basin is the impact of mining activities on the quality of the surface water of the basin.

2.4.1 Water quality monitoring

A water quality monitoring programme for the south-western and coastal river systems was initiated by WRC in 2005. In addition to the normal physico-chemical parameters, the programme also includes monitoring of trace metals, pesticides and biological parameters as well as phytoplankton and micro-pollutants as may be detected in bio-tissue (fish). As part of this programme two sampling locations on the Ankobra River at Prestea and Dominase were established. The stations are visited and water samples collected for laboratory analyses five times per year representing the hydrological regime, i.e. samples taken during the low flow and the high flow seasons.

[10] *Water Resources Commission: Water Resources Management Problems Identification, Analysis and Prioritization Study. CSIR-Water Research Institute (September, 2000).*

[11] *Mining Sector Support Programme (MSSP), Ghana: Strategic Environmental Assessment, Assessment of Riverine Material Transport in the Pra, Ankobra and Tano Rivers (April 2007).*

The MSSP monitored the quality of the Ankobra and its principal tributaries, Bonsa and Mansi, to assess the impact of the mining industry on the quality of its water. In all 13 monitoring sites were established on the Ankobra and its tributaries for monitoring purposes.

Many mining companies carry out baseline studies on water quality in developing their EIS for their regular reporting to the EPA. These have tended to be mostly site specific with only limited description of the main river water quality. However, some major investigations have been carried out in the past such as the groundwater studies by Smedley *et al*[12] to determine arsenic levels due to the natural geological setting and their association with gold bearing rocks.

The current trend in monitoring supports physico-chemical monitoring with biological monitoring like what was done during the Mining Sector Support programme[13]. Biological monitoring is premised on the fact that macro-invertebrates that live in streams react to pollution in different ways. While some species are pollution-tolerant and so will increase in numbers in such environments, others are pollution-intolerant and will decrease in number or disappear completely. Thus, by following the numbers as well as the diversity of the macro-invertebrate community present at any reach of a river, it is possible to measure the pollution occurring in a river. Also, comparison of the macro-invertebrate communities upstream and downstream of an effluent discharge point or an area suspected to undergoing an impact can provide direct evidence of such an impact.

2.4.2 Surface water quality

General overview

The results from the WRC study have suggested the following trend of ion dominance in these waters: Na>Ca>Mg>K and HCO_3>SO_4>Cl which therefore confirms the importance of Na and HCO_3. Most of the major trace metals were below detection limits with the exception, in some cases, of Fe, Mn, and Zn. Total suspended solids ranged between 10 and 120mg/l only. High Hg levels were detected in streams where active illegal mining is intense. Arsenic concentrations were also high in these streams. Sediment samples generally exhibited high values of As and Fe.

The increased activities in surface mining coupled with lack of adequate land use practices in the basin has led to accelerated erosion of top soil and consequently turbidity of the water. The trend, therefore, is towards increased turbidity (as shown in Map 7 inserted at the end of the chapter).

The human activities have impacted greatly on the ecosystem and diversity of extant species in the basin. Some of the protected areas have been lost to illegal chain-saw

[12] *Smedley, P. L., Edmunds, W. M., West, J. M., Gardner, S. J. & Peli-ba, K. B.: Vulnerability of shallow groundwater quality due to natural geochemical environment. Health problems related to groundwater in Obuasi and Bolgatanga areas. Report prepared for ODA under the ODA/BGS Technology Development and Research Programme. Project 92/5 (1995).*

[13] *Mining Sector Support Programme. National EIA and SEA Project. Strategic Environmental Assessment. Stage 2: Defining Baseline Conditions. 2B: Monitoring of the biophysical environment in river basins (August 2007).*

operations and from the large-scale surface mining activities. The high rate of timber logging as well as fuel wood extraction has also exacerbated deforestation and, hence, vulnerability of the surface water resource.

Water Quality Index

The Water Quality Index (WQI)[14] is used for comparing and classifying the extent to which water quality is affected by human activities. The index describes the state of a water body as a whole rather than looking at individual parameters and can indicate the suitability of the water for various purposes. The method incorporates selected key physical, chemical and microbial determinants and aggregates them to calculate a WQI value at a specific monitoring/sampling site.

Based on the WQI value, the index puts water quality into four categories as presented in Table 2.13 with a descriptive note concerning the pollution level of the water body in question. The aim of the WQI is to use it as a tool for the protection of natural waters from pollution such that the water falls at least in the upper portion of Class II and more desirably in Class I.

Table 2.13: Criteria for classification of surface waters

Class	WQI - range	Description
I	> 80	Good - unpolluted water
II	50 – 80	Fairly good quality
III	25 – 50	Poor quality
IV	< 25	Grossly polluted water

Table 2.14 and Figure 2.3 below present results of the Water Quality Index (WQI) of Ankobra River at Prestea and Dominase for the period 2005-2007[15].

The WQI for both sites during the period fell within Class II indicating that the quality is fairly good. A closer look at the WQI values, however, indicates that WQI at Prestea is poorer than at Dominase, a downstream station. Further, the WQI values at Prestea between 2006 and 2007 have been slightly better or equal to values at Dominase. Rainfall in the basin in 2006 and 2007 has been higher than in 2005. Thus, the WQI values are, most likely, a reflection of the hydrological condition of the river rather than an abatement of “galamsey” activities or environmental management actions within the basin. It should also be noted that the Dominase site is

[14] *Water Resources Commission (2003): Ghana Raw Water Quality Criteria and Guidelines. Adapted weighted raw water quality index application to Ghanaian river systems. 1st Edition. Produced by CSIR-Water Research Institute.*

[15] *CSIR-Water Research Institute: Water Quality Monitoring of the South-Western and Coastal River Basin Systems - 2005, 2006 and 2007. Annual Monitoring and Assessment Reports. Prepared forWater Resources Commission (January 2006, February 2007 and January 2008 respectively).*

near the estuary of the Ankobra and is under tidal influence so that the time of sample collection may influence the WQI values.

Table 2.14: Sampling results and WQI calculation, Ankobra River (2005-2007)

Parameter	Prestea			Dominase		
	2005	2006	2007	2005	2006	2007
Dissolved oxygen (% saturation)	85.6	95.7	86.0	83.5	89.3	83.0
BOD (mg/l)	3.9	3.6	3.8	3.1	3.9	3.7
Ammonia-nitrogen (mg/l)	1.19	1.51	1.93	0.93	1.17	1.29
pH	7.2	7.1	7.0	7.0	6.7	6.8
NO_3-N (mg/l as N)	0.62	0.69	1.26	1.39	0.89	2.39
Faecal coliform (counts/100 ml)	156	282	152	68	109	111
PO_4-P (mg/l as P)	0.08	0.08	0.04	0.01	0.08	0.04
Suspended solids (mg/l)	26.2	37.8	33.2	18.2	66.8	22.0
Elec conductivity (µS/cm)	102	82	79	100	75	83
Temperature (°C)	26.7	25.8	26.1	26.3	26.3	27.0
Total Score - S (%)	80	78	78	82	76	77
WQI = $S^2/100$	**64.0**	**60.8**	**60.8**	**67.2**	**57.8**	**59.3**

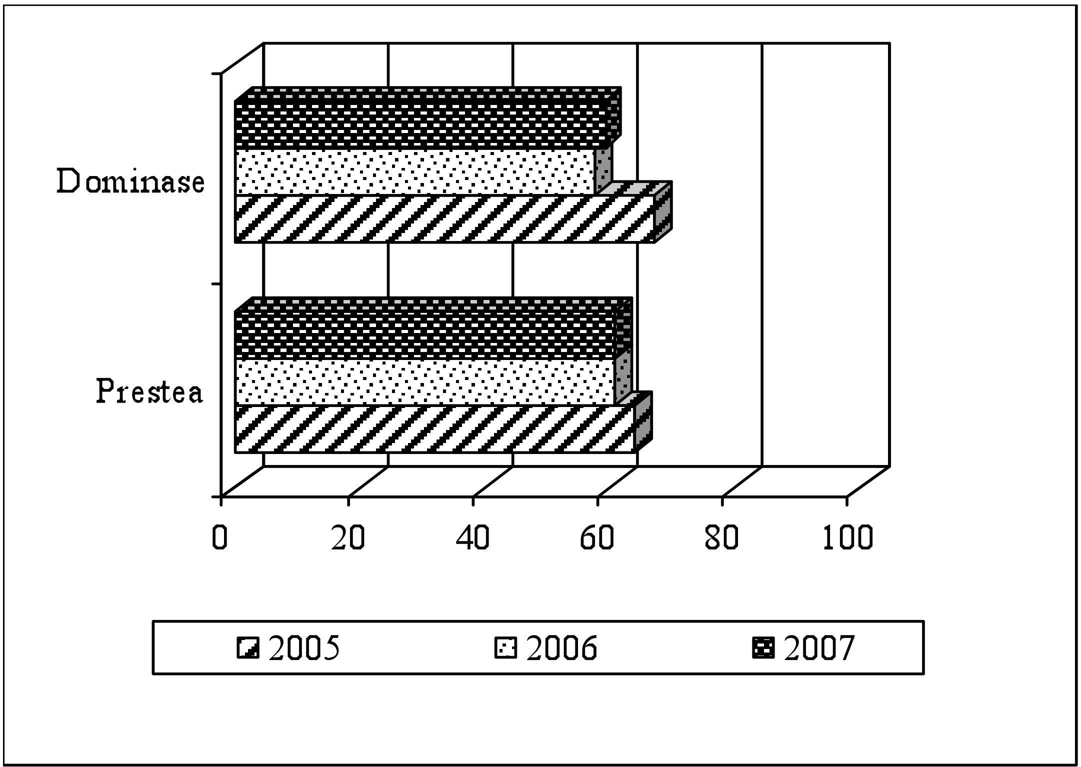


Figure 2.3: WQI, Ankobra River (2005-2007)

Trace metals and micro-organic pollutants

Most trace metals and metalloids are within acceptable limits and at background levels at all the monitoring points. The above cited MSSP study suggests that riverine arsenic seems to originate mostly from the main river, while the larger tributaries, Bonsa and Mansi, contribute less. The distribution of arsenic in Ankobra River is presented in Map 8 (inserted at the end of the chapter). The largest source of arsenic seems to be along the Ankobra River from Prestea and down to Dominase. In the Ankobra River, this could probably be linked to the extensive mining activities, especially "galamsey" operations along the banks of the river.

Biological monitoring

The number of macro-invertebrates collected (ref. above cited MSSP study) from the bed of Ankobra River from its upstream end at Ankwaso, to the downstream site at Dominase, is presented in Table 2.15. For comparison, samples were also collected from the Mansi tributary.

Table 2.15: Distribution of macro-invertebrate taxa in Ankobra River system

Taxon	Mansi at Bepo	Ankobra at Ankwaso	Ankobra at Prestea	Ankobra at Dominase
Oligochaeta		7		
Ostracoda		1		
Macrobrachium	5	12		
Baetidae	36	3	11	
Leptophlebiidae	62		3	
Hepagenidae	3		8	

Tricorythidae	7			
Caenidae	11		5	
Neoperla adusta	3			
Coenagriidae		8		
Calopterygidae		3		
Gomphidae	2			
Libellulidae	2			
Notonectidae		1		
Naucoridae		2		
Veliidae		1	6	
Ceratopogonidae		2		
Chronomini	15	53	15	1
Orthocladiinae	1	5		
Tanyodinae	39	8		
Haliplidae		1		
Gyrinidae	1	19		
Elmidae	113	6	2	
Dytiscidae		2		
Tipulidae				
Mysis larva				
Total Individuals	**300**	**134**	**50**	**1**

The highest number of macro-invertebrates was collected from Mansi at Bepo, whereas the lowest was at Dominase. Also, there are more pollution-intolerant species in Mansi River, which is relatively less impacted than any of the sites on the Ankobra proper. There is no pollution-intolerant taxon in the samples collected from Dominase, ref. Figure 2.4. This may be represented as H', the Shannon-Weiner Diversity Index, as in Figure 2.5.

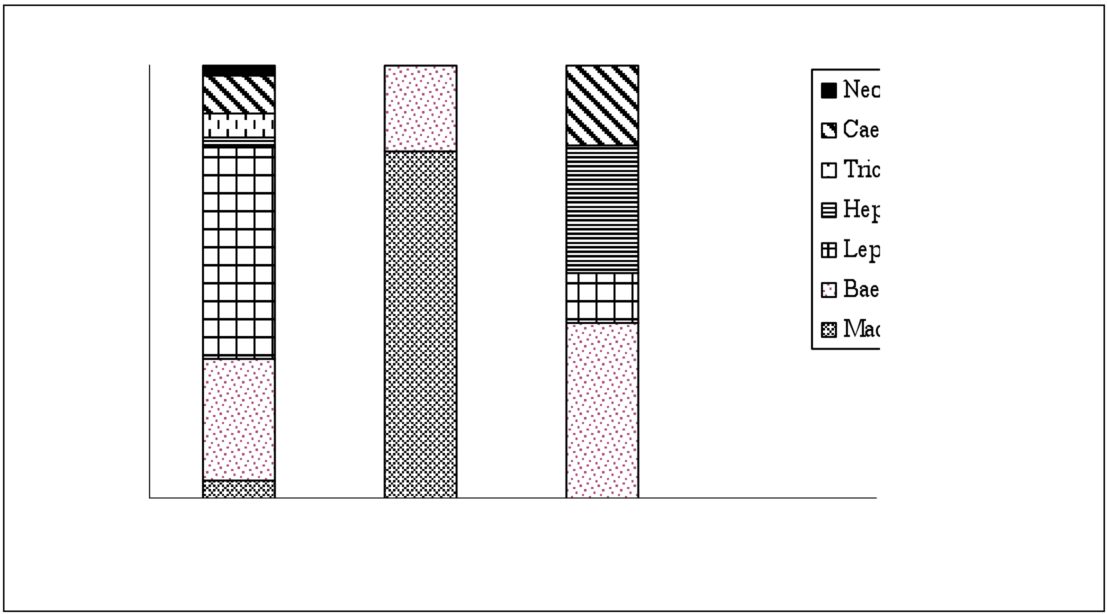


Figure 2.4: Proportions of pollution-intolerant taxa, Ankobra River system

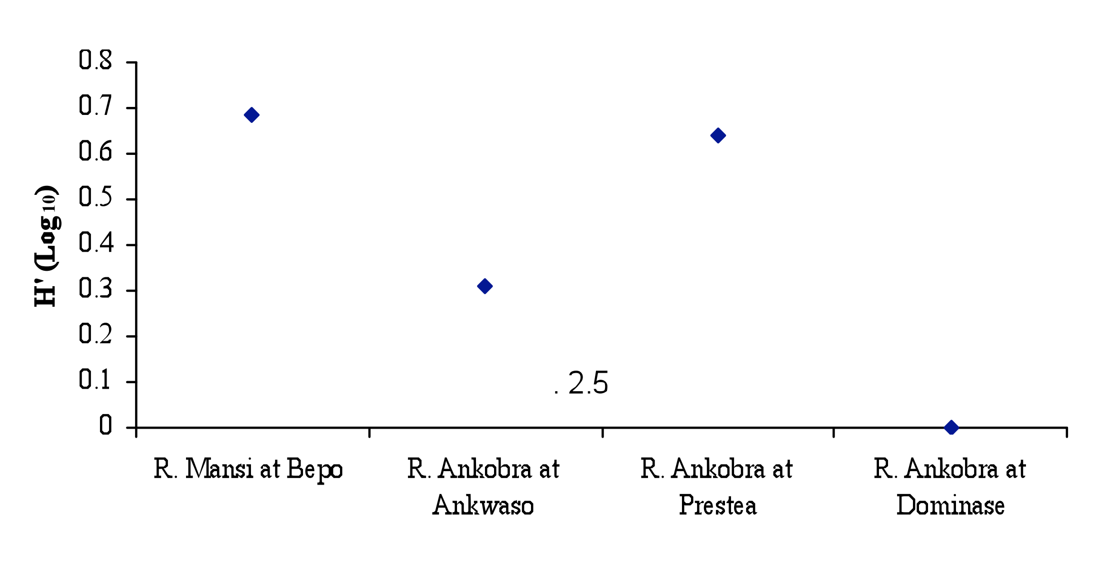


Figure 2.5: Diversity of pollution-intolerant taxa, Ankobra River system

Based on this method of monitoring, it is apparent that the most impacted reach of the Ankobra River is at Dominase, whereas the least impacted is at Prestea. When compared to Mansi River, it can be deduced that the impact of mining on Ankobra River at the Prestea area is not severe, but that the condition of the headstream waters at Ankwaso raises much concern.

2.4.3 Groundwater quality

A study of groundwater in the Ankobra Basin recently undertaken by Kortatsi[16] based on analyses of water from a total of 86 boreholes and hand-dug wells located in the basin found the groundwater to be mildly acidic, poor in conductivity and carbonates. However, HCO_3 and silicates had high concentrations, which are attributable to weathering. The majority of boreholes had a Ca-Mg-HCO_3 dominance. As, Al, Mn , Fe and Hg in some of the groundwater samples were in concentrations exceeding WHO maximum acceptable limits for drinking water. In summary:

- on the whole, the pH level of groundwater is mildly acidic (pH 4.5-6.9), a few boreholes, such as at Tamso have pH <4.0;
- concentration of chloride in waters of boreholes examined all fell below the WHO permissible limit of 250 mg/l;
- in general, taste was not a problem; but turbidity and colour due to high concentration of iron is a potential problem when borehole water is considered for domestic use as many of the water had concentrations higher than 300µg/l; and
- none of the boreholes examined had a concentration of nitrate exceeding the WHO limit of 50 mg/l for drinking water.

In general, it can be stated that the groundwater is of acceptable quality. The problem of high iron in the water can be overcome through the use of aerators or iron removal

[16] *Kortatsi, B. K: Hydrochemical framework of groundwater in the Ankobra Basin, Ghana. Aquatic Geochemistry 13:41- 74 (2007).*

plants. The high concentration of mercury in some boreholes in the basin must receive attention as they are not indigenous to the basin.

2.4.4 Sources of pollution and sanitary condition

Causes of water pollution

Degradation of the water quality of River Ankobra as indicated in Section 2.4.2 poses a series of threats. The increased turbidity, arsenic loads from old mine dumps and exposure of arsenic bearing rocks from the activities of the mining operations as well as accidental spillages from the mines are a threat to the quality of the surface water as well as the groundwater resources.

If not monitored, the large-scale mining operations and growing number of illegal mining activities within the basin have the potential of increasing suspended solids of the river, and consequently the turbidity of the water. Also as indicated earlier these activities tend to increase the arsenic loading of the river. Furthermore, the increasing use of the river for the disposal of both solid and liquid waste by the riparian communities also poses a threat to the water quality. The implications of the above to the water resources in the basin are:

- dwindling availability of good quality water for potable use;
- high water treatment cost;
- high disease prevalence and accidental deaths resulting from metallic poisoning and associated high medical costs;
- loss of biodiversity; and
- water use conflicts.

Overview of sanitary situation

Generally, the sanitary and waste disposal facilities across the basin are inadequate leading to disposal of domestic sewage and garbage into the river system. CWSA is providing KVIPs to households in various communities to improve on sanitation.

The Ankobra Basin is generally suitable for tree crop plantations, especially cocoa. Most of the cocoa plantations are young so little fertilizer is used on the farms presently. However, when plantations get older, farmers resort to improved agronomic practices, and hence, the use of fertilizers and agro-chemicals would undoubtedly be more widespread to increase yields. The result is that runoffs from farms would increase eutrophication of the surface waters and pollution with organic pollutants.

Trends in pollution load

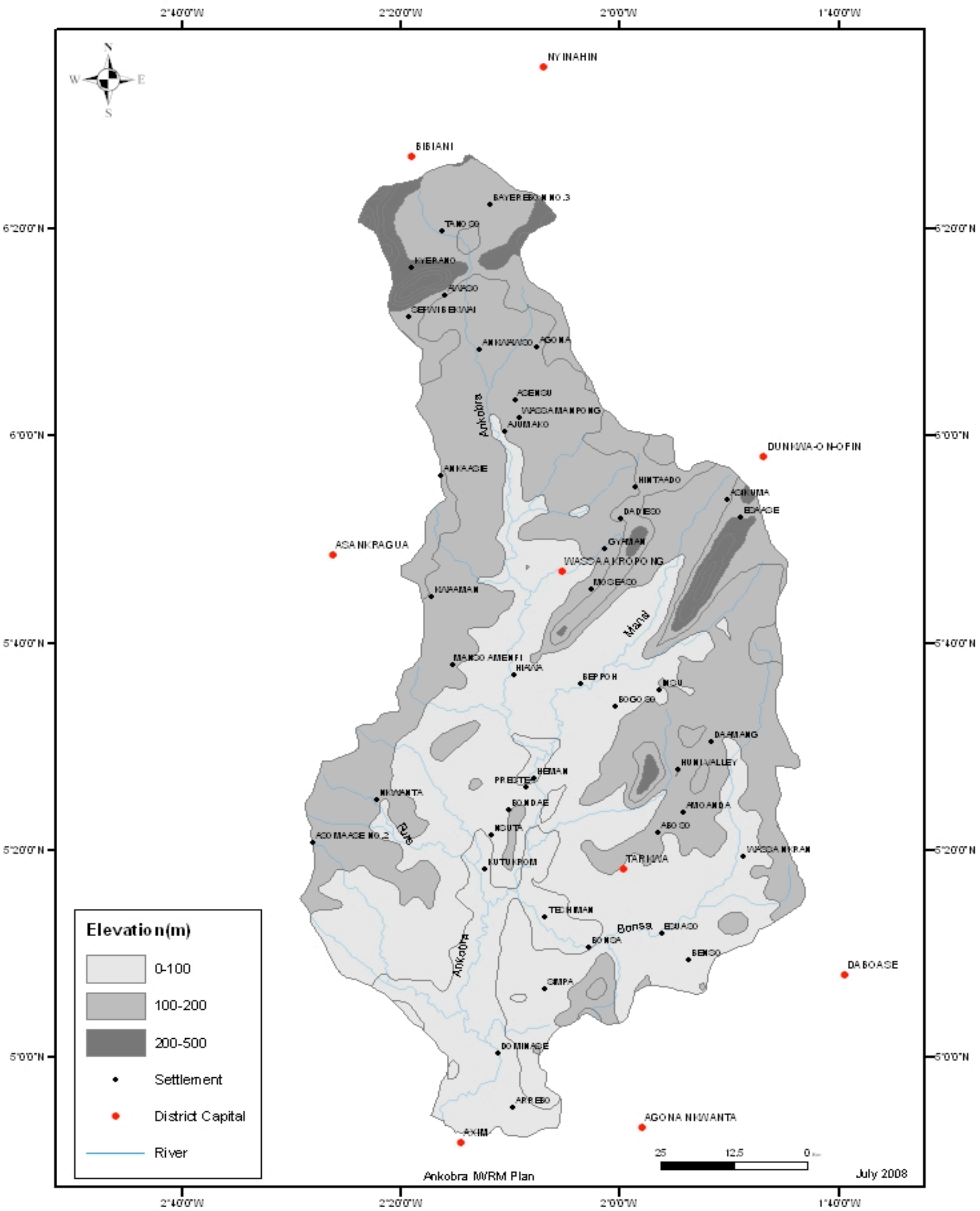
In step with further urbanisation and industrialisation, coupled with increase in water supply coverage in the basin, the likely pollution load and its impact on the water quality is bound to increase markedly.

Arsenic poisoning of surface waters and pollution of groundwater with Hg are likely to increase with the influx of people into the basin practicing “galamsey” activities. Arsenic is commonly present in the ore of the area.

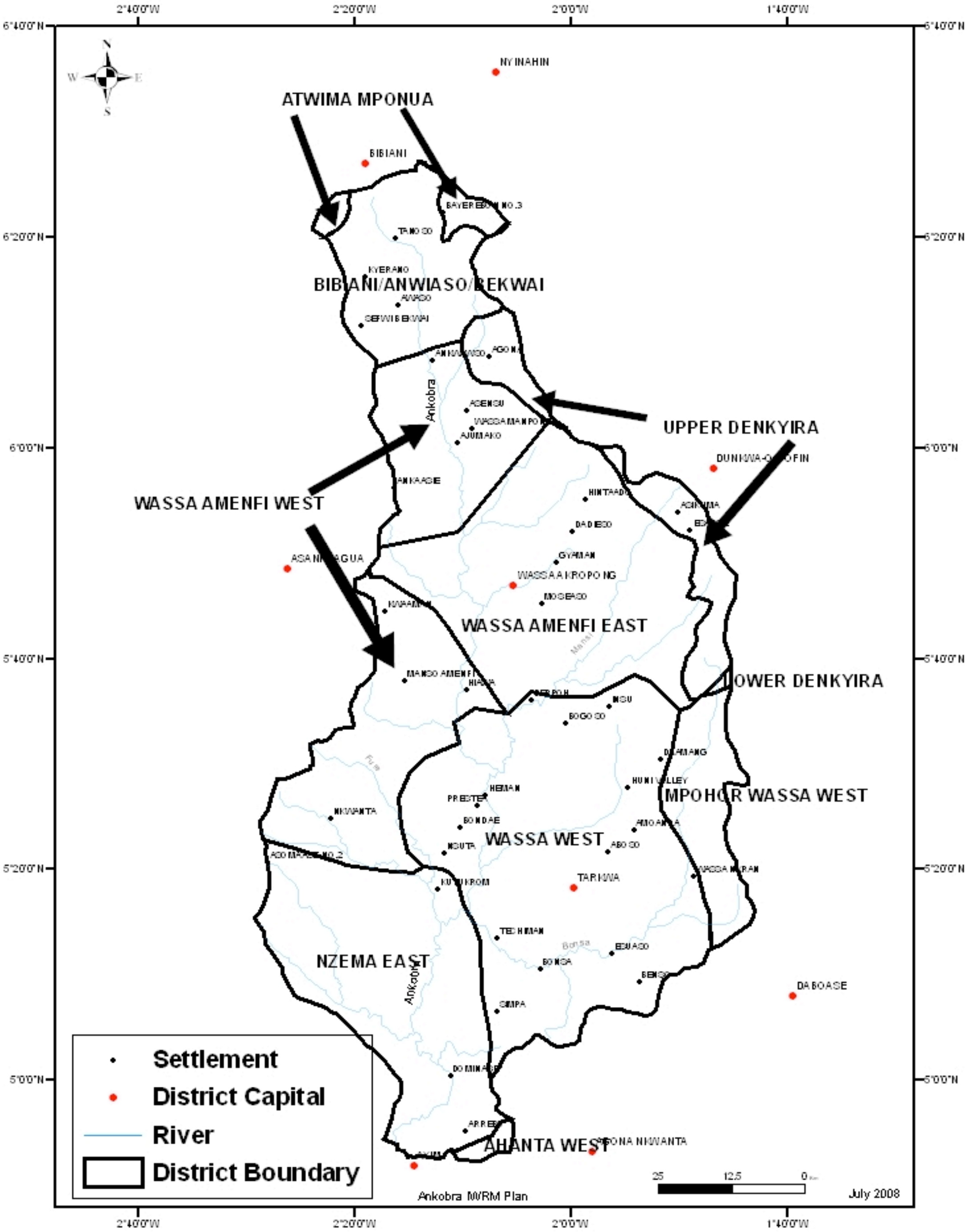
Phosphate levels are slightly more pronounced at the most upstream reach at Ankwaso and also at Dominase, the most downstream of the water quality monitoring points. Their closeness to urban centres would suggest some influence from these sources and this has implications for production of potable water.

The largest source of arsenic and suspended solids seems to be along the Ankobra River from Prestea down to Dominase; and this is likely to increase with expansion of the operations of the large-scale mines as well as the activities of both small-scale and illegal mining operations.

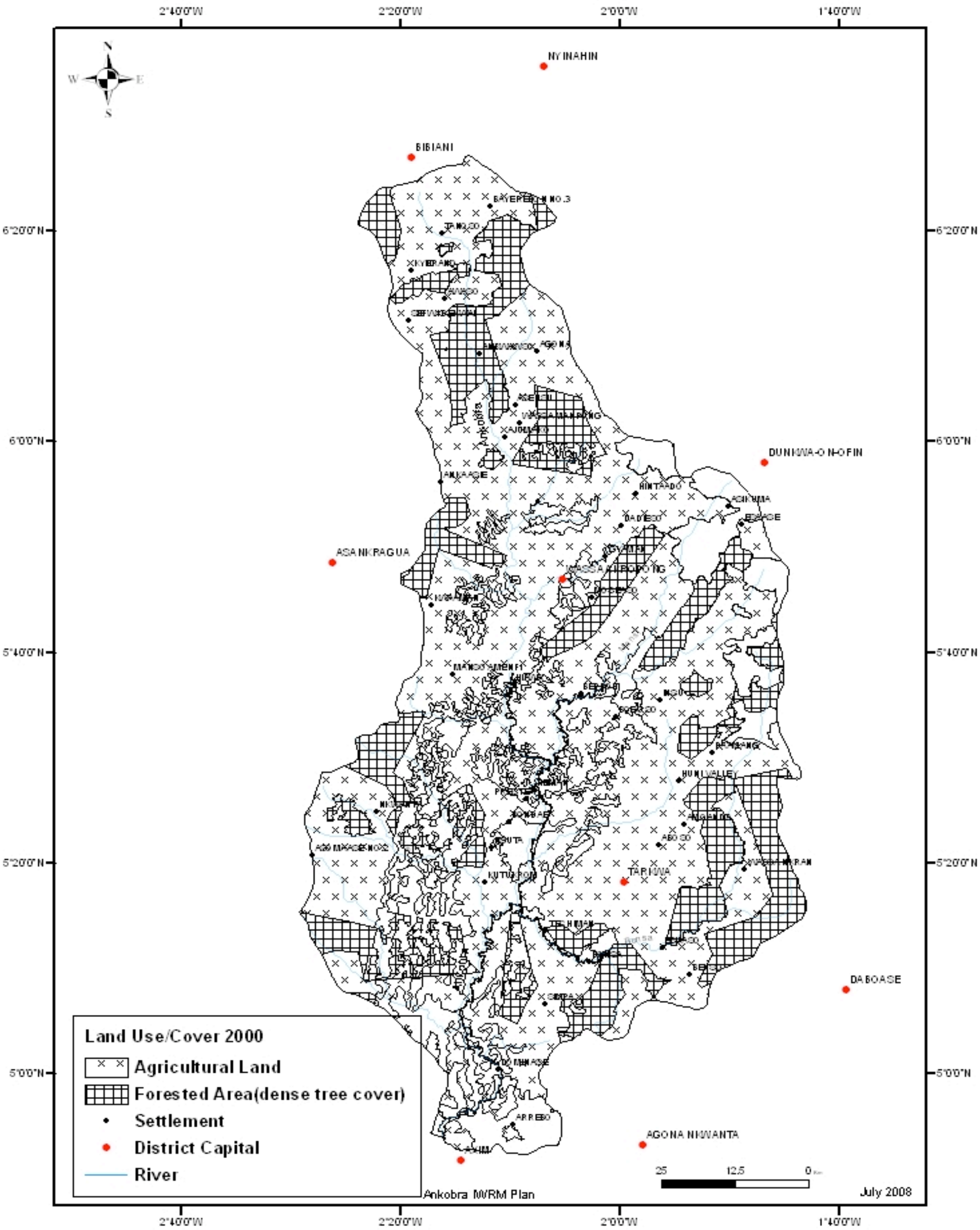
Undoubtedly, introduction of waste water treatment schemes on a broader scale will be required in parallel with further improvement and expansion of the water supply infrastructure.



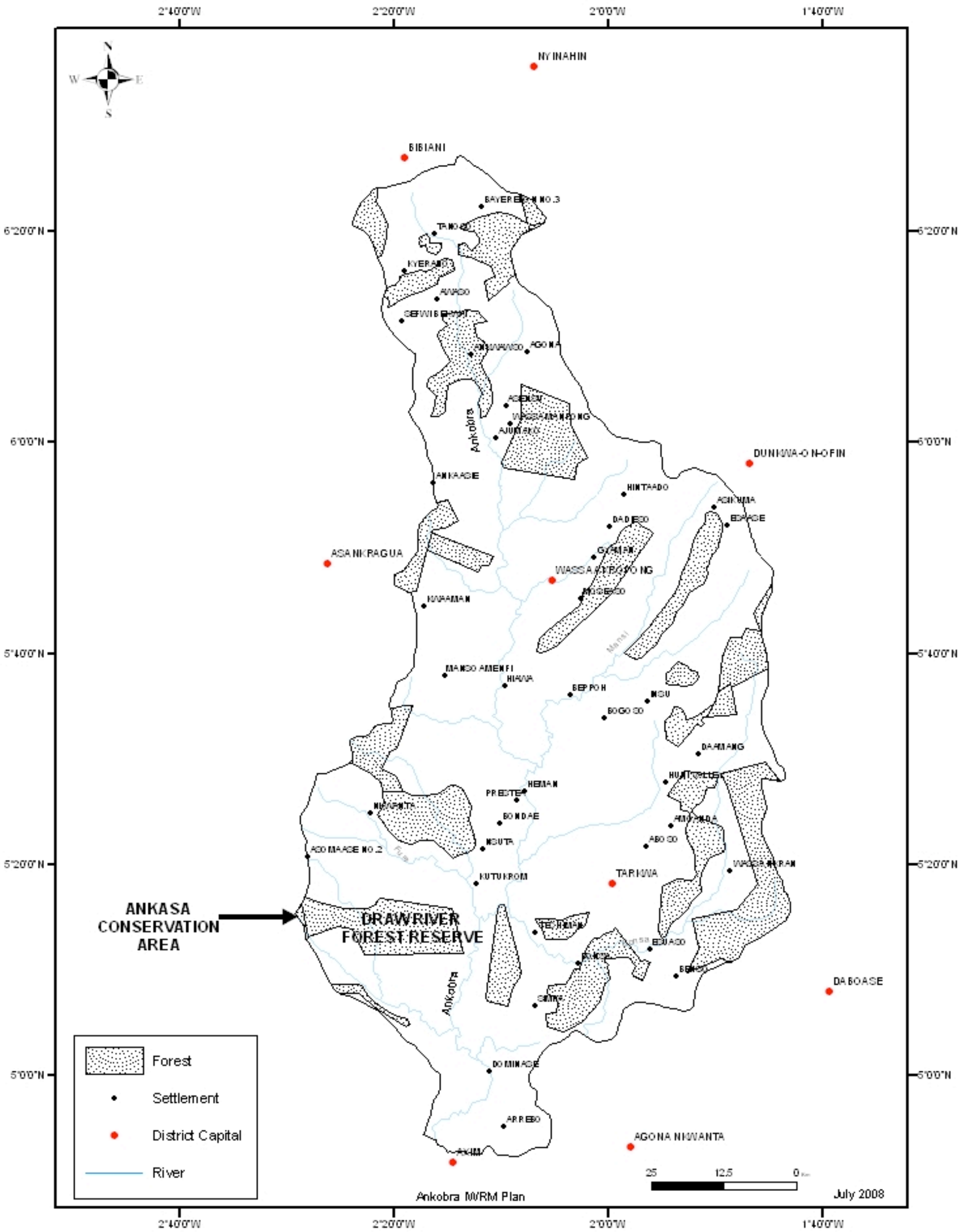
Map 1: Topography of Ankobra River Basin



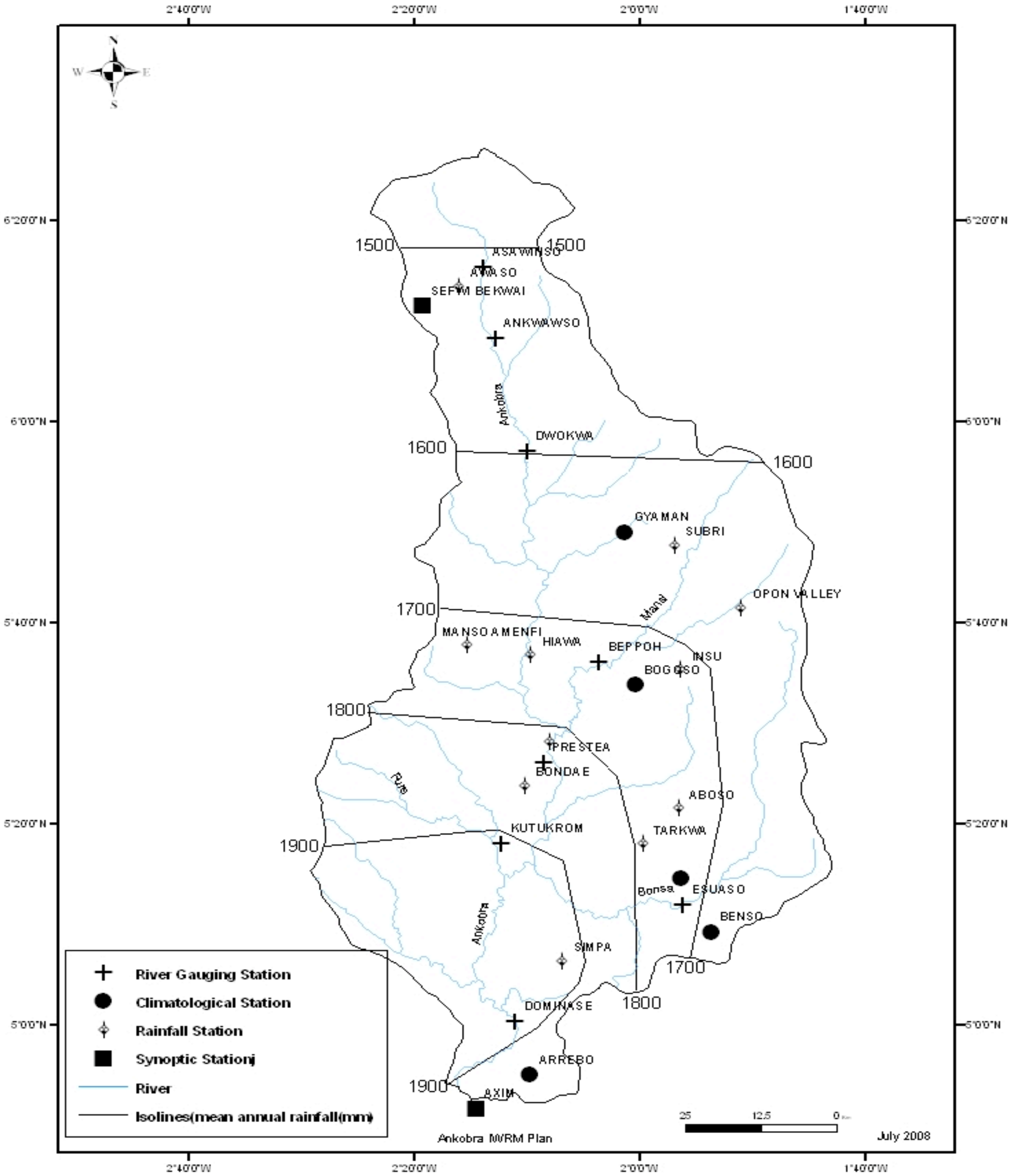
Map 2: Districts and towns/settlements in Ankobra River Basin



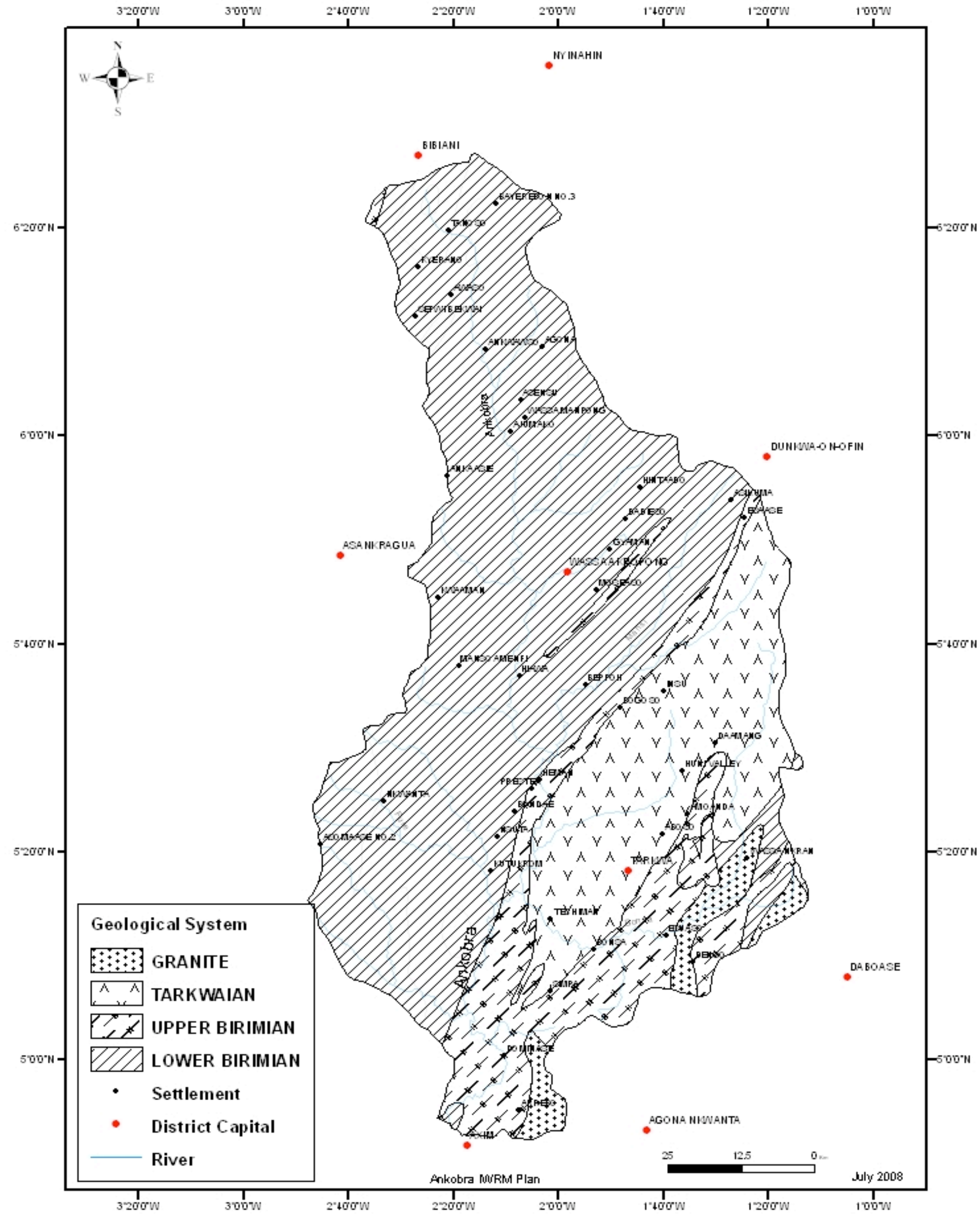
Map 3: Land use/cover (2000) of Ankobra River Basin



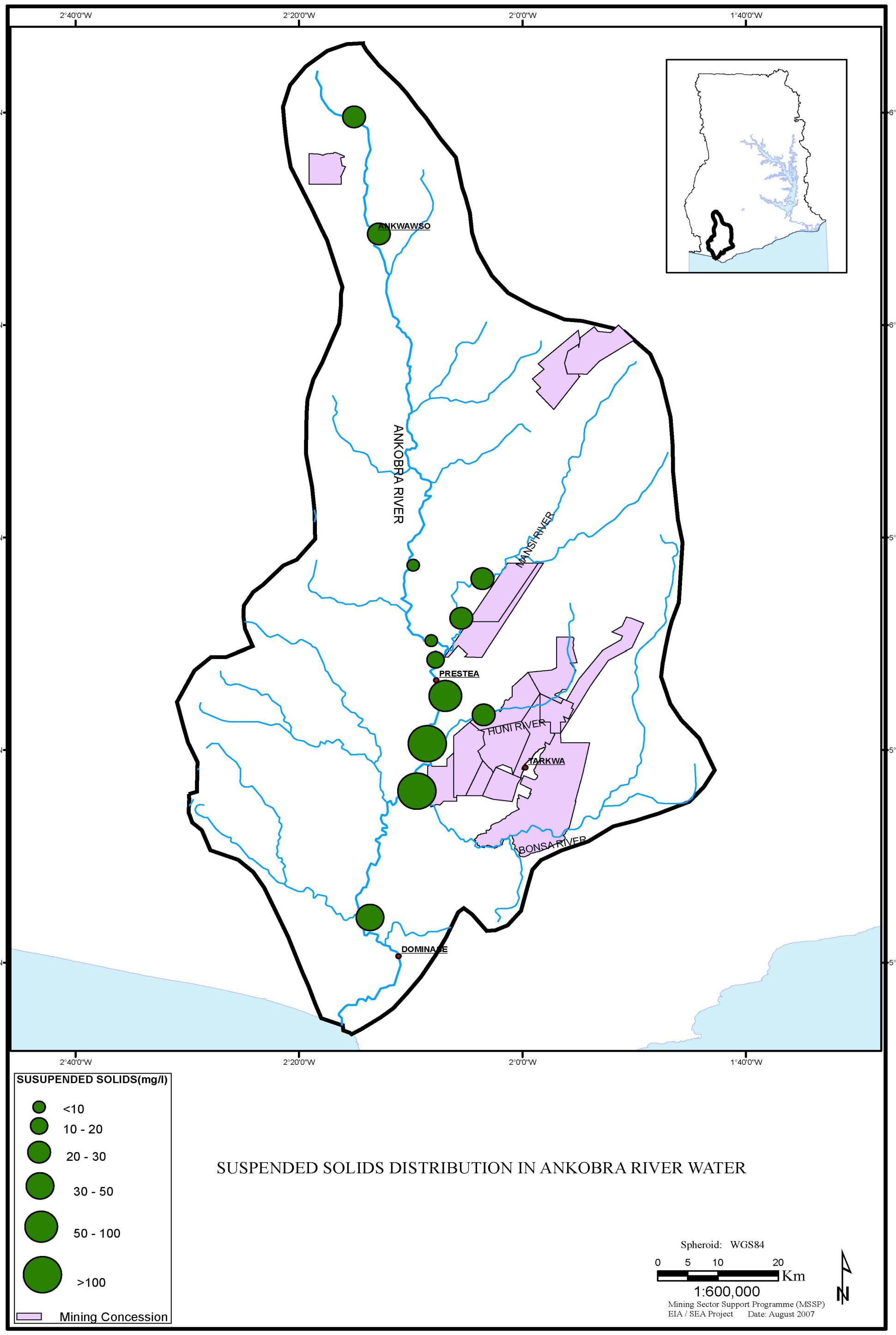
Map 4: Forest reserves in Ankobra River Basin



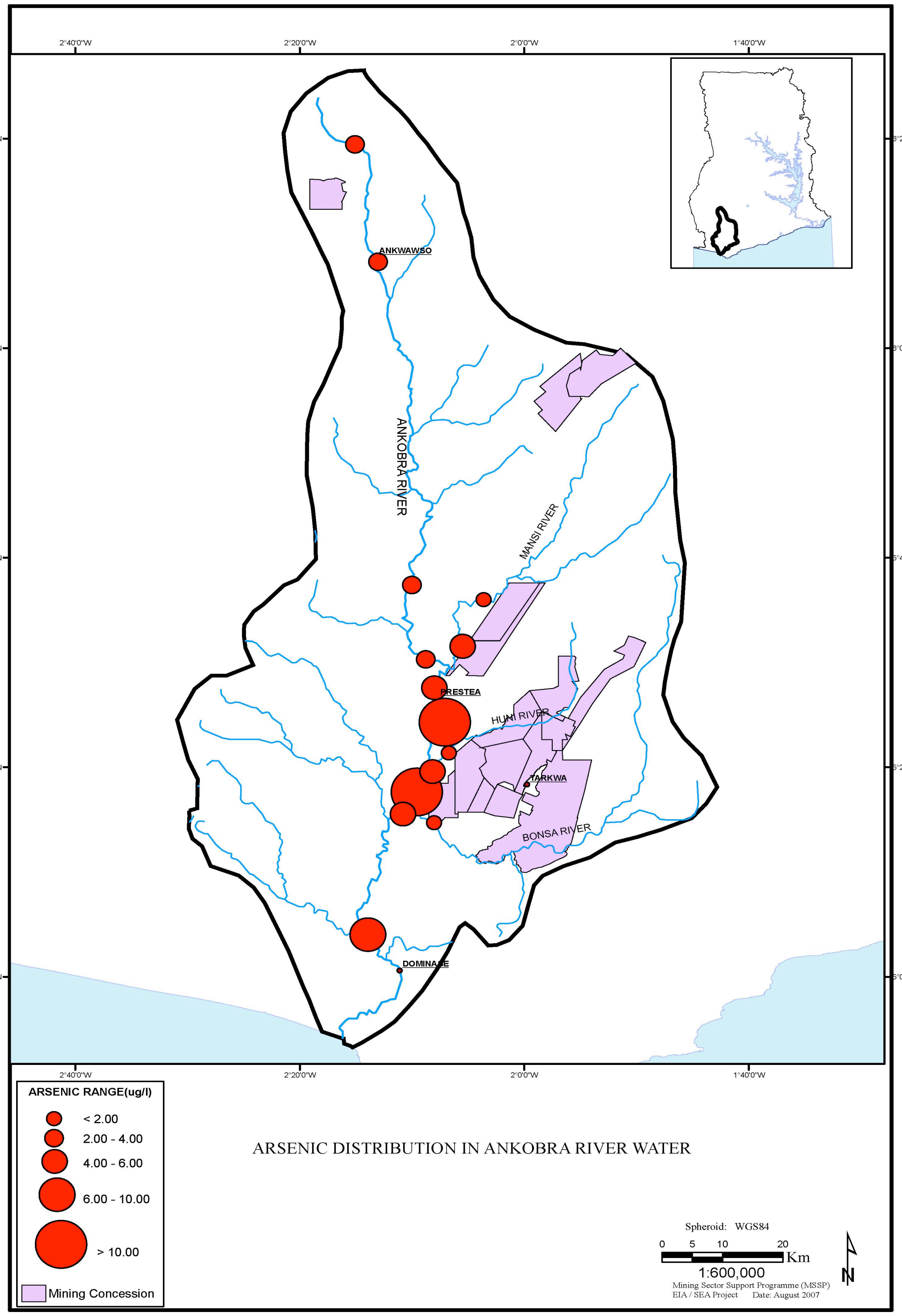
Map 5: Meteorological and hydrological stations in Ankobra River Basin



Map 6: Geological map of Ankobra River Basin



Map 7: Distribution of suspended solids in Ankobra River system



Map 8: Concentration of arsenic in Ankobra River system

3. WATER DEMAND PROJECTIONS AND WATER AVAILABILITY

Based on the demographic and socio-economic conditions, findings related to the overall water balance of the basin, the river flow regime and other data given in the baseline description in the previous chapter, this part of the IWRM plan provides information on projected water demands and assesses the balance between future requirements and water availability.

The demand projections versus future availability of water is addressed by presenting scenario analyses, which highlight various options related to utilisation and management of the water resources. The water demand projections are made covering a plan period ending by year 2025.

The scenario analyses capture some of the key ‘quantitative’ water resource planning issues associated with the Ankobra Basin, namely supply for the major demand centres, prominently the mining operations. Also the impacts of any likely climate change and of meeting environmental flow requirements are included in the scenario calculations.

3.1 Demographic and socio-economic development trends

The assumptions used in calculating water demand for the supply of potable (municipal/domestic) water and to meet water requirements for the main socio-economic activities, notably mining, are outlined below.

3.1.1 Assumptions for projection of potable water demand

The requirement for potable water for domestic, institutional and industrial purposes is determined based on estimates of per capita water demand figures, which are inclusive of these various categories of water use, and future population growth. The unit water demand (daily per capita demand) figures applied are adapted from the design values generally used by GWCL, which are differentiated according to settlement size and time horizon as depicted in Table 3.1.

Table 3.1: Unit water demand (litres/capita/day)

Settlement size	Category	2008	2015	2020	2025
< 5,000	rural	35	35	35	35
5,000-15,000	urban	55	65	75	85
15,000-50,000	urban	85	85	90	95
> 50,000	urban	105	110	115	120

The daily per capita demand of 35 l/c/d indicated for the rural communities is set relatively high to reflect the fact that some water from the point sources (bore-holes/wells) occasionally is also used for subsistence farming and cattle watering purposes.

With departure point in the 2000 Census population figures presented in Table 2.1, annual population growth rates as given in the individual District Poverty Profile reports[17] have been guiding to arrive at the 2008 population sizes for each district represented within the Ankobra Basin. In some cases, when the district population growth rates were not readily available, the regional growth rates were adopted. The annual growth rates used in the population projections are given in Table 3.2.

The latest inter-censual period (i.e. between 1984 and 2000) indicates that the Western Region recorded an average annual growth rate of 3.2%. As can be seen in Table 3.2, the similar figure, which has resulted from this study and valid for the period after 2000, is 3.1% as an average for the whole basin. Apparently, the development in the size of the population, expressed by the annual growth rate figure, seems rather constant when comparing the past eight years to the previous inter-censual period. Against this background, it is not expected that the growth rates given for the past recent years leading up to 2008 will change much (if at all), and in the context of this study are assumed to be valid throughout the whole plan period.

It can also be noted that the population growth rates for the districts do not make a distinction between municipalities/urban areas and rural settlements/villages, which means (it must be assumed) that the indicated growth rates represent "average" values combining both the rural and the urban settlements of the respective district. In the context of the IWRM planning these compounded figures provide sufficient detailing for overall water demand estimation, water balance analysis etc. Further details in this regard are only required, e.g. in connection with actual design of specific water supply schemes.

With these basic assumptions in mind, Table 3.2 presents the population forecasts per district and accumulated for the entire Ankobra River Basin. As mentioned in connection with Table 2.1, the districts of Ahanta West and Twifo-Heman/Lower Denkyira contribute hardly anything both in population and area to the basin, and thus have not been included in Table 3.2 and in the further analysis.

[17] *As part of the second generation Ghana Poverty Reduction Strategy (GPRS II, 2004) the National Development Planning Commission (NDPC) directed each District Assembly to prepare poverty profiling and pro-poor programming reports – the documentation is available on www.ghanadistricts.com*

Table 3.2: Population projections for the Ankobra Basin (2000-2025)

Region	District	Settle-ment category	Annual growth rate (in %)	Population				
				2000 Census	2008	2015	2020	2025
Western	Bibiani-Anhwiaso-Bekwai	rural	3.2	60,800	78,200	97,500	114,200	133,600
		urban		15,200	19,500	24,400	28,500	33,400
	Wassa Amenfi West	rural	3.2	104,500	134,500	167,600	196,200	229,700
		urban		0	0	0	0	0
	Wassa Amenfi East	rural	2.9	108,900	136,900	167,200	192,900	222,500
		urban		7,400	9,300	11,400	13,100	15,100
	Wassa West	rural	3.2	149,700	192,600	240,100	281,100	329,000
		urban		82,600	106,300	132,500	155,100	181,500
	Mpohor Wassa East	rural	3.2	25,000	32,200	40,100	47,000	55,000
		urban		0	0	0	0	0
	Nzema East	rural	2.7	69,500	86,000	103,600	118,400	135,300
		urban		21,800	27,000	32,500	37,200	42,400
Central	Upper Denkyira	rural	3.2	25,600	33,000	41,000	48,100	56,300
		urban		0	0	0	0	0
Ashanti	Atwima Mponua	rural	3.6	9,000	12,000	15,300	18,300	21,800
		urban		0	0	0	0	0
Ankobra Basin, total		rural	3.1	553,000	705,400	872,400	1,016,200	1,183,200
		urban		127,000	162,100	200,800	233,900	272,400

From the figures in Table 3.2 it can be concluded that the total population of the Ankobra Basin is expected to increase from the 2000 Census figure of 680,000 to about 1,455,000 in 2025.

3.1.2 Assumptions for projection of mining and industrial water demand

As mentioned earlier, the water demand for small-scale industrial, commercial and institutional purposes, which fall within the urban piped schemes' supply areas, is included in the projected potable water demand, and thus is accounted for in the unit figures given in Table 3.1 above.

As highlighted in Section 2.3.5, a number of mining operations and other industries have their own water supply systems, which rely on river water (about 60% of present total abstractions) and groundwater (accounting for the remaining 40%). For the purpose of estimating the future mining/industrial water demand, the assumption is made that the water requirements for these activities will increase in step with further development in the exploitation and mineral extraction from the existing mines and opening of new mining sites. To be on the conservative side, in the context of the IWRM plan it is further assumed that the mining sector will double it activities in the next 20 years, equivalent to 85% expansion during the plan period ending in 2025.

3.1.3 Assumptions for projection of agriculture water demand

The agricultural water demand category includes water for irrigation and livestock. As stated in Section 2.3.4, the land under irrigation in the Ankobra Basin is minimal, and due to its climatic setting irrigated agriculture is not expected to be of much importance in the context of water requirements. If more than a tripling of the irrigated area is envisaged, i.e. say up to around 100 ha to be cultivated with rice, it would imply a water requirement of 2.5 million m^3 annually.

The livestock watering demand constitutes only a negligible portion compared to the other water uses in the basin, and this situation is not expected to change drastically in the future. Even with a doubling in the number of livestock heads, it would add up to a water requirement of around 1,000 m^3/day, or 365,000 m^3 annually.

In conclusion, in the context of the IWRM Plan, the agriculture water demand will increase from the 2008 level of close to 1.0 million m^3 to a little less than 3.0 million m^3 towards the end of the plan period.

3.2 Future water demand and water balance for the basin

3.2.1 Water demand projections

By applying the various assumptions and figures given in the preceding section, the future water demand of the Ankobra Basin has been calculated with results given in Table 3.3. The figures for 2008 are extracted from Table 2.12. It should be emphasised that the table values represent the "ultimate" water demand as required by the whole population of the basin, i.e. assuming 100% service coverage both in the rural and urban settings from 2015 and onwards.

Table 3.3: Water demand projections, Ankobra Basin (2008-2025)

User category	2008 values represent current abstractions		2015		2020		2025	
	m^3/day	10^6m^3/yr	m^3/day	10^6m^3/yr	m^3/day	10^6m^3/yr	m^3/day	10^6m^3/yr
Urban population	5,255	1.9	20,200	7.4	24,700	9.0	30,400	11.1
Rural population	3,880	1.4	30,500	11.1	35,600	13.0	41,400	15.1
Industry and mining	60,000	21.9	80,000	29.2	95,000	34.7	111,000	40.5
Agriculture	2,550	0.9	4,500	1.6	6,200	2.3	7,900	2.9
Ankobra Basin, total	71,685	26.1	135,200	49.3	161,500	59.0	190,700	69.6

Not surprisingly, from the figures in Table 3.3, it can be concluded that the industrial/mining sector will continue to be the largest demand category, which in year 2025 according to the projections will constitute about 58% of the total water demand, whereas the combined domestic (urban and rural population) categories with full coverage will take up 38%. The remaining 4% is water for agriculture purposes (irrigation and upkeep of livestock).

3.2.2 Overall water balance assessment

As pointed out in Section 2.2.3, the notion is adopted that groundwater-based water supply schemes will continue to shoulder a considerable portion of the basin's water requirements also considering the future expanded supply systems for the industrial/mining activities and for reaching all communities eventually.

In the assessments presented in this chapter, it is further assumed that by the end of the plan period the percentage distribution as presented in Table 3.4 between the use of surface water and groundwater as a source for the supply schemes will prevail. The table also gives the projected amounts by year 2025 for each source and demand category.

Table 3.4: Source dependency, Ankobra Basin (2025)

Demand category	Surface water		Groundwater	
	percentage share	amount (m^3/day)	percentage share	amount (m^3/day)
Urban population	75%	22,800	25%	7,600
Rural population	25%	10,400	75%	31,000
Industry and mining	60%	66,600	40%	44,400
Agriculture	90%	7,100	10%	800
Total for basin	58%	106,900	42%	83,800

Groundwater resources

It can be seen in Table 3.4 that by the end of the plan period, the total demand for groundwater is projected to 83,800 m^3/day, which is equivalent to 30.6 million m^3 per year. This amount can be compared to the total renewable groundwater resources available taken as an average over the basin. In Table 2.5 the sub-surface water retention and groundwater recharge rate is stated to be 20% of mean precipitation, which gives a gross infiltration/recharge rate of 340 mm per year in average, equivalent to 2,880 million m^3 per year.

If it is assumed on the conservative side that only about 10% of this amount is converted into available (exploitable) groundwater, it would on a basin basis imply a sustainable groundwater yield of 288 million m^3 per year, which is still close to tenfold more than the future requirements.

In Section 2.2.1 it is stated that a likely impact from climate change, including reduced rainfall, may result in a 20% reduction in groundwater recharge. Even with this scenario taken into consideration, it appears that the basin's groundwater resources in general are ample to sustain the envisaged future abstractions. This does not mean, however, that locally there will not be problems in finding suitable groundwater occurrences.

As also pointed out earlier, to obtain optimal utilisation of the groundwater resources, it is imperative that groundwater schemes are based on state-of-the-art hydrogeological assessment methods, efficient borehole siting techniques as well as proper design, construction and development of the boreholes. It is also implied that future groundwater schemes may have to depend on deeper boreholes than usually drilled to obtain the required amount of water, and on longer pumping mains to bring the groundwater to the point of utilisation.

Surface water resources

Likewise, in Table 3.4 it is seen that by the end of the plan period the total demand for surface water is projected to 106,900 m^3/day, which is equivalent to 39.0 million m^3 per year. With reference to Table 2.6, the average annual flow of Ankobra River at its downstream section, e.g. at Dominase, is given as 2,207 million m^3 per year. Even with inclusion of a 10%-20% reduction in annual runoff due to likely effects of climate change (ref. Section 2.2.1), it appears when considering the basin as one unit that the surface water resources amply can cater for the future requirements. Actually, the future requirements accounts for a mere 2% of the total renewable surface water resources.

It should be pointed out that this conclusion is based on the "theoretical" water balance results, and that the measured runoff (with all the uncertainty surrounding these figures as highlighted in Section 2.2.2) is much lower. Nevertheless, even against this background, the surface water resources are plentiful on an annual basis when considering the basin as a whole.

3.3 Scenario analyses of water availability vs. requirements

3.3.1 Introduction to scenario analyses and model assumptions

Irrespective of the water demand and source availability overview presented in Section 3.2 above, it is a well known fact that it is the low-flow regime of a river, which determines its viability as a source for a year-round water supply (run-of-the-river scheme), i.e. direct abstraction without in-stream storage capacity provided. Therefore, to examine whether future water shortages will occur in step with increased demand, the low flow regime – as reflected in runoff records from a number of river gauging stations in the basin – is introduced as requisite input in the water accounts analyses.

The WEAP water accounts model tool

The computer-based <u>W</u>ater <u>E</u>valuation <u>a</u>nd <u>P</u>lanning (WEAP) model is used to carry out scenario analyses to facilitate the understanding and description of different water resource development choices, and to establish their consequences. It operates on on the principles of water balance accounting and examines alternative water development strategies in form of scenario analyses to provide answers to various "what if" questions.

For each model run (scenario), the various water requirements covering the whole river system are taken into consideration, and the induced upstream-downstream interactions are being accounted for and results shown in a number of optional ways to be chosen by the user, such as graphs, in table form or as histograms. Also the percentage of requirements met (coverage rate) at each demand site is calculated with increments of one month throughout the plan period.

The WEAP model has a built-in "priority" facility, whereby the domestic water requirements are met as first priority and water for e.g. mining operations has a lower priority. This optional facility is important in situations when there is "competition" for water due to scarcity in the supply.

It should be noted that conclusions reached, based on results of the scenario analyses, only consider coverage in term of water availability as a source for meeting the requirements, and does not take into consideration the various technical aspects as precondition for attaining the coverage, e.g. appropriateness and efficiency of water intake structure, expansion of transmission mains and distribution outreach.

The starting point of the basin modelling is to establish and define the basic water related elements of the basin and their relations as they currently exist. This overview of the existing situation is called the "current accounts", which includes the specification of supply and resource data as extracted from the information and figures presented in the previous chapters/sections and other sources.

Figure 3.1 below provides a schematic overview of the Ankobra River system and the basic set-up of the WEAP model components. The set-up depicts the main elements such as abstraction/demand sites (urban water supplies, industrial/mining schemes, etc) and other main features used in the scenario analyses.

Finally, it must be reiterated that the WEAP analyses deals only with the surface water situation of the basin, and does not incorporate considerations concerning utilisation of groundwater resources.

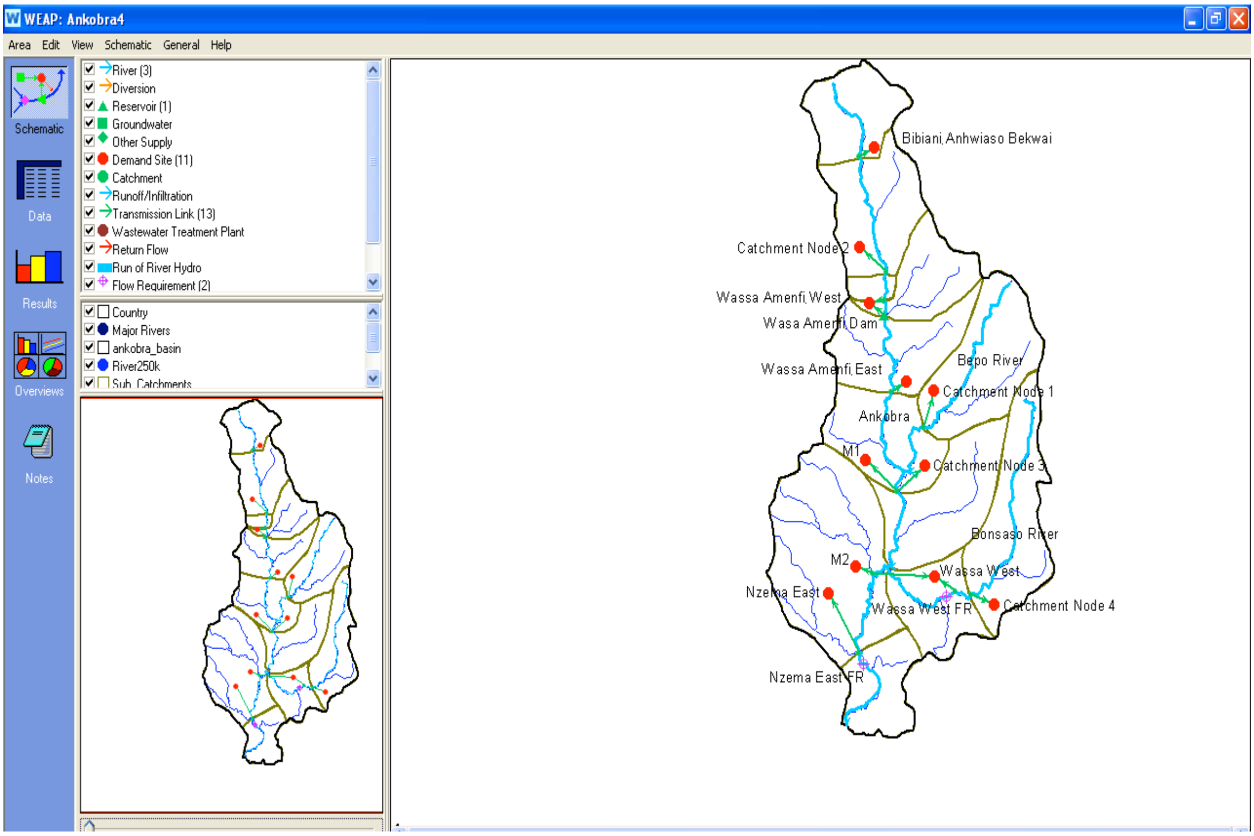


Figure 3.1: WEAP model configuration for Ankobra River Basin

Location of domestic water abstraction/demand sites and water requirements

Since the aim of the WEAP model application is to monitor the response of the river system as a whole to the projected water demands, and not to assess detailed supply aspects of individual supply schemes, the water abstraction points have been simplified to be represented by one demand site for each district with a sizeable area and population within the basin. Furthermore, the water demands associated with the smaller portions of the peripherally located districts, i.e. Atwima Mponua, Upper Denkyira and Mpohor Wassa East, are in the WEAP calculations included in the main abstraction points.

Based on the projected population figures (ref. Table 3.2) and the unit consumption rates given in Table 3.1, the 2025 surface water demand for both the urban and rural populations as given in Table 3.4 has been divided with a portion allocated as explained above to each of the identified abstraction points. Additionally, due to its small size in the overall water balance and mode of usage, the agriculture water requirement is not accounted for explicitly in the scenario analyses, but rather included as an integral part of the rural population water requirements.

The result of this exercise is presented in Table 3.5.

Table 3.5: Projected domestic/agricultural surface water demand per main abstraction point (2025)

District	Bibiani-Anhwiaso-Bekwai (*)	Wassa Amenfi West	Wassa Amenfi East	Wassa West	Nzema East	Total
Demand in m^3/day	1,200	6,000	6,500	19,000	7,600	40,300

(*) Being the district located in the most upstream zone (headwaters) of the Ankobra river system, it is assumed that the population in this area will be served mainly by groundwater-based schemes, and hence the surface water demand is small.

The largest share of the future surface water demand falls within the Wassa West District. This district is the most "urbanised" in the basin, and the high demand is for a large part attributed to the further expansion of the greater Tarkwa water supply scheme.

It should be noted, that within the supply areas of the surface water based pipe-borne schemes, the water usages by industries, manufacturing and other commercial activities as well as institutions are included in the schemes' production figures, and hence in the forecasted water demand figures, whereas the mining sector is accounted for separately as described below.

System losses (un-accounted for water)

It is a fact that the existing piped water supply systems in Ghana generally suffer from unacceptable high rates of un-accounted for water, i.e. physical losses, notable in the transmission mains and distribution network. At present, it is estimated that for certain schemes in average some 40% of water produced can be categorised as un-accounted for water. It should be noted that a high rate of un-accounted for water not only implies a non-efficient way of using the available water sources, but also results in extra costs related to water treatment, pumping (energy) and other operational aspects.

As part of the analyses presented below, it is opted in this plan to assume that system losses will (and must) gradually be brought down at least to a 25% level in average, which also is considered realistically to be achieved over the plan period. This un-accounted for water percentage figure is added to the demand figures as presented in Table 3.5 to arrive at the actual water requirements at the various demand sites.

Location of mining operations and their water requirements

Generally, the existing large-scale mining operations listed in Table 2.11 are located in the central to eastern part of the basin, predominantly in the Wassa West District. In the WEAP model application, the present and future abstractions are clustered and represented by two demand sites along the Ankobra River, i.e. one located some 5 km north of Prestea and the other a few km downstream of the Bonsa river confluence (named M1 and M2 in Figure 3.1, respectively).

Table 3.4 depicts the 2025 projected total mining/industrial surface water demand to be 66,600 m^3/day. It is assumed that the two sites will abstract equal amounts of water from the river system to cater for the various mining operations.

Environmental flow requirements

To sustain river flows for environmental "maintenance", minimum flow requirements have been introduced downstream of the water abstraction points in the river system. The assessment of the minimum flow requirements have been based on a low-flow frequency analysis on the monthly flow data and determined as the 95-percentile flow (i.e. the 20-year minimum flow return period) in each calendar month.

3.3.2 Results from the scenario analyses

In the context of this plan, the results from the scenario analyses are reported on and compared with each other by highlighting the level of coverage (% of requirement met) as calculated at the different demand sites towards the end of the plan period. Water supply system losses and environmental flow requirements are included in all the WEAP model runs presented below.

It must be emphasised that the presented scenarios and associated water resource development options should be regarded as a "point of departure" from which the basin modelling coupled with requirements for detailing can be further developed as the need for planning and decision-making at various levels (basin-wide or project specific) arises.

Scenario 1: Water resource capacity without effects of external factors

This scenario assumes a future *status quo* situation regarding the resource capacity, which implies, e.g. that impacts of climate change are not introduced. In this scenario the existing water abstraction and other facilities will be expanded in step with the "normal" increase in water requirements to cater for the growing population and socio-economic activities given the projected water requirements for the various demand categories as outlined above. This model run provides a "reference point" against which the effects of climate change/variability and other development aspects can be assessed.

Result:

Figure 3.2 shows the demand site coverage (% of requirement met) for each abstraction point along the river as extracted from the WEAP application. It is detected that the surface water requirements can be met to a large extent except for the northern part of Wassa Amenfi West and Wassa Amenfi East districts, where rather frequent shortages will be experienced particularly during the latter part of the 2008-2025 plan period. As far as the northern part of the Wassa Amenfi West is concerned, it can be seen that at 2 occasions the river can only sustain some 15%-20% coverage (15%-20% of water requirements met) in the low-flow season. Already this is an indication that some form of storage facilities will be required, or alternatively, that more of the water requirements will have to be met relying on groundwater-based piped water supply schemes than indicated in this plan.

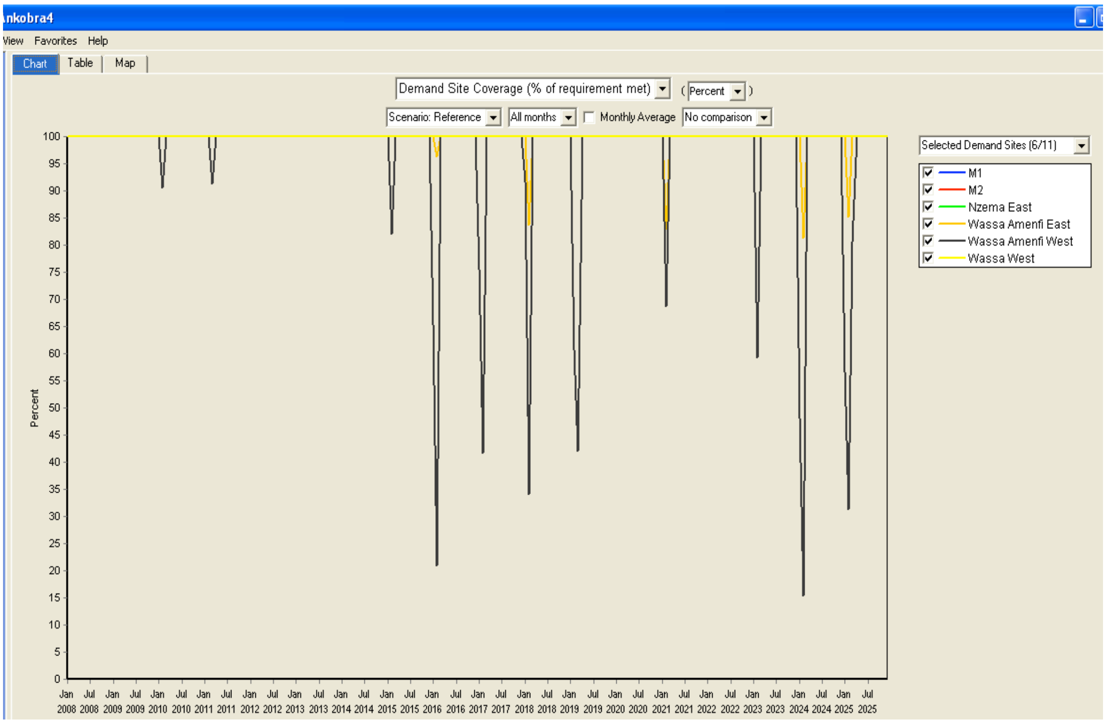


Figure 3.2: Demand site coverage (in %) in the status quo situation

Scenario 2: Impact of climate change

As explained in Section 2.2.1, the effects of a likely climate change can be quantified in terms of an anticipated decrease in surface water runoff. The study referred to in that section indicates that a climate change scenario considered realistically to occur, i.e. 10%-20% decrease in annual rainfall and a 1-2°C rise in temperature, will reduce the annual surface runoff by some 15% towards the end of the plan period.

The changed runoff regime caused by climate change has been imposed on the data series used in the calculations, and an alternative model run was made for the "*status quo*" situation (Scenario 1) to compare and assess the "order of magnitude" of a climate change impact on meeting the future water requirements.

Result:

With reference to Figure 3.3, it can be seen that in this scenario, where the impact of climate change has been taken into consideration, all demand sites will be affected to a varying degree, and shortfalls in meeting water requirements start occurring more and more frequently, particularly during the latter part of the plan period. In some instances the demand coverage dips down to zero.

It can be concluded that to be able to meet the projected surface water demands of the basin, in-stream or off-stream reservoir facilities will be required to store water from the high-flow season to the low-flow season.

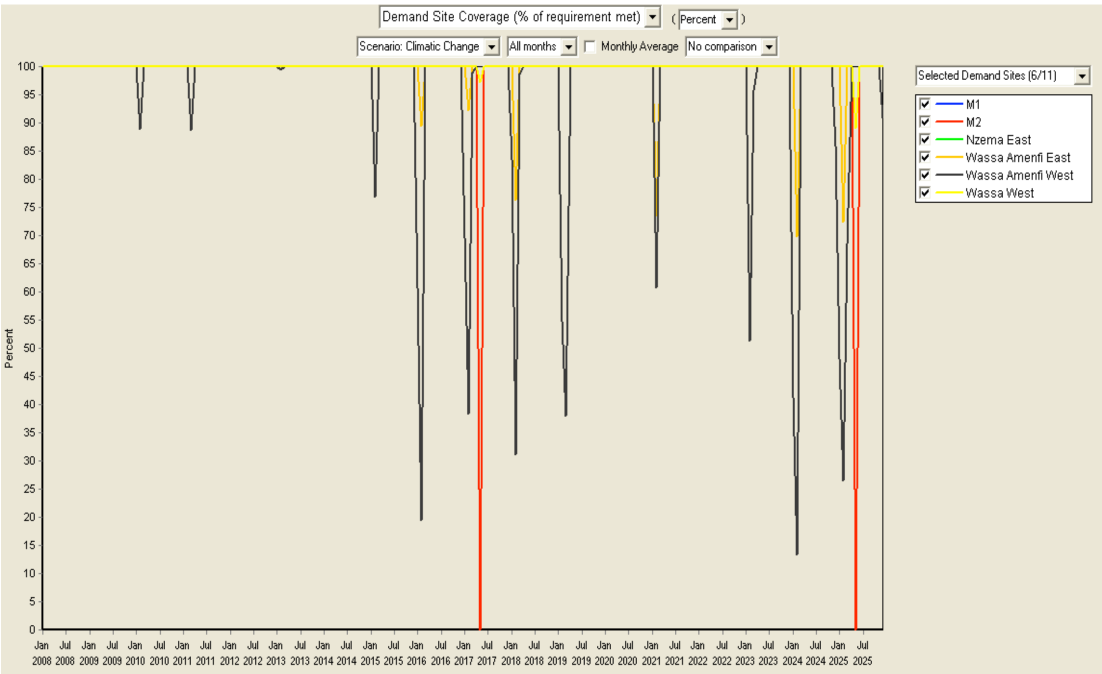


Figure 3.3: Demand site coverage (in %) with impact of climate change included

Scenario 3: Introduction of a dam on Ankobra River

It is proposed to construct dam/reservoir on the Ankobra River some 10 km downstream from the Dwokwa gauging station. WEAP "trial-and-error" runs were performed to provide an estimate of the optimal (smallest) size of the storage facility which will able to meet the surface water requirements of both the population and the mining operations by the end of the plan period, i.e. 2025.

In this scenario the situation is maintained from Scenario 2, namely that the impacts of climate change are included in the model runs. Furthermore, in the WEAP model calculations, the dam/reservoir is assumed to be brought into operation by year 2015.

Result:

The outcome of these WEAP model runs indicate that a reservoir size (storage facility) of about 11.0 million m^3 would be sufficient to attain a satisfactory coverage level towards the end of the plan period.

Figure 3.4 shows the demand site coverage (% of requirement met) throughout the plan period, and clearly depicts the impact of the dam with water shortages experienced before 2015 and 100% coverage at all demand sites in the remaining part of the plan period. Figure 3.5 shows the fluctuations of the storage volume and how the reservoir capacity is utilised reflecting anticipated dry/drought periods over the years.

A reservoir of this size constructed at the indicated location on the Ankobra River would imply a dam height of 12-13 metres with a crest length of 300-500 metres. As an alternative, the required storage volume of 11.0 million m^3 can also be created by construction of more than one dam which individually would be smaller in size.

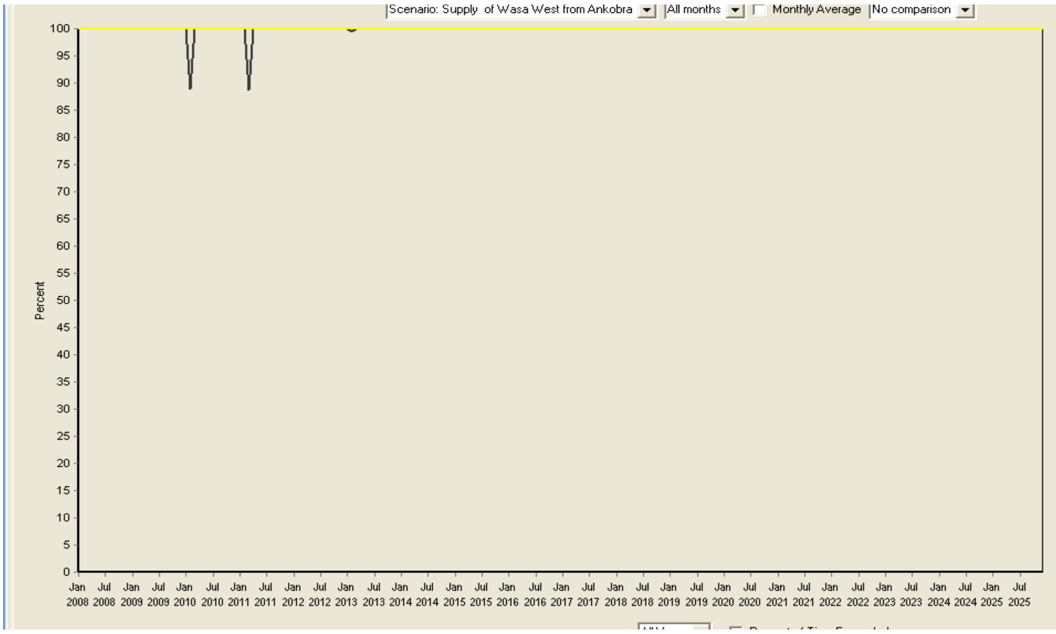


Figure 3.4: Demand site coverage (in %) with Ankobra reservoir built by 2015

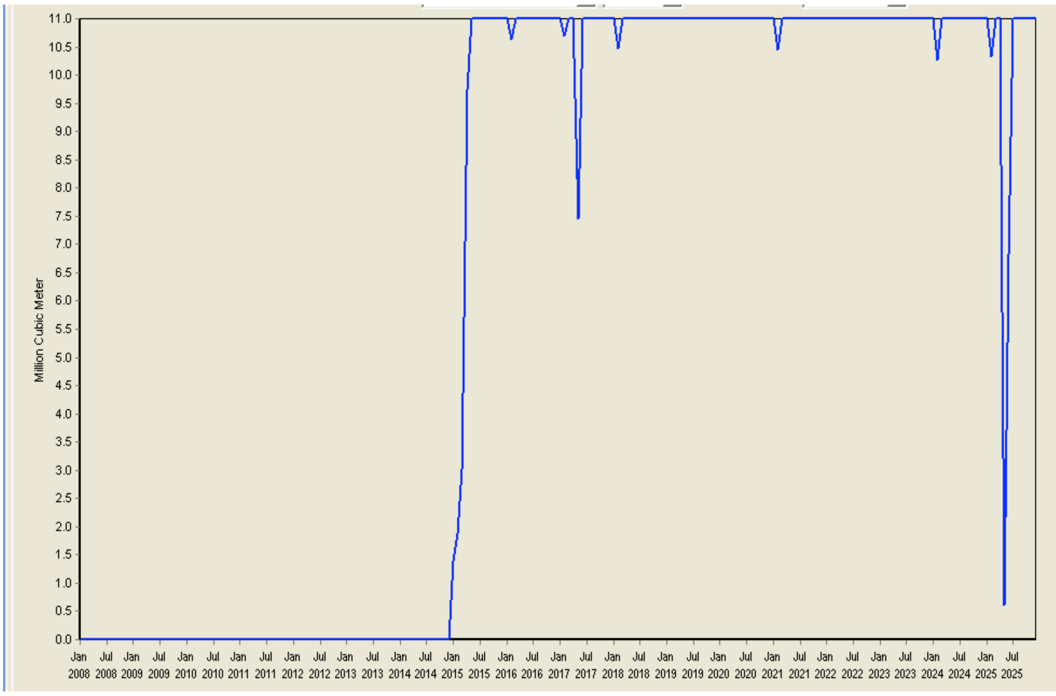


Figure 3.5: Ankobra reservoir storage volume in million m^3 (2015-2025)

3.3.3 Concluding remarks on scenario analyses

As already pointed out, it is important to note that the WEAP analyses deals only with the surface water situation of the basin, and does not incorporate considerations concerning utilisation of groundwater resources.

The groundwater potential is high and more widespread in this basin in comparison with other parts of Ghana. In particular many areas within the Wassa West, Wassa Amenfi East and Nzema East districts have groundwater occurrences to such an extent that they can sustain sizeable and even large scale abstractions for industrial and town/municipal water supply schemes. It is for this reason that this plan advocates for a reliance on groundwater to meet about half of the future water demands.

Although the Ankobra River and its tributaries constitute a well watered and perennial surface water system, which only rarely realises prolonged drought occurrences, it appears from the scenario analyses that the low-flow regime will not be able to meet the future surface water requirements on a year-round basis as run-of-the-river supply schemes, i.e. direct abstractions without storage capacity provided.

WEAP application results versus hydrological input data

as elaborated on in Section 2.2.2, the recorded flow data and information on runoffs used as input in the WEAP application possess broken time series with many gaps and inconsistencies over the years to such an extent that the available flow records are to be regarded as unreliable. What is most striking is the pronounced downward trend in the mean annual runoff as calculated from the published flow records, i.e. 1961-64: 59.5 m^3/sec; 1970-76: 36.0 m^3/sec; 1989-92: 25.1 m^3/sec; and 2001-07: 15.3 m^3/sec.

This apparent significant drop in annual mean flows is hard to explain when considering the annual rainfall amounts over the past 30-40 years, which show only a modest decreasing trend. It must be concluded that the available flow data must be used with extreme caution, and the results arrived at from using the data must be judged accordingly. Efforts are ongoing to have the Hydrological Services Department to rehabilitate and re-rate their river gauging stations in the Ankobra River system, and when updated flow data are available, the WEAP calculations should be repeated to confirm or adjust the findings presented here.

As mentioned earlier, the WEAP analyses have used the period 2001-2007 as hydrological data input due to lag of persistent runoff records before that. It has also been indicated above that the 2001-2007 period shows (unrealistically) low runoffs compared to previous periods where data exists. If the WEAP calculations for Scenario 3 are repeated with previous recorded data records included, the required storage volume will be reduced accordingly down to some 5-6 million m^3 from the 11.0 million m^3 indicated under Scenario 3 above.

This example shows the noticeable sensitivity which exists in the outcome of the model runs to the input (hydrological) data records used in the WEAP calculations.

Water demand management considerations

Although the Ankobra Basin is a well watered basin compared to other areas of Ghana, efforts should still be made more vigorously to bring down the unacceptable high rate of un-accounted for water (water supply system losses) in the urban schemes. A number of measures exist to assist towards the reduction of physical losses, some of which can be implemented by the service provider (GWCL), e.g. leakage detection/repair and renovation of old distribution network, and other measures which direct themselves more to the consumers, that be industrial, institutional and individual users.

Introduction of water demand management measures is also an important aspect in curtailing the otherwise ever increasing demand. In the water demand projections presented above, the departure point in the calculations is a list of pre-set unit consumption figures (ref. Table 3.1). The aim must be to halt the continuously increasing trend as reflected in the table values through measures, including public awareness raising, which should address, e.g. behavioural changes towards being “waterwise” individually and collectively, and being conscious about water (ab)uses.

Other measures which should be considered include changes to local building codes and bye-laws to make it mandatory to install water-saving devices (self-closing taps, low-flush toilets etc) particularly in public institutions, boarding schools and military barracks. Additionally, the introduction of rainwater harvesting from roofs and other surfaces should all be promoted as well as recycling of water in the mining operations.

4. CONSULTATIVE PROCESS

4.1 Application of SEA in the IWRM planning process

This IWRM plan is based on hydrological and other technical data, socio-economic trend analysis, and population census information that only partly has been presented earlier and not as an integrated assessment with the purpose of describing the present and future situation within the Ankobra River Basin concerning the availibility and quality of the water resources.

In parallel with the technical assessments and description of the water resource-related challenges as presented in the previous chapters, a consultative process has been carried out to involve basin-based stakeholders with the aim of capturing the local knowledge on water resources problems and actions required in addressing the identified water management issues and problems.

In the Ghanaian context, well anchored procedures exist where plans and programmes are elaborated and vetted following a participatory approach allowing for thorough public discussions – often in workshop settings – guided by principles which form part of the concept of Strategic Environmental Assessment (SEA). SEA procedures and tools[18] have been applied in the process of developing the Ankobra Basin IWRM plan.

A SEA approach for planning is defined as:

"*A systematic process of evaluating the environmental effects of a policy, plan or programme and its alternatives, including documentation of findings to be used in publicly accountable decision-making".*

Furthermore, the application of SEA procedures in IWRM planning means that the evaluation of environmental effects has an additional social dimension, viz.:

"…to safeguard the future sustainable use of water resources aimed at maintaining the economic and social welfare within a basin without compromising the preservation of vital aquatic ecosystems".

The district-based planning by District Assemblies is the cornerstone of the decentralised governmental approach for which the overall legal framework and institutional delegation of responsibilities are proven and understood - although gaps in legislation, overlapping responsibilities, lack of capacity/resources and enforcement still exist.

[18] *Support and Capacity Building to apply SEA Principles and Tools in preparing IWRM Plans at River Basin Level. WRC (October 2006).*

An IWRM plan for a basin addresses the basin-wide water management problems to achieve future sustainable management of the basin's water resources, and as such provide a framework for local water management planning at the district level.

Consequently, the effects of the IWRM plan should not be restricted to a description of broad existing and projected future environmental and social impacts, but should also try to describe the effects of the IWRM plan on other existing plans and programmes. The IWRM plan may entail legal and institutional consequences that may cause conflicting management structures, which then need to be coordinated and adjusted to ensure an efficient implementation of the plan.

In adherence with the SEA principles of embracing a participatory approach, stakeholders with specific interest/knowledge of the basin, including planners from District Assemblies, governmental departments, representatives from the mining industries, NGOs and water user organisations were gathered at three occasions in workshop settings convened by WRC at Tarkwa.

The objective of the first workshop was to identify water resource management issues and problems within the Ankobra Basin as perceived by the stakeholders, and to propose actions and interventions, which in a realistic way can address and mitigate the various identified problems. At a follow-up workshop, the identified problems were ranked and the proposed actions prioritised using pre-designed scoring tables.

At the third and last workshop the action programme was subjected to a test aimed at assessing the overall sustainability of the IWRM plan by the concerned decision-makers and other stakeholders.

The outcome of this consultative process with specific results emanating from the tool applications are reported in the following Sections 4.2 to 4.6.

4.2 Water resources management issues as identified by stakeholders

Table 4.1 presents the result of the exercise carried out as part of the first workshop aimed at identifying what are considered the important water resource issues and problems prevailing in the basin. The information in the table reflects the answers as provided by five working groups which the workshop's 28 participants were divided into. Each group was asked to agree on a list of the 10 most important water resource related problems based on the result of an identification (scoping) exercise carried out by all participants on individual basis, which preceded the group work. It should be mentioned that the listings of problems in Table 4.1 are not prioritised or ranked as such.

It can be seen from the listing that -

- although a diversity in opinion exists among stakeholders as to the main problems to be addressed, there are also quite coinciding views and similarity in the water resources problems listed by the five groups;
- the issues identified to a large extent have their background in individual perceptions of problems in everyday life without a direct view concerning implications for the basin looked at as a unit; and

- inadequate funding and lack of other logistic resources required to address the water resource management challenges in the basin were not included explicitly among the issues/problems listed.

Due to the rather marked similarity among quite many of the 50 problems, a careful scrutiny provided the basis for reducing the number of issues to 17 distinct different problems.

As mentioned above, the scoping exercise by the stakeholders did not list economic (cost) and financial aspects as a specific issue/problem. These aspects, nevertheless, are considered important and, subsequently, a specific problem area was added to the list.

Furthermore, for compilation and description of the findings from the identification of water resource management issues/problems, the problems were grouped into the following categories in accordance with commonly used criteria for describing the sustainable development in Ghana, viz.:

- natural resources,
- socio-cultural conditions,
- economic and financial aspects, and
- regulatory, administrative and institutional aspects.

Table 4.2 reflects the above described criteria for listing the identified issues and problems.