WORLD CONSERVATION UNION (IUCN)
(WEST AFRICAN REGIONAL OFFICE)

PROJECT FOR IMPROVING WATER GOVERNANCE IN THE VOLTA BASIN (PAGEV)

WATER AUDIT OF THE VOLTA BASIN

FINAL REPORT

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LIST OF ACRONYMS AND APPREVIATIONS

BF	-	Burkina Faso
BMB	-	German Ministry of Education and Research
CD	-	Compact Disk
CSIR	-	Council for Scientific and Industrial Research
DGRIH	-	Direction General for Inventory of Hydraulic Resources (Burkina Faso)
DSS		Decision Support System
GLOWA	-	Global Hydrological Cycle
GMA	-	Ghana Meteorological Agency
GOG	-	Government of Ghana
HSD	-	Hydrological Services Department
HYCOS	-	Hydrological Cycle Observing System
IUCN	-	World Conservation Union
IWRM	-	Integrated Water Resources Management
NMI	-	National Meteorological Institute
ONEA	-	National Office for Water and Sewerage
PAGEV	-	Project for Improving Water Governance in the Volta Basin
PET	-	Potential Evapotranspiration
SAP	-	Strategic Action Plan
SONABEL	-	National Electricity Company of Burkina Faso
TDA	-	Transboundary Diagnostic Analysis
VBTC	-	Volta Basin Technical Committee
WEAP	-	Water Evaluation and Planning System

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EXECUTIVE SUMMARY

This is the Final Report on the Water Audit study on the part of the Volta basin which is shared by Burkina Faso and Ghana. The two countries share 85% of the 400,000 km^2 area of the basin. The other riparian countries are Benin, Ivory Coast, Mali and Togo.

The audit was sponsored by the IUCN as part of its assistance to the two countries in particular and to the six countries in general to improve governance of the water resources of the basin.

The audit also fits within the context of GLOWA project in the Volta Basin which is focused on land use and climate changes on water resources. It also fits into the Challenge Programme on Water for Food which is aimed at finding ways of producing more food with less water.

OBJECTIVES

The objectives are to:-

- Make available and share scientific knowledge on the status and dynamics of surface and groundwater in the Volta given basin.
- Develop management options for the water resources under various scenarios of water availability and demand.
- Establish a decision support tool for the benefit of the countries.

APPROACH

The audit was carried out by a consulting team made of Burkinabe and Ghanaian experts.

To achieve the above objectives, 19 hydrometric stations were first selected to determine the available water resources in the sub basins namely the Black Volta, White Volta (with its sub-basins the Red, Sissili and Kulpawn) and the Oti. Of the stations, ten (10) are in Burkina Faso and nine (9) in Ghana. Further, six (6) are in the Black Volta, ten (10) in the White Volta and three (3) in the Oti. 63% of the stations had data ranging from 45 to 54 years while the remaining 37% had between 40 to 44 years of data.

The flow stations in Burkina Faso are Samendeni, Borono, Noumbiel and Batie on the Black Volta; Bissiga, Bagre and Bittou on the White Volta; Ziou on the Red Volta and Kompienga on the Oti. The stations in Ghana are Bui, Bamboi on the Black Volta; Nawuni, Pawlugu, Yarugu on the White Volta; Yagaba on the Kulpawn; Nakong on the Sissili and Saboba and Sabari on the Oti. See Map 2.

However, all the stations had varying periods of missing data. The data collected were scrutinized, validated and the missing ones estimated using rainfall-runoff model (Burkina Faso) and linear regression analysis (Ghana). The results of estimating the missing flow data are presented in Tables 2.1.1 to 2.1.10 for Burkina Faso and those for Ghana in Tables 3.1.1 to 3.1.9.

Water Availability Computations

Surface Water Resources

Secondly, water availability estimates at the selected stations covering long-term means, extremes and impact of climate change were computed. The long term means were based on 40-54 years of the flow data up to 2005. The extremes of water availability were defined on the basis of the percentile of flows over the periods of record with the:-

10	percentile	representing	Very Low Flow
25	“	“	Low Flow
75	“	“	High Flow
90	“	“	Very High Flow

The results of the computation of the long-term mean monthly and extreme flows are presented in Tables 2.2.1 to 2.2.10 and charts 2.2.1 to 2.2.10 for Burkina Faso. In the case of Ghana, they are presented in Tables 3.2.1 to 3.2.9 and Charts 3.2.1 to 3.2.9.

The climate change impact on flows arising from increases in greenhouse gases were taken into consideration. The changes in temperature and rainfall were computed using Global Circulation Models. Rainfall/Runoff Models were used to transform, the resulting temperature (evapotranspiration) and rainfall into runoff. The results show that water availability can be expected to decrease by 16% by year 2020 and 37% by year 2050 over flows in the base period 1961–1990.

Groundwater Resources

The current groundwater potential could not be evaluated because the data and information required by the planning model were not available at the time of the audit.

Water Quality

The surface and groundwater quality data and information were found to be in the same situation as described above for groundwater resources.

Water Demand Projections (2005-2030)

As a third step, water demand for various uses (viz domestic and industrial, irrigation and livestock, hydropower and ecosystem needs) based on current population and socio-economic activities and their expected growth rates were projected from 2005 up to the year 2030. The major water demand sites for which the projections were made include Ouagadougou, Bobo-Dioulasso, Kondogou, Ouahigouya, Pouytenga, Bagre in Burkina Faso and Tamale, Damongo, Bolgatanga, Tono, Vea, Bimbila and Wulensi in Ghana. See Map 3.

The water demand projections are presented in Tables 4.1.1B, 4.1.3A and 4.1.3B for Burkina Faso, and in Table 4.2.1 for Ghana.

The projection did not include hydropower impact at Bagre in Burkina Faso, nor irrigation water demand at Vea, Tono and Botanga in Ghana for lack of adequate and timely data.

Evaluation of Water Availability to meet Demand up to 2030

As the final step in the audit process a number of models were considered for use as a Decision Support System. In view of its cheaper cost and data requirements, the Water and Environmental Planning (WEAP) model developed by the Stockholm Environmental Institute (SEI) was selected.

The results of the water availability and water demand computations together with other data were fed into the WEAP model to customize it. It was then used to run the various scenarios namely: Mean, Very Dry, Dry, Wet, Very Wet years and under the impact of Climate Change, to find out the outcomes.

RESULTS OF THE EVALUATION

The results of the model run for all the scenarios mentioned above are presented in Table 5.7. For this Executive Summary, only the results for the significant or critical scenarios are presented.

The significant water availability situations relate to the Mean, Very Dry Year and Climate Change flows. For these, the preliminary results show that if demand is allowed to grow and "nothing is done" about the present resource capacity or infrastructure described as the Current Account Year (which for this study was chosen as year 2005), the ability to meet demand under the above water availability scenarios will be as follows:-

Water availability based on long-term mean flows

i) *In the case of domestic and industrial water supply*

There will be sufficient water to meet demand up to year 2030 in all the towns and cities in Ghana and Burkina Faso except Ouagadougou; Ouagadougou will experience water shortages in the dry months, starting from the year 2013. In 2015, 88% of Ouagadougou's demand will be met, while only 78% of the demand in 2030 will be met.

ii) *In the case of irrigation there will be shortfalls at:-*

- ♦ The Bagre scheme beginning 2013. In year 2015, only 45% of the water demand will be met. In year 2030, the available water will meet only 42% of the demand.
- ♦ The Lac Bam scheme. The demands that can be met will only be 23% in year 2010 to 2030. This is because the maximum area that can be brought under cultivation will be attained in 2010.

Water Availability in a Very Dry Year

i) *Domestic and industrial water demand*

- ♦ Demand can be met in all the towns and cities except the dry months in Ouagadougou, Tamale and Damongo.
- ♦ In Ouagadougou, 86% of the water demand can be met in 2015, and 69% in 2030.
- ♦ In Tamale, 99% of the water demand can be met in 2015 and 91% in 2030.
- ♦ In Damongo, 98% of the water demand in 2030 will be met.

ii) *In the case of irrigation water demand*

- Only 15% can be met between 2015 and 2030 at the Bagre irrigation scheme.
- Only 13.5% can be met at Lac Bam irrigation scheme between 2015 and 2030.

Water Availability with climate change impact

i) *Domestic water supply*
  - There will be pronounced shortages in the dry season months in Ouagadougou, Tamale & Damongo while other sites will have their demand met in full.
  - In Ouagadougou shortages will start from 2009 and by 2015, 88% of demand will be met reducing to 69% in 2030.
  - In Tamale the shortages will be experienced in the months of January, February and March. Demand shortages will be significant from 2030 when 93% of the demand will be met.

ii) *Irrigation water supply*
  - For the Bagre scheme 30% of the demand will be met in 2015, reducing to 15% in 2030.
  - For the Lac Bam scheme, only 18% of the demand can be met over the period 2015 to 2030.

CONCLUSIONS

From the study it is concluded that:-

i) The PAGEV project has resulted in a Decision Support System for assessing the feasibility of meeting water demand up to year 2030 for various needs at different locations or settlements within the Volta basin shared by Burkina Faso and Ghana. The Decision Support System is based on the WEAP Model. As presently constructed or customized, it can be used by the countries as a tool to provide preliminary information for policy making, negotiations, planning and development.

ii) The audit has enabled the gaps in the flow data at the selected stations to be filled. The SMAP Rainfall/Runoff Model was used in Burkina Faso while in Ghana, Linear Regression Analysis of hydrological and meteorological parameters were used. The results of the different methods were accepted for use in the assessment of water availability because a random check of results obtained by estimating the flows at Pwalugu with the SMAP Model showed good agreement with the results obtained by the Regression method.

iii) Long-term flow statistics have been computed for the stations for various water availability scenarios (viz means, extremes and climate change).

iv) The water availability/water demand (domestic, industrial, irrigation, environment) balance model constructed covers the period 2005 to 2030. The model has been run on the "Do Nothing" scenario and the preliminary results show that for:-

a. Domestic and industrial water demand;
    - Present supply will be inadequate to meet the demands in Ouagadougou, Tamale and Damongo from 2015 up to 2030;
    - The demand in Tamale will not be met in the dry season even for now. On an annual basis, the demand can be met except under climate change impact.

b. Irrigation
    - The demand cannot be met by the supply from the Bagre and Lac Bam dams from 2008.

v) The gaps in the stream flow data show that not enough resources are being made available to the relevant services in the two countries to provide regular and accurate data on a long-term basis.

vi) Water quality (surface and groundwater) monitoring is not being given the attention it deserves.

RECOMMENDATIONS

On the basis of the findings and conclusions, it is recommended that:-

i) The databases in the two countries be harmonized. Burkina Faso is better organized with spatial presentation of data within basin and administrative frameworks. The use of GIS data bases and GIS ArcView are well developed. Ghana on the other hand organizes its data in an administrative framework.

ii) Since the gaps in the river flow data were filled by different methods, the two countries investigate and adopt a method agreeable to them. This should take into account similar work being done under the GLOWA Volta and the Challenge Programme on Water for Food.

iii) Stream flow monitoring should be continued on a regular and long-term basis at all the 19 selected stations. Stream flow and ground water quality monitoring should form part of the water resource monitoring. This work should be harmonized with the Volta – HYCOS project.

iv) The Groundwater Assessment Project in Ghana should be completed to provide data on the groundwater characteristics at sub-basin and if possible at demand site levels. Similar assessment should be carried out in Burkina Faso using the data from the 38 monitoring stations of DGIRH. The information should be used to run the model for an evaluation of the groundwater potential to meet demand.

v) Since present and future water demand projections in the two countries are based on different standards (e.g. per capita water use per day), it will be important to adopt one standard wherever feasible.

vi) The model be refined by disaggregating the demands for irrigation and livestock to their proper locations in the sub-basins so as to avoid skewing the results.

vii) As the data on hydropower was incomplete, and was not incorporated in the model run, the data about the flow and reservoir characteristics should be completed and used to re-run the model to assess the impact of various flow sequences.

viii) Based on the results of the "Do Nothing Scenario", negotiations be entered into by the riparian countries to address the water shortages expected in Ouagadougou and Tamale under the mean and climate change low conditions from 2013 to 2030. This will contribute to meeting the National and Millennium Development Goals for water supply and sanitation.
Similarly, negotiations to increase water supply for irrigation after the domestic demands have been met should start concurrently.

ix) Since a number of structural and non-structural options are available for achieving the above, the feasible ones should be evaluated and their impacts assessed for equity and sustainability. These include:-
    a) Increasing storage at the intake of the Tamale water supply;
    b) Creating a new surface storage for the Bagre Irrigation project or do away with the plan to bring additional land under irrigation or mobilize groundwater to supplement the surface supply.
    c) Using non-structural means such as Water Demand Management and Regulatory Measures.

x) A training seminar should be organized for the staff of the relevant institutions in Burkina Faso and Ghana on the use of the WEAP model and how it has been customized for use as a Decision Support System by the two countries. The institutions should be assisted to acquire the model.

xi) It is suggested that the new Volta Basin Authority (VBA) leads the way in implementing the above recommendations.

1. INTRODUCTION

1.1 Background

This report represents the results and recommendations of the audit of the water resources of the Volta River Basin which is shared by Burkina Faso and Ghana. The other riparian countries of the basin are Benin, Ivory Coast, Mali and Togo. Burkina Faso and Ghana alone account for 85% of the 400,000 sq km surface area of the basin.

The Volta River has been a source of water for the populations in the basin for many years. Since the 1960s and with growth in population and economic development, there has been a corresponding growth in water use. The river is presently developed as a source of hydropower in Ghana, Togo, Benin and Burkina Faso. It is also a source of drinking and industrial water supply for rural communities and urban centres like Ouagadougou, Bobo Diolasso, Tamale and Accra. The development of agriculture particularly in the drier parts of northern Ghana and Burkina Faso depends very much on a number of dams (small, medium and large) which have been constructed to provide irrigation water for dry season farming and for livestock watering.

These have resulted in land and water management problems. These problems include water shortages, water quality degradation, water borne diseases, flooding, loss of biodiversity, growth of aquatic weeds, coastal erosion, etc. These problems have been worsened by the fact that the developments have been driven by individual national needs with less consideration for other riparians. In the past decade or so, there have been a number of initiatives to get the riparian countries to co-operate either at the bilateral or multilateral level to consult and co-operate in addressing the problems in an integrated manner.

1.1.1 Development Context (Water Management in the Volta River Basin)

The development of water resources to meet various sectoral needs in a sustainable manner should be seen within the national contexts of the National Water Visions and the Goals of National Poverty Reduction Strategy Papers, the West African Water Vision, The African Water Vision and the goals of the New Partnership for African Development, and the Millennium Development Goals.

Since the basin is shared by a number of countries, it is important that the management of the water resources to meet the needs of the riparian countries should be seen within the shared river basin context. Consequently, it is necessary to relate the water audit to current initiatives to manage the resources of the basin on a co-operative basis.

1.1.2 River Basin Context

The Ghana/Burkina Faso Joint Committee on the Volta Basin which was recommended in 1996 to provide a forum for periodic consultation in the use of the Volta River Basin saw the need to manage the water resources in a river basin context. The recommendation was not implemented but in April 2004 a Joint Ghana/Burkina Faso Declaration on the improved management of the natural resources of the Volta Basin was signed in Accra. To realise the aspirations of improved management, a Joint Technical Committee on Integrated Water Resources Management (IWRM) was created in December, 2005.

As the pressure of human development on the basin grew, the six riparian countries have sought assistance from the Global Environmental Facility to help them manage the basin. Towards this end, a Transboundary Diagnostic Analysis (TDA) has been carried out and a Strategic Action Programme (SAP) has been developed towards joint management of the basin for the equitable benefit of the countries. This was developed between 2001 and 2002. Following this, an Intergovernmental Consultative Committee called the Volta Basin Technical Committee (VBTC) made up of representatives of the six riparian countries was established in 2004 to facilitate the creation of the Volta Basin Authority.

Another initiative in the basin is by the German Ministry of Education and Research (BMBF) to obtain an understanding of the trends in global climatic change and its effects on the water resources. This is called the GLOWA Project.
The Volta basin has been selected as one of the basins to carry out the study. This is the GLOWA-Volta project. It is a 9-year programme. The first phase started in 2000 and ended in 2003. The second phase was completed in 2006. The third phase is expected to start in 2007.
The GLOWA Volta Project is a scientific study funded by BMBF, to conduct a comprehensive, integrated analysis of the physical and socio-economic determinants of the hydrologic cycle within the Volta Basin, focused on the impacts of changes in land use and climate. The principal objective of the project is to establish a scientifically sound and adequately tested Decision Support System (DSS) for water and land management. The DSS will provide a comprehensive monitoring and simulation framework, enabling decision makers to evaluate the impacts of climatic trends, along with deliberate policies, investments of other interventions on the social, economic and biological productivity of water resources. The project consists of 15 sub-projects grouped into four research clusters namely: Atmosphere cluster; Land use cluster; Water use cluster; and Technical integration and decision support cluster.

Another initiative which is also related to the Water Audit is the project aimed at improving the productivity of water for food production being implemented under the Challenge Programme on Water and Food (CPWF). The CPWF is a multi-institutional research initiative that aims to increase water productivity for agriculture – that is, to change the way water is managed and developed to meet food security goals – in order to leave more water for other users and the environment. Its overall goal is to contribute to efforts by the global community to increase food production to achieve internationally adopted food security and poverty eradication targets by 2015, while ensuring that global diversions of water to agriculture are maintained at the level of the year 2000. The Program is guided by five Research Themes which ensure that research will focus on those disciplinary areas where increases in water productivity are most likely to be achieved. The themes are Crop-Water Productivity Improvement; Water and People in Catchments; Aquatic Ecosystems and Fisheries; Integrated Basin Water Management Systems; The Global and National Food and Water Systems.

It is being carried out in nine (9) different river basins around the world including the Volta Basin. The first phase of the 15-year programme which started in 2003 will end in 2008. Preparation for the second 5-year phase is underway as a follow up after 2008.

1.1.3 IUCN initiatives

Since 2004, the World Conservation Union (IUCN) also initiated the project for Improving Water Governance in the Volta Basin (PAGEV). The project is aimed at Policy and Institutional Change; promoting the use of Principles of IWRM and developing a Decision Support System to assist in the allocation and conservation of water among the riparian countries. In this regard, it has:-

i) Provided assistance for the Ghana/Burkina Faso Joint Technical Committee on the Volta Basin to prepare a Code of Conduct for the integrated management of the Water Resources Volta Basin between Ghana and Burkina Faso to be adopted.
ii) Assisted the VBTC to prepare a Convention and Statutes for establishing a Volta Basin Authority comprising all six riparian countries. The agreement to establish the Volta Basin Authority was signed in Lome in July 2006. By October 2006, the Secretariat had been established in Ouagadougou. The statutes of the authority were ratified by the six Heads of State in January 2007.
iii) Carried out a Water Audit of the Volta Basin shared by Burkina Faso and Ghana.

In all these, the management of the water resources to meet socio-economic development and environmental needs on a sustainable basis will depend on the allocation of water resources; conservation of water quantity and quality; prevention of conflicts. To accomplish the above, the IUCN is assisting the Burkina Faso/Ghana Joint Technical Committee to assess:-

a) Water availability under various conditions (natural geophysical and climate change conditions);
b) The water demand to meet current and projected needs including those of the environment balance what is available with the demand.
c) Identify the hot spots (areas of supply storage, pollution, land degradation) by superimposing the demands on the suppliers;
d) Negotiate and assess the various regulatory (structural, non- structural, or both) that can be put in place to maximize the benefits to the riparian countries.

The basis for negotiation will be a Decision Support System that will be developed to provide information which riparians and their constituents can use to make choices and assess their inputs and guide actions at national provincial (regional), district and community levels. If this can be achieved among the riparians which share the greatest percentage of the basin viz Burkina Faso and Ghana, the management of the whole basin can be made easier.

1.2 Objectives

This audit was preceded by a pre-audit in 2005 which carried out among other things an inventory of the available water resources data (quantity and quality) and data collection networks in the sub-basins of the Volta river, a compilation from accessible reports and published papers; the hydrological information on present water availability and demand with respect to the sub-basins and assessment of the adequacy of the existing data and data collection network for carrying out a water audit and to develop water management scenarios to cope with trends in water demand and availability and water resources planning in general. The pre-audit found information gaps with respect to:-

- Quality control and filling of gaps in the river flow data;
- Environmental river flow requirements;
- Direct abstractions from the river and springs for irrigation in the Burkinabe part of the Black Volta Basin;
- Flow requirements/releases by the existing and planned dams in Ghana;
- Groundwater abstractions for Irrigation;
- Data on water uses and water availability in the other riparian countries (Oti River in Togo and Benin, Black Volta River in Cote d'Ivoire and Mali) because the focus of most projects in the basin is on Burkina Faso and Ghana.

On water resources and uses in the basin, the pre-audit also found that:-

- There is an enormous amount of suggested future surface water uses in the basin Ghana and, to a lesser extend, also in Burkina Faso. This underlines the need for a water audit in the basin;
- The non-linear relation between the rainfall and the river flow (Andreini, 2000) makes the runoff in the Volta Basin very sensitive to climatic variations;
- Large multi-year oscillations appear to be more frequent and extreme after the late 1980s (Dai et al., 2004). This may result in large inter-annual variations in river flow;
- Two studies that investigated the impact of downscaled global climate scenarios on the water resources in the Volta Basin predict an increase in river flow, while a third study predict a decrease in river flow;
- Between 1955/65-70 and 1972-98, in the upstream part of the White Volta in Burkina Faso the mean river flow increased despite a reduction in rainfall and an increase in the number of dams. The increase was due to the following changes in land use; increase in cultivated area, increase in area with bare soil and a decrease in area with natural vegetation (Mahe et al., 2003 and 2005a);
- The estimated quantity of used groundwater by drilled wells for rural and urban water supply in 2001 (GLOWA Volta) is less than 5% of the mean annual groundwater recharge;
- At this stage the information on groundwater resources is too scarce and too dispersed for the development of a groundwater flow model for the basin.

For the Audit itself, the objectives are:-

- To make available and share the scientific knowledge on the status and dynamics of water quantity and quality in the Volta river system.
- To develop management options for the water resources under various scenarios of water availability and demand in the basin.
- To develop a decision support system, which would be used by the countries to manage the resources to meet their needs on an equitable and sustainable basis.
- The Terms of Reference for the study is attached as Annex 6.

1.3 Approach/Methodology

The assignment was carried out by a team consisting of Burkinabe and Ghanaian specialists under the leadership of Nii Consult. The members were:-

- Nii Boi Ayibotele (Ghana) – Water Resources Management – Team Leader;
- Mr. Innocent Ouedraogo (Burkina Faso) – Water Resources Specialist ;
- Mr. Kandaogo Sawadogo (Burkina Faso) – Hydrologist;
- Dr. Yaw Opoku-Ankomah (Ghana) – Hydrologist;
- Mr. Isaac Asamoah (Ghana) – Water Planning Modeling Specialist.

The assignment was carried out in four phases with tasks under each phase as shown in Fig. 1.

Phase 1

Was devoted to data collection on surface and groundwater and on water uses as follows:-

Task 1.1: Consisted of data collection on the water resources (surface and groundwater) water levels, discharge at various stations, etc.

Task 1.2: Consisted of data collection on settlements water uses for domestic industrial, livestock, irrigation, etc. uses.

The outputs of phase I were fed into phase II as inputs.

Phase 2

The data collected in Phase I were analysed in Phase II as follows:-

Task 2.1: The determination of water availability under past and present conditions and water availability under climate change were carried out.

Task 2.2: Under this task Estimate of present water demand and projections of water demand for 2010, 2015, 2020, 2025 and 2030 were carried out.

Phase 3

The outputs of Phase II were used as inputs of Phase III.
Phase III addressed the water balance under different water supply and demand conditions and evaluation of the results in the following tasks.

Task 3.1: The water balance between demand and supply under various combinations of demand and water availability were determined using the Water Evaluation and Planning (WEAP) model.

Task 3.2: The results together with the, environmental impact of the results were evaluated. The adequacy of surface and groundwater data used in the study were evaluated and appropriate recommendations made.

Phase 4

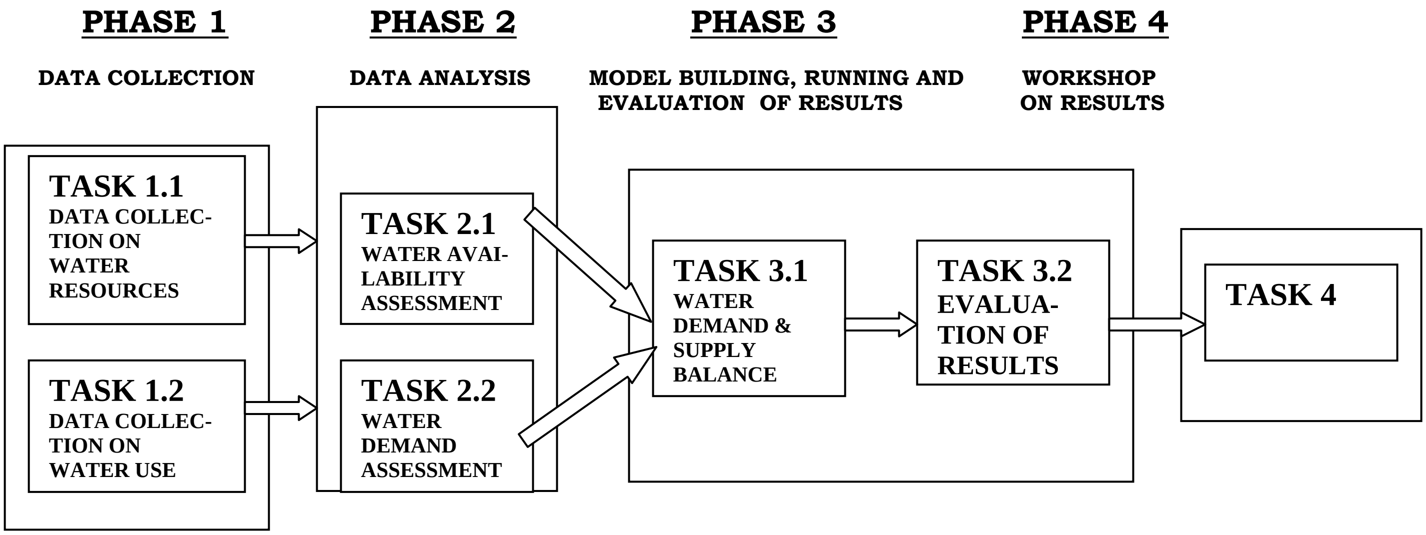
This Phase was dedicated to organise a Workshop to present and discuss the findings of the assignment. It consisted of the following tasks and corresponding activities:-

Task 4.1: *Preparation of Workshop*
A Draft Report was prepared and selected participants were invited.

Task 4.2: *Organisation of Workshop*
The consultants presented their findings and the participants made various comments and suggestions and validated the draft report for finalisation.

Task 4.3: *Preparation of Workshop Report*
The workshop comments together with those received from outside have been used to prepare this Final Report.

Fig. 1: Phasing of Assignment and Tasks carried out



The assignment was guided by PAGEV who on the basis of the pre-audit selected a total of 20 river flow stations (in both countries in the Black, White and Oti sub-basins). These were considered the best candidate stations by which the surface water resources can be assessed. Another set of meteorological stations were selected which report rainfall, temperature humidity and other parameters.

The team held three meetings. The first was in Ouagadougo from June 20th to 21st 2006 to finalise the work plan and contract agreements. The second was in Tamale on 17th November 2006 to review the methodologies, harmonise and integrate the results so far. The third was held in Accra from 6th to 9th February, 2007 to update WEAP module runs with additional data from Burkina Faso.
A progress report was submitted in September 2006 and updated in November, 2006. A draft report (version 1) was submitted on 22nd December and updated on 1st March 2007 as version 2. The final report was produced after the draft had been validated at a workshop held in Accra on 22nd and 23rd May 2007. It was attended by experts from Burkina Faso, Ghana and representatives of international organizations working on related problems in the Volta Basin.

1.4 Structure of the Report

The report consists of an Executive Summary and a Main Report.

The main report is in six Sections. The first section provides the background to the project. The second and third parts deal with the assessment of water availability in Burkina Faso and Ghana respectively. The fourth part deals with current and projected water demand in the two countries up to 2030. The fifth part addresses the balance between demand and supply and identifies the hot spots (namely centres where the demand cannot be met, points on the river where the pollution loads will negatively affect aquatic flora or fauna or will be unsafe use as a source of drinking water). These will point the way to water resources management interventions. The sixth and final section deals with conclusions and recommendations.

The report is supported by a list of persons and documents consulted. It also contains a list of tables, charts, maps and figures which are the results of the analysis and the running of the WEAP Model. There are also annexes. The raw data is on a CD Rom.

2. WATER AVAILABILITY – BURKINA FASO

The process of determining the water availability consisted of collecting flow and ground water data, the screening of the data to ensure that they are of good quality and use of various methods to fill the data gaps detected and the extension of data. This was followed by analysis to assess the water availability under mean extreme and climate change conditions. The above processes were followed independently for the Burkina Faso and Ghana sides of the basin.

2.1 Surface Water Availability

This was focused on the Black Volta with its main tributary the Sourou; the White Volta with the Red, Sissili and Kulpawn as its main tributaries and the Oti river.

2.1.1 Selected River Flow Stations for Water Availability Assessment

The stations selected by PAGEV to assess the water availability are:-

- Samendeni on the Black Volta
- Borono on the Black Volta
- Noumbiel on the Black Volta
- Batie on the Bambassou on tributary of the Black Volta
- Bissiga on the White Volta
- The Bagre Dam on the White Volta
- Ziou on the Red Volta
- Nebbou on the Sissili
- Bittou on the White Volta
- The Kompienga Dam on the Oti River.

The flow data used were provided by the DGRE. Previously, it had undertaken an improvement in the quality and re-organisation of hydrometric data at all the hydrometric stations in the country. This consisted of screening water levels, re-establishment of rating curves/update of existing flow measurement files, rating curves, reservoir levels, an update of monthly flow data, piezometric levels as well as water quality. For the water audit, reviews of the different coding of data as well as the geographical co-ordinates were carried out. As found during the pre-audit, there were gaps in the flow data and some were of short duration as in the case of Ziou. The flows at Bagre and Kompienga had been affected by dam development.

It was therefore decided to fill the gaps in the flow records and extend the record using a Rainfall/Runoff Model called SMAP. The model uses meteorological data to estimate the stream flow.

The meteorological data used are the monthly values for the following parameters Rainfall; PET, Penman, Class A Pan Evaporation; Wind Speed 10 m above round, Temperature and Relative Humidity. The data were obtained from the meteorological services and are of good quality. A summary of the various stations and their locations, the period covered and the sub-basins in which they are located are presented in Annexes 2.1, 2.2, 2.3, 2.4, 2.5 and 2.6 respectively. The corresponding data for each station are on the CD Rom. A map of the rainfall stations are presented as Map 1.

For the hydrometric stations a summary showing the rivers on which they are located, the year in which the stations were opened, the catchment area behind them, the equipment used and the state of operation are presented in Annex 2.7. Their locations are shown in Map 2.

2.1.2 Analysis of the size of the observation samples

The objective of this phase of the analysis was to verify and control the size of the samples of the available data to conform to the norms required for statistical analysis: viz; stable mean annual flows, minimized mean error. A comparison between the calculated values of coefficient of variation (Cv), E_m (mean error) and n (sample size) with the theoretical values allows for verification of the sufficiency of the sample size. This is shown in Annex 2.8.

2.1.3 Use of SMAP Model to Fill Gaps and Extend Data

The filling in of the missing data was done using SMAP which is a hydrologic model based on simplified reservoirs that permits the transformation of rainfall into runoff, considering the physiographic features of the basin. For the running of the model, the data used were monthly rainfall, potential evapotranspiration and river discharges.

Rainfall (mm/month):

The monthly precipitation in every selected sub basin was estimated as the average of the rainfall of the stations close to the basin or by using the method of the Thiessen polygon. Some weights were assigned to every rainfall station according to the percentage of the basin covered by the corresponding polygon. Most sets of monthly rainfall data had gaps. It was important to take into account this when adjusting the Thiessen weights for stations with missing data. The quality of the precipitations data seemed good, although there were incomplete sets.

Potential Evapotranspiration (mm/month):

The potential evaporation (PET) was estimated by the National Meteorological Institute. The quality of evapotranspiration data was satisfactory enough for the intended use.

These two parameters needed to be complete for the purposes of running the model.

Available observed discharge:

The SMAP model was run using the available observed discharge. The available observed discharge was used directly to describe the water availability in the sub basin. However, a lot of the data sets were of a short duration and were not representative for the general climatic variation in the basin. The SMAP model was used for all selected stations. The output from the model is essentially the simulated flows for months with missing flows and observed flows for the years for which data is available. The SMAP model does not change any observed value. The agreement between the simulated and observed flows was generally good for all stations selected except Nobéré and Dapola where the simulation was so bad that those stations had to be abandoned.

A brief description of the SMAP model is presented in Annex 2.9.

2.1.4 Results of the Analysis and filling of gaps by station

Among the hydrologic parameters the long-term flow is the one that best characterizes water resources of a river basin.

The definition of the sample size necessary: While considering the long-term flow as being the most stable parameter for quantifying the water resources in a basin, it can be defined as the average inter annual flow of a river for given period of years of data after which, an increase in the sample size does not significantly change the flow value. It is defined in this case as:

$$M_O = \frac{\sum M_i}{n} \qquad (2.1)$$

Where M_B is the long-term flow, M_i is the flow in year I and n is the number of years of data. In this case it is possible to calculate the mean error for the value which is defined in statistical terms as:

$$E_{moy} = 100 \frac{C_v}{\sqrt{n}} \% \qquad (2.2)$$

where n is number of years of observation and
C_v is the coefficient of variation for the following values of n

$$C_v = \sqrt{\frac{\sum (k-1)^2}{n-1}} \; for \; n \langle 30 yrs \qquad (2.3)$$

$$C_v = \sqrt{\frac{\sum (k-1)^2}{n}} \; for \; n \geq 30 yrs \qquad (2.4)$$

Where k corresponds to the position of each value when the flow values are arranged in ascending or descending order. Thus k varies from I to n.
The error is minimised if the sample size is large.

Having filled the gaps and extended the data as presented in Tables 2.1.1 to 2.1.9 the next steps was to compute flow statistics (co-efficient of variation and standard error of the mean flows) over the period for which the data are available. These were then compared the theoretical values, to ascertain the stability of the long term mean monthly and annual flows.

Table 2.1. 1:Samendeni on Black Volta

Reconstituted mean monthly flows in m^3/ s												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
1961	4.03	3.3	2.78	2.51	2.68	3.64	9.58	58.6	131	34.2	10.4	5.49	**22.3**
1962	3.99	3.3	2.71	2.57	2.73	2.94	4.15	19.8	63.4	31.8	10.3	4.51	**12.7**
1963	3.24	2.85	2.47	2.53	2.64	2.68	6.32	40.4	109	44.9	13.8	5.43	**19.7**
1964	3.66	3	2.65	2.07	2.59	2.51	15.5	73.4	116	46	10.9	9.57	**24.1**
1965	7.03	4	2.66	1.95	2.89	5.7	8.67	52	89.7	43.5	14.1	6.58	**19.9**
1966	4.01	2.92	2.21	2.03	2.42	3.51	8.44	23.1	35.5	41	13.6	5.23	**12.1**
1967	2.89	2.24	1.97	1.93	8.63	4.07	4.81	28.9	66.2	61.4	14.1	8.67	**17.2**
1968	8.46	8.22	7.96	8.06	8.01	9.75	27	56.1	78.6	38.9	20	14.1	**23.8**
1969	8.79	8.54	8.3	1.84	7.83	4.75	13.9	30.3	84.1	31	14.3	5.82	**18.3**
1970	3.11	2.19	1.43	1.39	1.9	6.37	17.7	105	104	32.1	11.2	6.75	**24.5**
1971	3.45	2.87	1.68	1.57	3	4.2	8.18	58.4	48.9	13.6	3.3	3.19	**12.8**
1972	9.17	8.9	8.63	1.48	4.32	8.52	7.13	21.6	22.4	12	1.8	1.31	**8.94**
1973	6.9	6.69	6.49	6.3	6.29	5.13	7.73	30	16.8	3.48	1.48	5.72	**8.61**
1974	1.18	0.98	0.87	0.81	1.34	4.26	23.9	62.5	51.5	20	5.98	2.36	**14.7**
1975	1.61	1.29	1.31	1	3.34	6.34	18.6	53.7	61.9	24.3	6.86	2.89	**15.3**
1976	2.21	1.49	1.07	2.43	4.75	6.69	7.7	27.3	31.5	24	21.9	6.64	**11.5**
1977	2.58	2.07	1.37	1.21	2.59	4.18	4.97	14.4	37.1	16.6	3.92	3.13	**7.85**
1978	1.74	1.19	1.76	3.09	2.62	2.93	10.8	25.1	40.1	39.6	9.69	4.8	**12**
1979	1.45	0.95	0.66	5.58	6.94	13.9	21.1	60	73.4	27.6	12.7	4.87	**19.2**
1980	2.16	1.07	0.79	0.85	7.22	9.89	16.6	30.1	55.6	17.4	6.86	2.69	**12.6**
1981	1.32	0.87	0.6	0.61	1.87	4.34	11	28	48.5	17.3	4.99	1.72	**10.1**
1982	0.95	0.83	0.83	1.48	1.34	9.19	10.6	43.3	51.2	18.6	10.5	3.77	**12.8**
1983	1.81	0.88	0.6	0.92	1.51	3.05	3.94	11.3	16.6	6.06	1.28	0.95	**4.09**
1984	0.59	0.27	0.19	0.05	2.23	3.18	4.34	3.73	12.6	8.33	1.34	0.89	**3.16**
1985	0.31	0.11	0.05	0.02	1.03	5.61	25.7	57.5	54.2	18.3	4.58	1.91	**14.2**
1986	1.11	0.51	0.3	0.47	1.42	3.17	8.14	27.8	67	32.5	9.09	3.13	**12.9**
1987	1.44	0.9	0.63	0.18	0.02	7.92	3.42	28.4	36.8	14.3	4.19	1.7	**8.34**
1988	1.01	0.5	0.31	2.62	0.91	7.29	12.7	48.5	39.4	27.4	7.57	3.4	**12.7**
1989	1.28	0.61	0.42	0.22	0.43	2.33	11.9	37	47.4	15	3.77	1.5	**10.2**
1990	0.86	0.39	0.13	0.07	2.09	6.02	17.5	35.3	25.4	12.2	3.34	1.25	**8.78**
1991	2.36	2.34	2.22	0.11	4.38	7.94	13.3	41.5	76.6	26.2	12.9	7.57	**16.5**
1992	3.49	3.27	3.17	3.08	1.16	5.6	16.2	20.4	53.8	18.7	8.55	2.4	**11.7**
1993	0.8	0.56	0.47	0.07	0.91	2.6	11.7	26.6	37.5	15	6.84	1.72	**8.76**
1994	4.34	0.4	0.14	0.07	0.87	3.42	16.6	61.7	69	52.7	33.5	3.57	**20.6**
1995	3.52	3.42	3.31	3.21	2.94	7.78	11	37.2	42.4	21.6	7.96	3.21	**12.3**
1996	1.26	0.7	0.29	0.83	1.98	4.44	20.1	40.4	70.3	39.2	9.08	4.17	**16.1**
1997	3.66	0.31	0.15	0.08	2.76	6.73	10.5	24.6	48	27.5	9.06	5.82	**11.6**
1998	3.85	2.38	1.24	0.97	8.1	10.2	14.6	42.5	55.7	37.8	9.29	3.1	**15.9**
1999	1.33	0.57	0.21	0.37	2.03	3.24	19.2	86.2	60.6	54.5	21.7	9.17	**21.8**
2000	4.5	1.46	0.6	0.54	4.77	17.9	22.4	91.7	58.8	40.2	15.5	8.42	**22.4**
2001	4.61	2.08	0.93	2.43	5.96	7.13	26.3	45.4	43.9	21.5	8.07	3.84	**14.4**
2002	1.09	0.43	0.31	0.3	0.68	16.5	18	42	27.8	17.9	8.1	3.8	**11.5**
2003	0.46	0.17	0.01	0.17	1.16	11.9	30	94.7	67.8	26.4	9.1	7.48	**20.9**
2004	2.34	7.18	6.95	6.74	1.3	3.51	10.5	25.6	21.5	3.32	3.23	0.99	**7.76**
2005	0.45	5.63	5.46	5.31	5.15	11.9	18.8	29.3	50.7	15.6	3.25	4.43	**13**

Table 2.1. 2: Boromo on the Black Volta

Reconstituted mean monthly flows in m^3/ s												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annuel
1961	21	12.4	8.62	7.35	9.01	11.6	23.6	90.6	158	112	86.3	63	**50.4**
1962	38.2	21.9	12	8.22	8.68	12.8	17.5	62	167	131	72.6	46.1	**49.9**
1963	21.7	12.1	8.15	7.37	32.8	10.3	27.6	82.8	88.4	81.7	72.1	61.4	**42.4**
1964	35.6	17.6	9.5	6.77	8.17	23	39.2	69.9	156	130	80.9	67.6	**53.8**
1965	43.6	23.8	12	8.18	8.54	17.2	32	75.4	114	110	70.4	56.8	**47.8**
1966	31.3	15.9	9.76	6.8	14.3	15.2	15.9	34.8	64	74.7	50.5	31.5	**30.5**
1967	14	9.04	7.29	6.82	9.2	10.3	22.5	56.3	93	72.8	57.7	42.8	**33.6**
1968	18.1	10.5	7.71	7.33	12.2	39.3	30.8	59.2	72.1	72	65.3	49.1	**37.1**
1969	25	12.9	8.22	7.78	6.54	14.1	52.4	86	140	106	67	48.7	**48.1**
1970	23.5	12.1	7.79	6.31	7.68	13.9	31.7	85.2	123	105	85.9	65.1	**47.4**
1971	40.5	22.6	11.4	9.29	6.34	21.1	31.9	58.4	122	83	54.8	27.2	**40.7**
1972	13.2	7.62	6.68	6.76	11.1	36.1	23	53.8	53.5	35.9	17.6	8.16	**22.8**
1973	5.6	3.73	4.15	5.96	12.3	8.67	36.3	86.6	47.9	23.4	6.83	4.51	**20.7**
1974	3.27	2.72	1.96	2.28	11	14	43.2	111	132	100	61.6	31.1	**43.1**
1975	16.2	16	3.18	2.37	6.29	12.9	30.2	56.2	91.7	52	50.1	26.7	**30.3**
1976	7.97	4.81	3.11	2.24	13.6	24.9	32.7	40	43.3	43.9	37.9	22.4	**23.2**
1977	9.35	5.37	2.9	1.9	3.17	18.7	30.1	57.4	85.3	47.1	29.1	9.44	**25.1**
1978	4.23	2.44	1.75	5.39	11.8	22.3	43.5	76.1	57.8	46.9	43.4	22.6	**28.4**
1979	6.58	2.98	1.8	1.26	7.25	39.6	47.7	47.5	102	72.2	57.5	28.5	**34.7**
1980	8.42	4.19	2.08	1.25	5.93	21.5	27.8	62.1	89.6	47.1	36.9	9.51	**26.4**
1981	5.27	3.48	2.61	2.04	6.08	22.4	42.6	87.9	84.4	34.1	24.2	7.26	**27**
1982	3.51	2.16	1.74	1.7	11.7	16	23.2	32.3	36.3	33.5	29.5	10.1	**16.9**
1983	5.14	3.3	1.73	1.36	3.51	9.99	41.8	72	29.6	18.9	0.6	0.09	**15.8**
1984	11.3	11.2	11.1	11	10.9	13	14.9	6.34	13.6	2.93	1.07	0.43	**8.95**
1985	0.38	0.27	0.16	0.05	1.3	8.31	95.6	98.3	57	43.4	41.9	17.9	**30.7**
1986	1.4	0.38	2.58	1.04	3.12	14.6	19.3	25.3	58.3	13	27.6	13.8	**15**
1987	4.56	3.66	2.37	2.09	2.07	19.1	14.1	39.6	11.1	5.55	8.97	4.13	**9.82**
1988	3.5	2.59	2.24	2.2	1.15	11.5	42.1	95.8	102	46	45.7	31.1	**32.3**
1989	4.81	3.66	3.07	3.38	1.88	0.73	49.8	53.8	55	19.1	24.6	21.2	**20.2**
1990	13.9	6.98	3.27	1.97	0.75	5.95	23.2	19.9	17.1	3.11	2.48	2.47	**8.45**
1991	2.61	2.56	2.45	1.99	1.91	5.63	38.3	51	68	57.2	8.43	8.26	**20.8**
1992	15.2	4.73	3.02	2.52	10.2	13.6	25.3	45.3	59.2	10.6	24.9	18.6	**19.5**
1993	4.79	3.43	2.76	3	3.23	13.5	18.2	47.2	55.6	18.5	29.2	16.7	**18**
1994	3.5	2.79	2.96	3.16	3.21	8.09	56.4	139	143	100	63.6	55.1	**48.7**
1995	47.8	40.1	27.9	4.4	6.6	17.8	11.5	25.1	17.5	11.5	14.5	11.7	**19.6**
1996	4.72	4.72	4.54	11.2	23.8	13.2	42.1	80.7	65.7	40.7	23	5.66	**26.8**
1997	5.65	3.41	3.29	10.5	11.3	12.6	16	36.1	27.1	25.2	18.6	7.9	**14.9**
1998	5.18	3.51	3.01	10.6	14	15.8	29.9	91	43.1	39.4	21.8	12.2	**24.3**
1999	6.17	4.76	9.24	9.15	13.6	11	28.1	158	208	100	66.3	58.9	**56.3**
2000	30.1	21.6	7.77	4.07	4.47	28.4	31.9	53.1	26.5	43.4	42.9	26.1	**26.7**
2001	5.81	3.9	3.69	10.2	17.2	26.5	83.4	60.1	54	22.9	15.3	4.09	**25.8**
2002	3.9	3.67	3.44	3.56	3.14	14.1	50.6	26	14	13.1	3.77	3.61	**12**
2003	3.67	3.36	3.29	3.37	17.9	36.2	40	86.2	153	88.6	48.6	35.3	**43.4**
2004	15	8.5	8.01	7.99	7.31	19	56.2	98.1	74.8	9.07	7.47	7.09	**26.7**
2005	6.57	6.29	3.19	3.27	7.1	16.5	42.6	28.9	46.1	16.1	9.71	9.58	**16.4**

Table 2.1. 3: Noumbiel on Black Volta

Reconstituted mean monthly flows in m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annuel
1961				0.39	4.35	24.3	95.6	244	421	60.5	67.3	14.8	**77.8**
1962	2.19	0.09	0	0.42	17.8	89	154	684	1238	735	780	215	**327**
1963	122	57.7	12.4	10.8	15.8	63	251	1078	1324	1483	490	370	**443**
1964	112	25.4	11.5	3.23	3.12	23.5	152	474	839	434	205	167	**205**
1965	51.2	14.9	1.97	0.37	0	30.6	209	717	898	582	234	125	**240**
1966	31.2	4.95	1.33	0	13.1	35.1	92.8	330	673	514	140	81.6	**160**
1967	18.1	2.45	0.44	0	6.81	18.9	58.3	213	577	126	141	41	**100**
1968	7.43	5.57	1.24	0.31	12.9	44.9	233	632	1295	628	499	222	**299**
1969	63.1	14.2	5.49	0.78	2.3	10.9	98	471	926	766	274	163	**234**
1970	48.8	7.89	1.21	0.01	2.84	12.3	69.7	420	914	369	228	93.4	**181**
1971	22.7	10.1	5.43	3.1	4.32	9.92	73.2	398	726	216	156	95.1	**144**
1972	12.4	5.13	0.95	0	11.2	54.1	144	372	445	434	71.8	54.4	**135**
1973	12.7	2.17	0.67	0	3.31	13.6	65.9	297	376	196	56.7	37.8	**88.9**
1974	4.24	0.6	0.31	0	3.91	6.87	49.6	369	756	411	169	90.5	**155**
1975	23	5.06	3.62	0.84	1.91	17.8	97.2	266	626	242	67.7	32.5	**116**
1976	10.5	3.59	1.72	1.79	9.38	57.1	55.2	114	151	256	302	41.8	**83.8**
1977	49.3	6.67	7.18	60.2	0	33.8	63.8	86.9	604	212	16.1	8.58	**95.6**
1978	3.6	1.99	2.6	2.8	35.2	29.7	144	198	277	192	78.8	47.4	**85**
1979	10.7	1.22	0.13	0	0.96	32	181	431	690	274	186	56.8	**156**
1980	19.1	2.17	0.09	0	5.64	17	52	279	634	383	140	78.8	**135**
1981	14.2	2.29	1.71	0.14	0.29	11.8	44.1	169	323	67.6	31.1	8.27	**56.2**
1982	3.39	1.95	3.91	13.5	47	13.5	62.9	197	248	103	53.5	13.1	**63.7**
1983	5.55	1.97	0.83	0.43	17.5	50.5	76.9	163	163	46.1	2.99	0.03	**44.3**
1984	0.19	0.01	0	0.21	42.4	69	58.7	78.3	124	79.4	3.77	0.05	**38.2**
1985	3.81	0.42	0.07	0.06	8.74	65.2	217	529	583	197	50.5	22.8	**141**
1986	1.04	1.93	0.51	0.19	7.4	49.9	81.2	210	521	198	46	16.8	**94.6**
1987	3.55	1.23	1.68	1.1	0.01	106	121	480	464	237	17.5	4.27	**120**
1988	0.39	0.23	3.25	5.36	7.89	17.9	125	275	667	522	56.5	41.2	**144**
1989	2.86	0.3	0.01	0.03	0.42	4.2	40.1	265	679	449	154	128	**144**
1990	8.52	1.81	0.61	4.96	4.11	28	69.9	205	137	40.3	4.39	0.47	**42.4**
1991	1.43	0.17	2.13	1.56	8.69	31.8	100	443	395	385	94.4	53	**127**
1992	15.7	3.33	0.41	0.27	0.17	20.4	63.2	132	188	83.6	49.8	5.22	**47**
1993	1.35	0.27	0.01	0	1.09	6.16	34.8	195	431	181	62.6	27.7	**78.6**
1994	0.88	0.25	0.17	0.27	8.49	34.5	128	302	674	610	218	82.7	**172**
1995	11.7	2.47	13.4	5.6	17.2	140	115	286	253	165	33.1	5.31	**87.8**
1996	2.1	1.43	1.45	4.31	14	49.6	90.8	311	668	366	28.2	6.88	**129**
1997	2	0.37	0.23	15.3	17.1	92.4	71	155	308	334	24.7	9.35	**86.2**
1998	2.43	0.58	0.1	3.18	63.4	42.3	62.2	221	404	235	51.7	8.15	**91.5**
1999	2.87	1.83	0.27	10.1	13	34.6	60.7	307	800	592	104	68.6	**167**
2000	36.8	19.4	5.23	4.86	4.48	62.9	107	150	227	115	19.6	7.99	**63.5**
2001	1.28	0.13	0.01	0	0.53	9.85	65.1	258	405	134	56.4	17.7	**79.2**
2002	3.82	0.42	0.05	0	1.04	0.65	35.5	155	262	183	29.2	13.4	**57.3**
2003	2.67	0.68	0.06	0	2.3	8.9	80.4	430	723	415	195	72.4	**161**
2004	30.1	5.6	2.64	1.57	6.37	10.4	51.8	231	246	102	43.2	15.3	**62.5**
2005	3.69	0.46	0.08	0	2.98	20.8	74.1	205	381	140	51.6	20.1	**75.2**

Table 2.1. 4: Batie on the Baambassou

Reconstituted mean monthly flows in m^3/s												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1961	0	0	0	0	0.03	0.36	2.38	7.92	12.5	3.22	2.53	1.48	**2.54**
1962	1.03	0.62	0.48	0.87	2.81	8.37	15	40.1	54.7	31.1	30	12.6	**16.5**
1963	10.8	8.61	4.98	5.96	7.56	11.3	21.1	77.9	114	128	34.3	35.2	**38.6**
1964	27.6	18.3	15.9	9.22	8.56	11.4	29.5	34.3	83.3	55.3	17.7	26.1	**28.2**
1965	19.9	11.3	6.72	5.37	6.5	13.2	30.8	88	77.8	64.1	25	24	**31.2**
1966	17.4	11.4	7.9	8.28	10.9	14.1	17.8	48.9	51.8	46.1	13.6	13.4	**21.9**
1967	9.81	6.46	4.54	4.55	3.6	5.9	5.94	15.1	36.9	11.7	9.53	7.34	**10.1**
1968	4.42	5.14	4.16	6.03	8.37	13.5	56.1	91	177	84.1	43.9	46.1	**45.1**
1969	28.4	18.7	13.2	10.9	9.1	17.9	25.3	68.3	81	79.7	30.7	23	**34**
1970	18.1	11.9	7	7.42	5.76	5.95	14.9	49.1	96	27.3	20.7	19.3	**23.6**
1971	13.9	9.37	8.67	7.42	5.21	1.27	8.68	42.2	61.3	30.4	5.91	1.37	**16.3**
1972	9.07	6.48	5.16	0.84	2.83	4.18	15	13.9	24.5	9.28	2.04	8.01	**8.46**
1973	5.94	3.88	3.53	2.97	4.19	2.83	11.1	42.4	39.1	8.51	9.48	11.7	**12.2**
1974	5.95	3.95	4.69	0.25	0.53	1.51	13.2	27.8	123	45.1	8.06	0.74	**19.5**
1975	0.22	10.3	7.56	0.74	1.78	2.7	35.8	82.3	89	39.9	5.01	1.14	**23.1**
1976	0.85	0.17	0.07	5.87	6.5	3.63	2.05	2.76	2.89	39.5	65.9	4.13	**11.2**
1977	1.07	0.12	9.94	4.05	10.9	8.5	14.4	38.6	110	25.4	2	0.23	**18.8**
1978	10.1	6.61	6.25	3.64	5.18	3.87	29.7	30.1	56.8	55.9	6.89	0.79	**18.1**
1979	0.21	6.02	4.95	3.28	6.1	44	39.2	49.6	121	50.6	8.16	1.78	**27.9**
1980	0.33	4.36	2.63	3.05	1.6	0.72	5.23	39.1	123	63.7	4.48	2.26	**20.9**
1981	0.28	0.22	0.87	0.05	3.36	0.95	6.88	14.6	20	4.99	0.5	0.03	**4.42**
1982	1.81	0.01	0.98	1.24	1.03	1.48	6.24	44	24.7	9.22	5.07	0.38	**8.08**
1983	0.03	4.76	2.22	0.15	0.46	1	4.41	9.35	14.9	3.74	0.26	0.01	**3.42**
1984	1.3	0.83	0.05	0.02	5.79	6.73	6.25	7.71	13	19.3	1.13	0.09	**5.22**
1985	3.47	2.34	2.64	0.52	0.96	1.64	12.1	84.4	120	31.7	2.47	0.28	**21.9**
1986	0.05	5.15	3.45	3.15	1.11	1.12	10	39	100	48.3	5.71	0.82	**18.2**
1987	0.2	7.52	5.94	0.01	3.58	3.31	6.57	89	105	56.5	4.62	0.9	**23.7**
1988	10.6	7.14	6.36	2.8	1.26	2.58	31.6	40.9	110	64.2	3.87	1.08	**23.6**
1989	0.19	6.54	5.06	0.27	0.31	0.5	13.7	52.9	155	33.8	2.74	0.85	**22.6**
1990	0.15	11.3	7.43	0.89	0.82	2.63	21.2	61.1	41	8.04	0.93	0.25	**13**
1991	6.81	4.68	5.56	1.54	7.61	9.82	23.4	12.4	92	35	3.04	1.15	**16.9**
1992	19.5	13.3	8.45	9.58	0.08	2.45	16	14.4	35.3	8.18	1.75	0.58	**10.8**
1993	5.29	3.72	3.66	4	4.96	0.36	2.62	21.9	90.5	14.8	4.61	5.71	**13.5**
1994	4.57	3.18	2.51	2.17	2.69	2.1	5.02	9.51	24.5	33.8	3.76	5.96	**8.36**
1995	5.26	3.79	4.12	5.1	5.46	7.83	20	31.9	35	38.3	13.5	10.6	**15.2**
1996	7.36	9.46	4.12	9.85	14.6	13.3	18.2	57.1	82	37	14.3	15.7	**23.6**
1997	12.2	8.38	7.24	8.26	2.88	64.7	21.1	25.7	53.1	57.2	14.6	4.24	**23.3**
1998	1.48	0.51	0	1.33	5.08	6.85	14.4	92.5	96.1	69	13	4.02	**25.5**
1999	1.22	1.31	0.45	2.1	2.34	6.19	23.6	31.7	137	111	25.5	7.05	**29.2**
2000	3.45	1.26	0.51	3.42	1.97	7.5	16.9	56.9	85.8	90.2	18.5	5.71	**24.5**
2001	2.93	2.63	2.71	6.86	8.64	36.1	8.56	29	67.1	47	11.4	2.33	**18.8**
2002	0.77	0.09	6.02	3.18	5.86	5.61	10.6	43.8	103	37.3	6.37	1.68	**18.7**
2003	0.44	0.13	1.8	2.54	1.77	37	36.6	57.2	145	76.9	8.68	4.84	**31.1**
2004	15.4	10.4	5.53	5.43	7.1	16	48.6	72	108	47.7	7.12	2.94	**28.9**
2005	1.44	12.1	11.7	11.7	15.8	21.1	25.7	70	79.7	68.7	21.4	21	**30.2**

Table 2.1. 5: Bissiga on White Volta

Reconstituted mean monthly flows in m^3/s													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1961	0	0	0	0	0	0.49	4.44	64.5	139	45.7	0	0	**21.2**
1962	0	0	0	0	0	0.06	2.78	60.4	159	73.4	66.3	0	**30.1**
1963	0	0	0	0	0.17	0.02	7.24	43.1	52.9	50.9	0	0	**13**
1964	0	0	0	0	0	0	11.6	98.1	165	76.5	0	0	**29.4**
1965	0	0	0	0	0	0.07	6.62	43.8	170	57.9	0	0	**23.2**
1966	0	0	0	0	0	0.6	9.06	33.4	56.7	42	0	0	**11.9**
1967	0	0	0	0	0	0.6	9.06	33.4	56.7	42	0	0	**11.9**
1968	0	0	0	0	0	0.6	9.06	33.4	56.7	42	0	0	**11.9**
1969	0	0	0	0	0	0.53	3.88	38.7	71	39.8	0	0	**12.9**
1970	0	0	0	0	0	0.03	0.49	18	33	6.84	0	0	**4.87**
1971	0	0	0	0	0	0	3.51	23	66.3	11	15.9	2.61	**10.2**
1972	0	0	0	0	0	0.24	3.93	14.7	26.3	15.5	2.96	0	**5.32**
1973	0	0	0	0	0.16	0	3.43	29.9	47.1	8.34	0	0	**7.43**
1974	0	0	0	0	0	0.11	0.76	67.6	130	85.4	51	12.2	**29**
1975	0	0	0	0	0	0.02	1.1	76.1	102	43	34.4	6.35	**21.9**
1976	0	0	0	0	0.23	1.39	1.48	3.9	5.42	1.86	0.67	0	**1.25**
1977	0	0	0	0	0.02	1.39	3.34	8.87	16.9	3.51	0.54	0	**2.88**
1978	0	0	0	0	0	0.02	3.17	54.6	15.1	1.69	0.25	0	**6.31**
1979	0	0	0	0	0	0	1.84	6.14	9.19	4.1	0.28	0	**1.8**
1980	0	0	0	0	0.73	4.53	4.11	29.1	10.5	0.95	0.06	0.78	**4.27**
1981	0	0	0	0	1	3.7	22	77.3	35.4	1.65	0.14	0	**11.9**
1982	0	0	0	0	1.28	7.75	6.95	20.7	17.3	1	0.06	0	**4.61**
1983	0	0	0	0	0.11	1.78	19.6	65.8	11.7	2.25	0.02	0	**8.56**
1984	0	0	0	0	0	0	6.29	10.1	20.2	3.87	0.26	0	**3.4**
1985	0	0	0	0	0	3.56	45.4	38.9	36.4	1.82	0.02	0	**10.6**
1986	0.04	0	0	0	0	3.49	9.93	18.6	52.2	5.99	0.29	0	**7.54**
1987	0.05	0	0	0	0	5.43	4.84	14.9	10.6	13	,	0	**4.12**
1988	0.04	0	0	0	0.07	1.43	6.85	143	151	9.29	0	0	**26.1**
1989	0	0	0	0	0	0.08	3.85	55.1	37.1	22.6	9.68	0	**10.8**
1990	0	0	0	0	0	0.98	2.39	9.67	16.3	4.15	0	0	**2.8**
1991	0	0	0	0	5.37	12.8	14.3	33.6	31.5	7.19	9.82	0	**9.58**
1992	0	0	0	0	4.25	1.2	2.3	19.5	35.1	10.6	0	0	**6.09**
1993	0	0	0	0	0	0.09	8.66	31.7	10.4	1.13	0.01	0	**4.39**
1994	0	0	0	0	0	0.92	4.56	63.5	106	101	28.6	0	**25.5**
1995	0	0	0	0	0	3.52	3.86	7.76	4.95	0.25	0	0	**1.7**
1996	0	0	0	0	0.16	2.6	1.24	37.2	38.1	4.93	0	0	**7.04**
1997	0	0	0	0.01	0.09	0.28	2.53	11.4	22	2.19	0	0	**3.21**
1998	0	0	0	0	1.07	8.5	24.5	33.7	24.3	24.7	0	0	**9.83**
1999	0	0	0	0	0	0	46.8	53.8	11.3	1.25	0	0	**9.58**
2000	0	0	0	0	0	0.23	19.1	8.49	1.29	0	0	0	**2.47**
2001	0	0	0	0	0.56	21.4	26.8	45.8	23.1	3.88	0	0	**10.2**
2002	0	0	0	0	0.03	0.68	25.1	29.9	5.93	2.94	0	0	**5.47**
2003	0	0	0	0	0	0.26	12.9	50.1	107	37.7	0	0	**17.3**
2004	0	0	0	0	0	0.11	1.48	19.3	9.94	4.19	0	0	**2.95**
2005	0	0	0	0	0	25.5	54.9	61.9	22.3	0.62	0	0	**13.9**

Table 2.1. 6: Bagré on White Volta

Turbine flows (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1995		30.5	46.8	46	44.1	29.7	17	16.2	18	20	8.5	11.4	25.3
1996	21.7	22	16.9	19.6	18.4	29.1	27.9	12.8	8.15	19.9	16.2	17.3	22
1997	22.8	29.4	23.3	26.7	24.1	19.4	21	7.27	13.2	19.9	20	13.8	20.5
1998	7.5	11.6	10.7	2	13.2	23.9	32.9	48.3	35.1	29.1	29.3	39.1	24.7
1999	44.5	48	48.8	48.5	48.3	41.6	22.2	28.4	54.9	48.9	37.5	36.6	48
2000	36.5	34.6	33	47.6	42	49.9	38.3	16.8	21.5	18.1	12.1	0.943	37.5
2001													
2002													
2003													
2004	26.5	40.3	38.6	42.9	11.7	45.4	36.1	26.9	0	38.3	28	16.7	14
2005	16.1	30.3	29.8	30.6							41.7	33.1	
2006	22.2	17.3	17.1										18.9
Mean	**14.8**	**24.7**	**25.1**	**24**	**27.6**	**23.9**	**23.6**	**48.3**	**17.7**	**24.6**	**25.8**	**39.1**	**26.4**

Table 2.1. 7: Ziou on Red Volta

Reconstituted monthly flows in m^3/s												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1963	0	0	0	0	0.08	0.19	1.85	13.6	38.5	10.5	0	0	**5.39**
1964	0	0	0	0	1.18	2.12	12	78	131	17.7	0	0	**20.2**
1965	0	0	0	8.61	7.64	7.95	19.1	69.6	91.3	55.4	10.6	0	**22.6**
1966	0	0	8.47	7.69	7.02	8.13	10.9	25.7	46.6	34	0	0	**12.4**
1967	0	0	4.09	3.3	2.95	2.76	3.94	21.2	69.1	8.07	0	0	**9.6**
1968	0	6.33	5.9	7.02	11.7	21.3	54.5	81.4	84.8	68.1	0	0	**28.6**
1969	0	0	0	7.63	6.66	6.04	8.54	43	140	46.4	15.4	0	**22.7**
1970	0	0	0	9.25	8.71	9.26	14.7	50.8	124	18.6	0	0	**19.6**
1971	0	0	9.4	7.6	6.93	6.85	10.7	43.4	86.1	15.3	8.1	11.8	**17.2**
1972	0	0	0	5.39	4.91	5.32	10.2	23.9	30.8	12	0	0	**7.74**
1973	0	0	2.2	1.97	1.94	2.46	7.13	24.5	25.5	7.68	0	0	**6.15**
1974	0	0	0	1.27	1.12	1.09	1.95	20	56.4	25.2	0	0	**8.93**
1975	0	0	3.18	2.68	2.4	2.46	5.48	36	62.5	0	0	0	**9.56**
1976	0	0	3.56	3.11	2.79	4.27	9.05	17.7	32.5	51.3	0	0	**10.4**
1977	0	0	0	2.52	2.32	2.99	6.87	28.9	42.4	20.8	0	0	**8.93**
1978	0	0	0	2.7	2.97	4.05	10.2	31.1	34.8	27.9	0	0	**9.56**
1979	0	0	0	2.09	1.84	3.07	11.6	37.5	80.6	54.9	7.99	0	**16.7**
1980	0	0	0	4.86	4.59	5.3	10.6	47.9	69.2	46.1	0	0	**15.8**
1981	0	0	0	5.12	4.56	4.59	9.54	47	47.4	16.4	0	0	**11.3**
1982	0	0	3.55	3.21	3.08	3.43	8.23	35.9	75.6	18.7	10.4	0	**13.5**
1983	0	0	0	3.63	3.32	4.54	12.7	21.7	32.8	3.57	0	0	**6.88**
1984	0	0	1.89	1.63	1.47	1.91	2.74	5.18	11.7	10.2	1.88	0	**3.23**
1985	0	0	0	0.53	0.46	0.44	2.18	16.5	38.1	3.31	0	0	**5.11**
1986	0	0	1.35	1.2	1.1	1.6	3.88	15.7	37.6	11.8	3.97	0	**6.52**
1987	0	0	0	1.41	1.23	1.19	4.42	18.7	30.1	20.1	3.57	0	**6.75**
1988	0	0	0	1.81	2.26	3.1	8.36	36	59.4	0	0	0	**9.24**
1989	0	0	3.49	2.69	2.39	2.28	6.36	33.7	96.4	33.8	6.51	14.4	**16.9**
1990	0	0	0	2.92	2.34	7.87	21.6	26.3	4.87	1.05	0.51	0	**5.69**
1991	0	1.9	1.76	1.5	1.6	7.63	13.9	62.3	79.9	55.6	0	0	**18.9**
1992	0	0	0	7.02	6.19	6.2	10.1	19.1	59.5	7.13	17.2	0	**11**
1993	0	6	5.31	4.5	4.07	4.55	11.6	46.3	70.1	18.2	8.49	0	**14.9**
1994	0	0	0	4.35	3.96	7.14	14.7	70.3	168	107	22	0	**33.2**
1995	0	0	0	14.2	12.9	13.5	23.6	85.7	135	38.2	23.3	0	**28.9**
1996	0	0	0	11.4	10.7	32.5	6.27	63.3	74.1	19	0.37	0	**18.2**
1997	0	0	0	5.23	0.14	5.9	4.75	20.8	20.3	1.85	0.09	0	**4.93**
1998	0	0	0	1.9	7.01	7.49	20.6	21.1	114	27.1	0	0	**16.6**
1999	0	0	0	5.96	5.6	2.47	26.8	86.7	86.4	32.4	0.8	0.4	**20.8**
2000	0	0	0	8.21	11.1	15.3	12.7	53.3	11.1	3.82	0	0	**9.72**
2001	0	0	2.8	2.43	2.12	8.81	15.7	51.8	71	8.92	0.99	0	**13.7**
2002	0	0	0	2.76	2.46	2.35	2.9	10.4	37.8	28.4	3.45	0	**7.56**
2003	0	0	0	1.94	1.67	18.8	52.7	35.5	118	55.5	0	0	**23.8**
2004	0	0	0	7.36	6.87	7.87	31.7	85	84.5	23.9	10.1	0	**21.6**
2005	0	0	0	5.87	5.1	4.64	9.04	42.5	75	17.9	0	0	**13.4**

Table 2.1. 8: Nebbou on Sissili

Reconstituted mean monthly flows in m^3/s													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1961	0	0	0	0	0	0.02	0.77	2.29	5.05	0.46	0	0	**0.72**
1962	0	0	0	0.01	0.03	0.16	0.7	4.23	15.5	7.06	3.36	0	**2.59**
1963	0	0	0	0	0.06	0.12	0.38	7.63	23.5	14.9	1.76	0	**4.04**
1964	0	0	0.19	0.17	0.19	0.32	1.3	7.71	16.7	1.49	0	0	**2.34**
1965	0	0	0	0.2	0.2	0.26	1.5	5.32	9.5	4.45	0	0	**1.79**
1966	0	0	0	0.21	0.21	0.27	0.72	4.32	12.7	7.25	0	0	**2.15**
1967	0	0	0	0.23	0.22	0.23	0.33	1.68	7.04	0.67	0	0	**0.86**
1968	0	0.31	0.24	0.22	0.25	0.43	2.52	6.58	11.1	8.17	1.38	0	**2.62**
1969	0	0	0.29	0.25	0.24	0.3	1.05	7.64	26.9	11.9	0	0	**4.05**
1970	0	0	0	0.41	0.4	0.42	0.57	2.07	5.86	0	0	0	**0.81**
1971	0	0	0.3	0.29	0.29	0.3	0.4	3.86	12.8	2.48	0	0	**1.72**
1972	0	0	0	0.29	0.29	0.35	1.01	3.51	4.39	2.57	0	0	**1.04**
1973	0	0	0.27	0.27	0.27	0.3	0.75	3.28	4.6	1.82	0	0	**0.97**
1974	0	0	0.25	0.25	0.25	5.43	11.3	3.73	0.47	4.33	0	0	**2.19**
1975	0	0	0	0.26	0.26	0.02	1.34	2.27	5.89	0.32	0	0	**0.86**
1976	0	0	0.27	0.26	0.26	0.08	0.66	0.55	0.35	1.03	0.33	0	**0.32**
1977	0	0	0.24	0.23	1.37	0.39	3.25	23.1	12.3	0.55	0.02	0	**3.48**
1978	0	0	0	0.22	0.23	0.39	2.38	0.91	0.62	0.02	0.5	0	**0.44**
1979	0	0	0.21	0.21	0.2	0.38	4.92	4.3	2.49	0.59	0	0	**1.12**
1980	0	0	0	0.21	0.21	0.21	3.15	2.53	3.75	0.09	0	0	**0.85**
1981	0	0	0	0.2	0.21	0.28	0.93	8.44	7.05	0.1	0.2	0	**1.46**
1982	0	0.22	0.2	0.2	0.22	0.87	0.91	2.23	2.17	0.12	0.01	0	**0.6**
1983	0	0	0	0.19	0.17	2.58	2.91	0.32	0.06	0.01	0	0	**0.52**
1984	0	0	0.18	0.18	0.21	0.25	4.11	1.15	0.65	0.18	0.31	0	**0.61**
1985	0	0	0	0.16	0.36	0.92	7.83	7.27	1.59	0.06	0.36	0	**1.57**
1986	0	0	0.15	0.12	0.86	3.31	2.18	5.13	13.9	0.2	1.12	0	**2.24**
1987	0	0	0	0	0.18	1.24	1.9	6.23	1.39	0.17	0.17	0.17	**0.96**
1988	0.17	0.17	0.17	0.17	0.17	0.85	0.56	2.53	4.52	0	0	0	**0.77**
1989	0	0	0.16	0.16	0.16	0	4.74	4.51	2.53	0.33	0.1	0.73	**1.13**
1990	0	0	0	0.16	0.16	0.16	0.48	1.88	3.05	0.3	0.23	0	**0.53**
1991	0	0	0	0.15	0.16	1.05	0.56	6.44	4.76	7.87	0	0	**1.77**
1992	0	0	0	0.16	0.17	1.74	1.11	0.69	2.81	0.72	0.48	0	**0.65**
1993	0	0	0.15	0.15	0.15	0.22	2.64	4.78	2.69	0.01	0	0	**0.91**
1994	0	0	0.16	0.16	0.16	0.55	8.43	20.1	20.8	4.54	0.97	0	**4.68**
1995	0	0	0	0.23	0.68	0.7	1.42	1.82	6.71	2.84	0	0	**1.2**
1996	0	0	0	0.22	0.23	0.31	0.58	2.91	8.67	1.86	0	0	**1.23**
1997	0	0	0	0.86	0.91	1.38	2.93	4.91	5.41	0.77	0.07	0	**1.44**
1998	0	0	0	0.2	0.23	0.38	0.92	3.97	11.4	5.38	0	0	**1.88**
1999	0	0	0	0.2	0.2	0.24	10.3	11.8	17	1.69	0.81	0	**3.54**
2000	0	0	0	0.21	0.21	0.36	0.9	2.51	2.3	0.8	0	0	**0.61**
2001	0	0	0	0	0.19	1.03	3.52	2.8	9.54	2.46	0	0	**1.63**
2002	0	0	0	0.19	0.19	0.19	0.29	1.19	3.64	2.15	0	0	**0.65**
2003	0	0	0.17	0.17	0.17	1.7	5.4	12	18	4.67	0	0	**3.54**
2004	0	0	0	0.17	0.17	0.29	1.33	6.23	7.16	0.81	0	0	**1.35**
2005	0	0	0.17	0.17	0.17	0.18	0.39	1.54	3.88	1.18	0	0	**0.64**

Table 2.1. 9: Bittou on Nouaho

Reconstituted mean monthly flows in m^3/s													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1961	0	0	0	0	0	11.7	26	38.3	69.4	2.32	0	0	**12.3**
1962	0	0	0	0	3.96	8.3	18.4	73.8	91.2	33	12.3	0	**20.2**
1963	0	0.02	0	0	4.16	3.28	12.6	47.2	43.3	8.66	0	0	**10**
1964	0	0	0	0.64	0	5.17	15.9	46.2	85.2	8.93	0	0	**13.5**
1965	0	0	0	0	1.63	0	24.1	55.5	52.1	7.97	0	0.03	**11.9**
1966	0	0	0	0.71	0	16.7	22.5	41.4	64.5	16.5	0	0.03	**13.6**
1967	0	0	0.03	0	1.64	0	14.7	57.8	97.9	3.2	0.24	0	**14.6**
1968	0	0	0.17	0	12.1	17.2	52	80.6	38.5	27.1	0	0	**19.2**
1969	0	0	0	1.41	0	3.61	4.53	24	48.4	9.87	2.65	0	**7.86**
1970	0	12.1	7.79	6.31	7.68	13.9	31.7	85.2	123	105	85.9	65.1	**45.4**
1971	0	0	0.01	0	1.2	1.45	5.84	36.8	53.5	8.01	0	0	**8.92**
1972	0	0	0	0.15	5.15	3.44	8.69	32.3	35.8	14	0	0	**8.34**
1973	0	0	0	0	0.54	0	24.6	56.5	31.1	5.54	0	0	**9.96**
1974	0	0	0	0	2.2	0.1	15.9	113	71	14.1	0.5	0.1	**18.2**
1975	0	0	0	0.19	6.6	2.5	34.8	17.8	97.6	4.6	1	0	**13.7**
1976	0	0	0	0	0.76	3.5	4.6	23	9.4	15.7	1.6	0	**4.93**
1977	0	0	0	0.02	0	2.8	8	57	20.2	1.3	0	0	**7.52**
1978	0	0	0	0.85	0	13.1	17.7	39.1	42.9	17.5	0	0	**11**
1979	0	0	0	0	0	15.2	25.7	66.9	60.7	23.1	0	0	**16.1**
1980	0	0	0	0.03	0	8.36	15.9	45.3	30.5	17.6	0.59	0	**9.93**
1981	0	0	0	0	3.27	0.79	8.48	41.4	29.6	8.81	0	0	**7.76**
1982	0	0	0	0	2.74	4.53	16.4	45	11	2	0.04	0.02	**6.9**
1983	0	0	0	0	2.8	8.1	9	29	15	0.5	0	0	**5.41**
1984	0	0	0	0.4	1.6	5.7	4.3	13.8	5.9	3.53	0	0	**2.96**
1985	0	0	0	0	1.2	13.9	43.9	30.3	73.2	2.2	0	0	**13.7**
1986	0	0	0	0	0	4.6	40.5	28.4	0.2	7.24	0.63	0	**6.91**
1987	0	0	0	0	0	5.2	12.2	37.4	9.9	0.8	0	0	**5.52**
1988	0	0	0	0	0.1	29.5	17.7	65.4	57.9	2.8	1.3	0	**14.6**
1989	0	0	0	0	0	3.74	12.7	47.8	99.5	45.8	0.19	7.4	**18.2**
1990	0	0	0	0	1.43	0	11.7	33.6	30.2	2.27	0	0	**6.64**
1991	0	0	0	3	0	29.8	58	45.3	27.4	30.9	0	0	**16.3**
1992	0	0	0	0.02	0	9.29	26.2	70.1	52	7.8	0	0	**13.9**
1993	0	0	0	0	0	1.82	3.96	29.2	35.1	8.17	1.36	0	**6.66**
1994	0	0	0	0	2.05	3.27	19.6	87.6	92.9	41	0.3	0	**20.7**
1995	0	0	0.01	1.88	0.29	1.2	6.7	102	28.2	4.5	0	0	**12.2**
1996	0	0	0	0	0	15.8	2.5	53.7	41.5	8.8	0	0	**10.2**
1997	0	0	0	0	1.1	9.7	5.2	28.5	14	4.4	0	0	**5.28**
1998	0	0	0	0	7.42	7.76	13.8	24.1	101	10.7	0	0	**13.7**
1999	0	0	0	0	2.94	2.58	14.2	59.9	86	15.9	0	0	**15.2**
2000	0	0	0	0	1.24	20.2	11.3	57.7	18.1	5.72	1.2	0.58	**9.75**
2001	0	0	0	0.04	0	16.3	21	40.1	49.7	4.56	0	0	**11**
2002	0	0	0	0	0	1.6	0	23	33.5	12.9	0	0	**5.93**
2003	0	0	0	0	1.88	0.2	7.03	52.6	38	15.9	0	0	**9.72**
2004	0	0	0	0	9.77	13.6	49.5	109	34.5	8	2.01	0	**19.1**
2005	0	0	0	0	0.95	0.38	27.5	59.1	57.1	14.3	0	0	**13.4**

Table 2.1. 10: Kompienga Dam on Oti-Penjari

Turbine flows (m^3/s)													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**
1995	16.4	20.3	23.5	21.3	29	20.1	20	31.3	35.2	9.03	6.98	16.4	**21.2**
1996	30.1	29.2	25.1	22.5	19.1	22	19.2	14.8	9.05	10.1	9.25	12.6	**18.2**
1997	14.4	7.13	16.2	17.4	13.4	10.4	12	7.76	14.6	18.4	8.88	6.04	**13.3**
1998	6.88	16.2	15.3	25.4	32.1	24.2	9.49	2.31	12.1	14	25.1	23.2	**14.7**
1999	21.5	22.9	30.5	31.8	30.5	31.1		9.56	12	21.7	24.3	19.3	**21**
2000	26.3	27.3	35	23.6	36.4	27.4	20.6	13.8	16.7	17.1	14.9	4.87	**35**
2001													
2002													
2003													
2004	2.4	14.7	18.1	30.9	50.2	8.83	6.79	8.24		33.5	28	17.8	**20**
2005	26.3	28.8	26.7	26.1							27.1	16.1	
2006	11.6	7.68	6.5										
MEAN	**9.4**	**17.5**	**23**	**26.6**	**30.9**	**17**	**12.9**	**19.8**	**20.6**	**16.7**	**17.5**	**18.6**	**20.5**

2.1.5 Flow Statistics and Water Availability Scenarios at the selected stations

Apart from the water availability situations which were presented by the long term mean flows, the situations under extreme conditions were computed. These related to very low flows, low flows and high flows, very high flows. The impacts of climate change were also determined.

For the extremes the flows were defined as follows:-

- Very low flows - 10 percentile
- Low flows - 25 percentile
- High flows - 75 percentile
- Very high flows - 90 percentile

The flows in the Current Account Year (2005) needed for the WEAP Model were also included in the summary of water availability scenarios. In addition the water availabilities were charted for comparison. The results at each station are presented in the following paragraphs. The flows are the mean monthly flows.

i) The Mouhoun at Samendeni

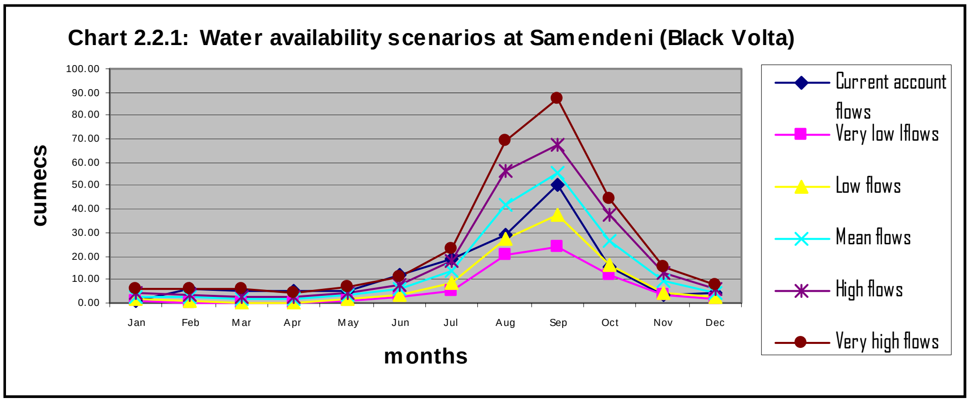
There were neither systematic nor accidental errors in the Samendeni dataset. However some gaps exist in the data for the following years 1968, 1969, 1972, 1973, 1981, 1992, 1994, 1995, 2004 and 2005. It was therefore necessary to fill the gaps in the dataset. The coefficient of variation for the flow dataset at Samendeni for the period 1961-2005 is estimated as C_v=0.37 with a mean error, E_{moy} of 5.5%. The study of the dataset over the reference period shows that, the inter-annual mean flow found is stable and represent the long-term flow from the station. With an error of 5.5% during the period of observation (1961-2005), it is foreseen that the mean value will not change during several years. For Samendeni, the theoretical value of n=47 years which is virtually equal to the sample size. The completed monthly flows are presented in Table 2.1.1.

The summary of the water availability scenarios are presented in Table 2.2.1 and compared in Chart 2.2.1.

Table 2.2- 1: Water availability scenarios at Samendeni on Black Volta (m^3/s)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cu. Ac. 05	0.45	5.63	5.46	5.31	5.15	11.90	18.80	29.30	50.70	15.60	3.25	4.43	13.00
10%	0.80	0.40	0.20	0.10	0.90	2.90	4.90	20.90	23.60	12.10	3.20	1.40	8.50
25%	1.30	0.60	0.40	0.40	1.30	3.50	8.20	27.30	37.50	16.60	4.60	2.40	11.50
Mean	2.90	2.30	2.00	1.80	3.10	6.30	13.60	42.30	55.60	26.50	9.40	4.40	14.20
75%	3.85	3.00	2.65	2.51	4.38	7.92	18.00	56.10	67.80	37.80	12.70	5.82	18.30
90%	5.98	6.27	6.08	4.47	7.11	11.22	23.30	69.04	87.46	44.34	15.02	8.08	22.10

Chart 2.2. 1: Chart of scenarios at Samendeni



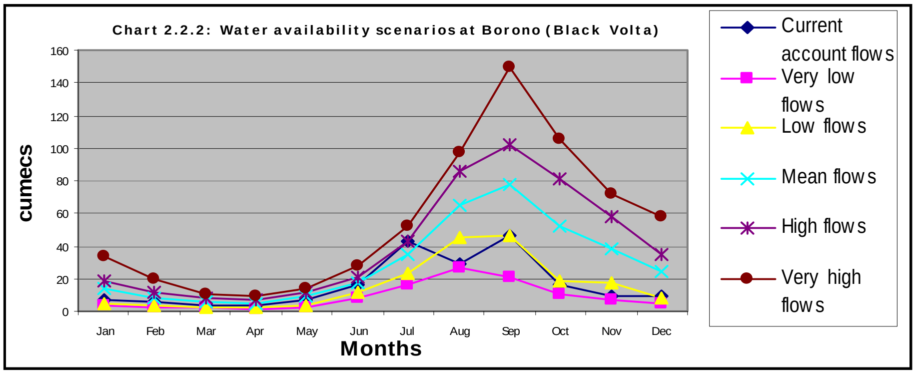
ii) *The Mouhoun at Borono*

All errors (systematic and accidental) were corrected by the national hydrological service. The times series flow data at Borono station has some gaps in some years which had to be filled. The important element to note is the disruption in the hydrological regime of the stream at this station, following from the construction of the Léry dam. Indeed, since July 1984 derivation works were carried out at the Léry bridge to divert the Mouhoun to join the Sourou which has a dam on it. It is the dam releases from the Sourou dam that flow into the Mouhoun to sustain the flow downstream of the dam. The coefficient of variation, C_v = 0.44 and E_{moy} = 6.6% for the considered period (1961-2005). The study over the reference period lead to the conclusion that the mean inter-annual flow found is satisfactory and can be considered as the long-term flow of the Mouhoun at Borono of the period 1961 to 2005. The theoretical sample size, n was 47 years.

Table 2.2- 2: Water Availability Scenarios at Borono on the Black Volta in m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cu.ac. 05	6.57	6.29	3.19	3.27	7.1	16.5	42.6	28.9	46.1	16.1	9.71	9.58	16.4
10%	3.5	2.6	1.9	1.5	2	8.5	16.6	27.2	21.1	11	7.1	4.1	14.9
25%	4.7	3.4	2.6	2.2	3.5	11.6	23.2	45.3	46.1	19.1	17.6	8.2	19.6
Mean	13.4	8.3	5.5	5.1	8.7	16.9	35	64.6	78.2	52.5	38	24.7	29.4
75%	18.1	12.1	8.01	7.37	11.7	21.1	42.6	86	102	81.7	57.7	35.3	40.7
90%	33.88	20	10.56	9.84	14.18	27.64	51.68	97.18	149	105.6	71.42	58.06	48.46

Chart 2.2. 2: Scenarios at Boromo



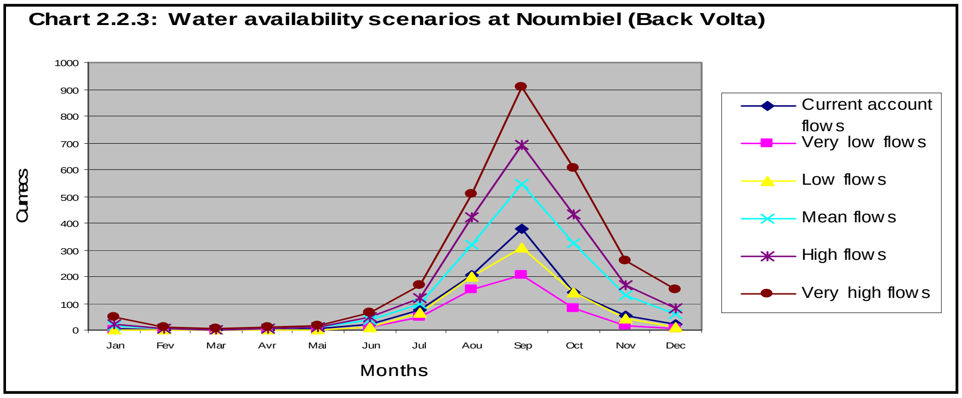
iii) The Mouhoun at Noumbiel

No accidental error or systematic were found in this dataset. However the gaps which appear in the dataset for that needed to be filled covered the years1975, 1979, 1980, 1995, 1997, 1998, 1998, 2000, and 2002. It is noted that the dataset at Noumbiel has a coefficient of variation Cv of 0.61 with a mean error of 9.1% over the period 1961-2005. The study over the reference period leads to the conclusion that the mean inter-annual flow value is stable and can represent the long-term flow at the station. The theoretical sample size, n, was 46 years.

Table 2.2- 3: Water Availability Scenarios at Noumbiel on the Black Volta in m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cu. Ac 05	3.69	0.46	0.08	0	2.98	20.8	74.1	205	381	140	51.6	20.1	75.2
10%	1.3	0.2	0	0	0.3	9.3	50.5	151.7	203.5	81.1	18.3	5.3	56.6
25%	2.6	0.4	0.1	0	2.3	13.5	62.2	198	308.3	139.7	43.2	9.4	78.6
Mean	17.9	5	2.2	3.5	10	35.7	97.2	320.6	548.1	322.1	128.6	59.7	129.7
75%	16.93	11.15	7.38	6.80	10.95	20.05	42.60	80.65	96.05	74.40	52.78	32.65	37.88
90%	25.99	16.05	9.29	8.60	12.94	24.37	47.14	91.59	125.50	93.65	64.56	46.68	44.58

Chart 2.2. 3: Chart of scenarios at Noumbiel



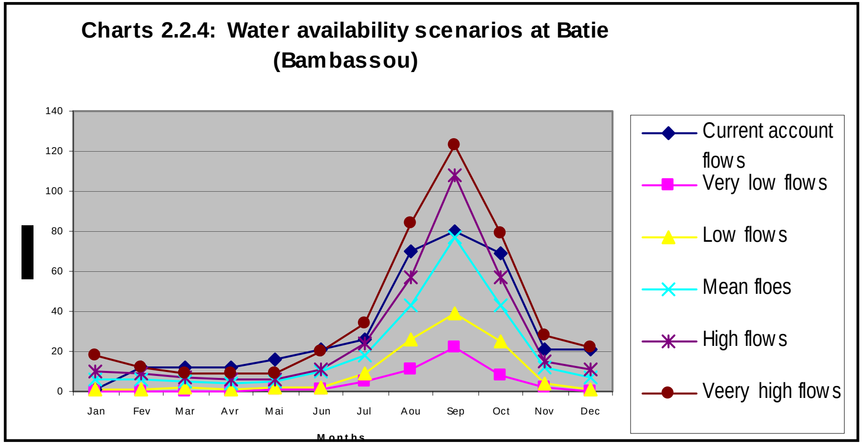
iv) The Bambassou at Batié

Flow data series on the Bambassou at Batié has neither accidental nor systematic errors. There were however some gaps in the data over the following years: 1971, 1972, 1974, 1975, 1978, 1979, 1980, 1986, 1992, 1996, 1997, 2001, 2002, 2004 and 2005. The gaps had to be filled through reconstruction of the data series. The dataset at Batie gives a mean with coefficient of variation, Cv, 0.47 and a mean error E_{moy} of 7%. The study over the reference period leads to the conclusion that the value is relatively stable (theoretical n = 46 years).

Table 2.2- 4: Water availability Scenarios at Batié on the Baambassou in m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cur. Ac.05	1.44	12.1	11.7	11.7	15.8	21.1	25.7	70	79.7	68.7	21.4	21	30.2
10%	0.2	0.1	0.5	0.2	0.6	1	5.1	10.7	21.8	8.3	1.9	0.3	8.2
25%	0.8	1.3	2.5	0.9	1.8	2.1	8.6	25.7	39.1	25.4	3.8	0.9	13
Mean	6.5	5.9	4.8	3.9	4.7	9.6	17.9	43.5	77.2	43.4	12	7.5	19.8
75%	17.66	9.61	6.09	5.98	10.71	23.48	71.13	203.25	362.83	139.93	61.61	43.17	77.75
90%	21.95	13.60	8.33	7.70	11.95	30.04	85.65	262.80	464.55	231.05	96.58	53.19	104.15

Chart 2.2. 4: Chart of scenarios at Batie (Bambassou)



v) *The Nakanbé at Bissiga*

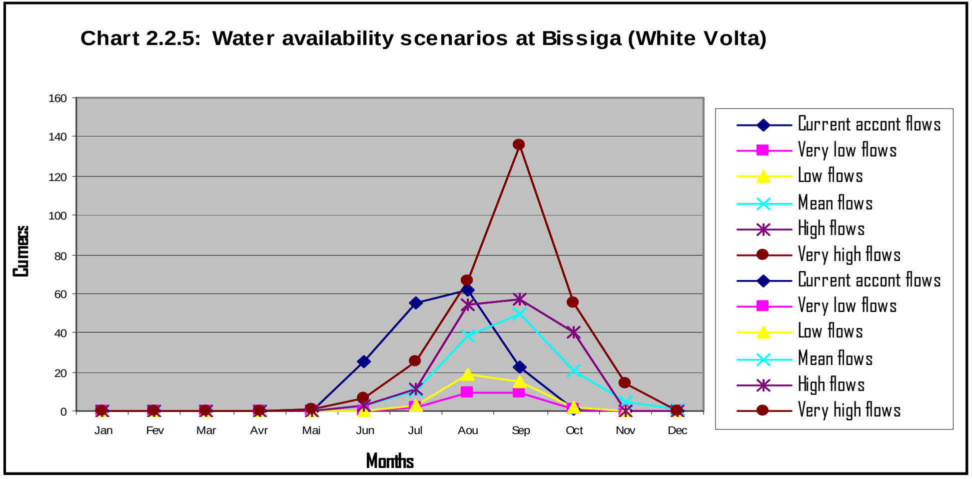
Some gaps existed in the observations series of the flow data at this station and gaps covered the following years: 1973 -1978, 1980 -1981, 1989, 1990, 1991, 1992, 2000, 2003, 2004 and 2005. The gaps were filled by reconstruction of the data series. The mean inter-annual flow on the Nakanbe at Bissiga was estimated with a coefficient of variation of 0.76 and a mean error of 11.3.

The study over the reference period indicates that the inter-annual mean found is stable (theoretical n = 47 years).

Table 2.2- 5: Water availability Scenarios at Bissiga on the White Volta in m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cu. Ac. 05	0	0	0	0	0	25.5	54.9	61.9	22.3	0.62	0	0	13.9
10%	**0**	**0**	**0**	**0**	**0**	**0**	**1.5**	**9.2**	**9.5**	**1.1**	**0**	**0**	**2.8**
25%	**0**	**0**	**0**	**0**	**0**	**0.1**	**3.2**	**18.6**	**15.1**	**2.2**	**0**	**0**	**4.4**
Mean	**0**	**0**	**0**	**0**	**0.3**	**2.6**	**10.4**	**38.7**	**49.5**	**20.4**	**4.9**	**0.5**	**10.7**
75%	**14.87**	**11.48**	**7.77**	**7.27**	**11.64**	**22.88**	**59.77**	**169.94**	**292.04**	**122.12**	**51.56**	**37.63**	**65.86**
90%	**19.80**	**12.85**	**10.02**	**9.70**	**13.87**	**26.76**	**78.39**	**233.03**	**413.69**	**185.49**	**79.10**	**48.18**	**90.95**

Chart 2.2. 5: Chart of scenarios at Bissiga (White Volta)



vi) The Bagré Dam

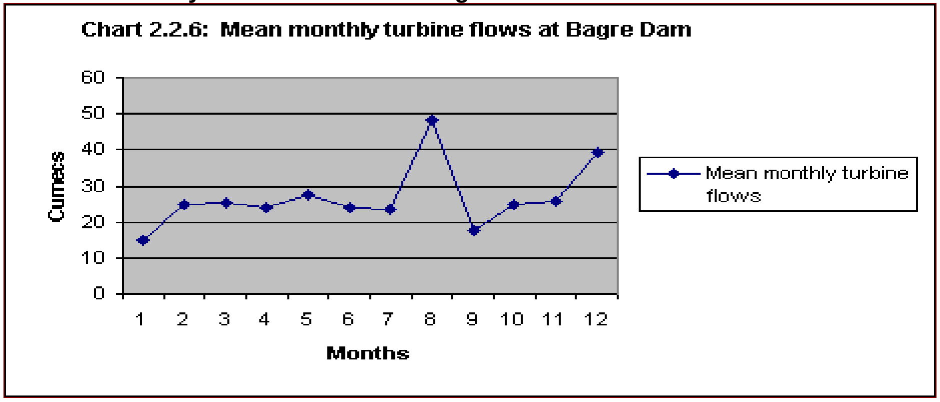
Flow data downstream of the Bagré Dam are the releases by SONABEL flow through turbines as a result of its operations for hydro-electric power production. These data essentially depend on the demand fluctuations with time and are difficult to predict. They could not be simulated by the SMAP model.

Table 2.2- 6 Turbine releases from Bagré Dam on the White Volta

Turbine flows (m3/s)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
1995		30.5	46.8	46	44.1	29.7	17	16.2	18	20	8.5	11.4	25.3
1996	21.7	22	16.9	19.6	18.4	29.1	27.9	12.8	8.15	19.9	16.2	17.3	22
1997	22.8	29.4	23.3	26.7	24.1	19.4	21	7.27	13.2	19.9	20	13.8	20.5
1998	7.5	11.6	10.7	2	13.2	23.9	32.9	48.3	35.1	29.1	29.3	39.1	24.7
1999	44.5	48	48.8	48.5	48.3	41.6	22.2	28.4	54.9	48.9	37.5	36.6	48
2000	36.5	34.6	33	47.6	42	49.9	38.3	16.8	21.5	18.1	12.1	0.943	37.5
2001													
2002													
2003													
2004	26.5	40.3	38.6	42.9	11.7	45.4	36.1	26.9	0	38.3	28	16.7	14
2005	16.1	30.3	29.8	30.6							41.7	33.1	
2006	22.2	17.3	17.1										18.9
Mean	**14.8**	**24.7**	**25.1**	**24**	27.6	23.9	23.6	48.3	17.7	24.6	25.8	39.1	26.4

Chart 2.2. 6 Mean monthly turbine flows from Bagré Dam



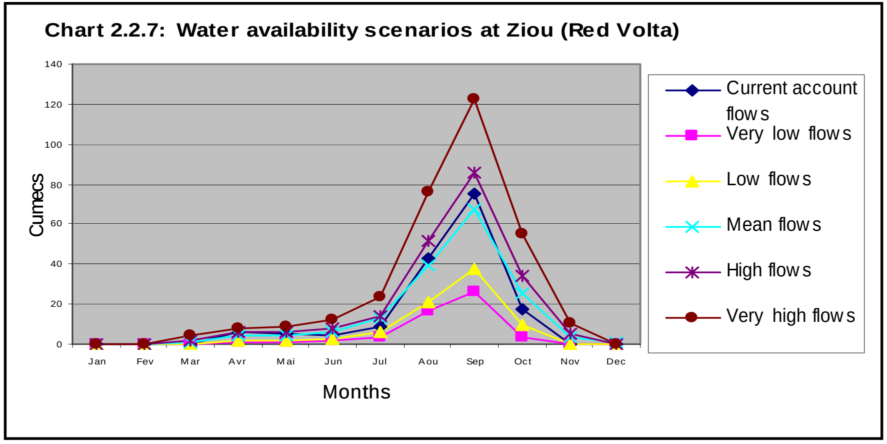
vii) The Nazinon at Ziou

No accidental or systematic errors were found in the Ziou data set. However there were gaps which appear in the dataset covering some years: 1994, 1998, 2003, 2004 and 2005,. The mean inter-annual flow at Ziou was calculated for the period 1961-2005 and found to have a coefficient of variation, C_V of 0.69 and a mean error of = 7.9. The study over the reference period lead to the conclusion that the mean inter annual flow value is stable.

Table 2.2- 7: Water Availability Scenarios at Ziou on the Red Volta in m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cur act 05	0	0	0	5.87	5.1	4.64	9.04	42.5	75	17.9	0	0	13.4
10%	0	0	0	1.3	1.1	1.7	3.1	16.7	26.4	3.4	0	0	5.8
25%	0	0	0	2	1.9	2.5	6.3	21.2	37.7	9.6	0	0	8.3
Mean	0	0.3	1.3	4.3	4.2	6.3	12.7	39.6	67.1	25.2	3.6	0.6	13.8
75%	26.50	33.58	37.20	46.00	42.53	42.55	33.70	33.38	24.90	31.40	29.30	36.60	26.40
90%	38.10	41.07	47.00	47.78	45.36	46.75	36.76	48.30	41.04	41.48	38.34	39.10	39.60

Chart 2.2. 7: Scenarios at Ziou (Red Volta)



viii) The Sissili at Nebbou

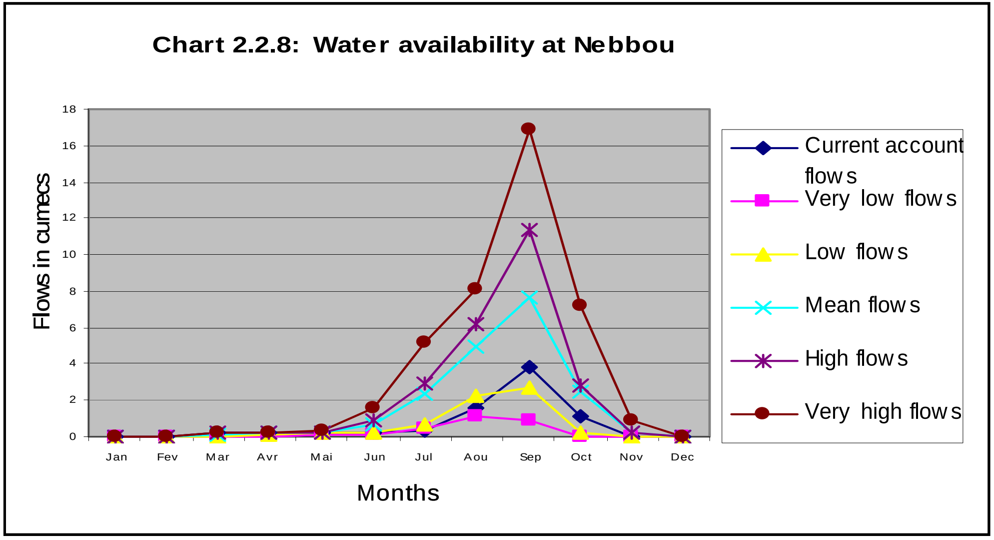
The Nebbou data series had neither accidental nor systematic errors. There were however some data gaps for some years: 1974, 1979, 1980, 1981, 1995, 2000, 2001, 2002 and 2003. The gaps were filled by reconstruction of the data series.

The mean inter annual flow at Nebbou was calculated for the period 1961-2005 with the coefficient of variation C_V=0.55 variation and a mean error of 8.21%. The study of the reference period of 1961-2005 lead to the conclusion that the mean inter annual flow is stable (n theoretical =46 years).

Table 2.2- 8 Water Availability Scenarios at Nebbou on the Sissili in m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cur act 05	0	0	0.17	0.17	0.17	0.18	0.39	1.54	3.88	1.18	0	0	0.64
10%	0	0	0	0.05	0.16	0.13	0.43	1.17	0.95	0.04	0	0	0.6
25%	0	0	0	0.16	0.17	0.23	0.7	2.23	2.69	0.2	0	0	0.77
Mean	0	0.02	0.08	0.2	0.27	0.69	2.36	4.91	7.63	2.43	0.27	0.02	1.58
75%	19.88	25.26	28.23	35.97	33.17	33.49	28.45	41.78	60.59	29.85	22.88	27.60	23.25
90%	32.30	37.32	42.10	46.89	43.94	44.65	35.23	45.40	71.05	36.44	33.82	37.85	33.00

Chart 2.2. 8: Chart of water availability scenarios at Nebbou



ix) *The Nouhao at Bittou*

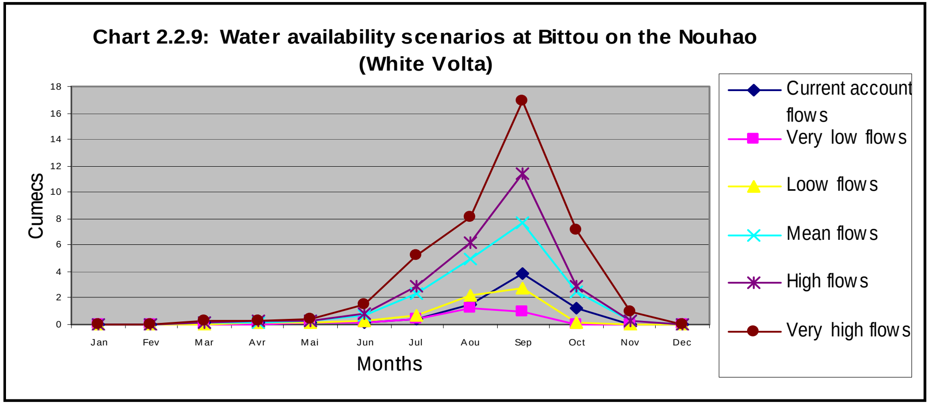
The Bittou data series had neither accidental nor systematic errors. There were however some gaps in the data covering the years: 1973, 1976, 1977, 1978, 1980, 1989, 1990, 1991, 1992, 1993, 1994, 1998, 1999, 2000, 2003, and 2004. The data gaps were filled through the use of model to reconstruct the dataset. The mean inter-annual flow at Bittou was calculated for the period 1961-2005 and it had a coefficient of variation, C_V 0.55 and a mean error, E_{moy}, of 8.2.

The study over the reference period lead to the conclusion that the mean inter annual flow value is stable and can be considered as the long-term flow from the station.

Table 2.2- 9 Water Availability Scenarios at Nouhao/Bittou in m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cur act 05	0	0	0	0	0.95	0.38	27.5	59.1	57.1	14.3	0	0	13.4
10%	0	0	0	0	0	0.1	4.6	24	12.2	2.2	0	0	5.7
25%	0	0	0	0	0	1.8	8.5	32.3	29.6	4.5	0	0	7.8
Mean	0	0.3	0.2	0.3	2	7.6	18.4	50	49.1	13.6	2.5	1.6	12.2
75%	0.79	14.91	18.95	21.21	27.03	24.94	25.29	21.93	32.56	47.35	23.00	17.22	20.71
90%	0.86	26.09	31.29	35.16	41.43	38.56	39.07	31.84	43.59	65.82	33.15	28.35	32.73

Chart 2.2. 9: Availability Scenarios at Bittou on Nouaho (White Volta)



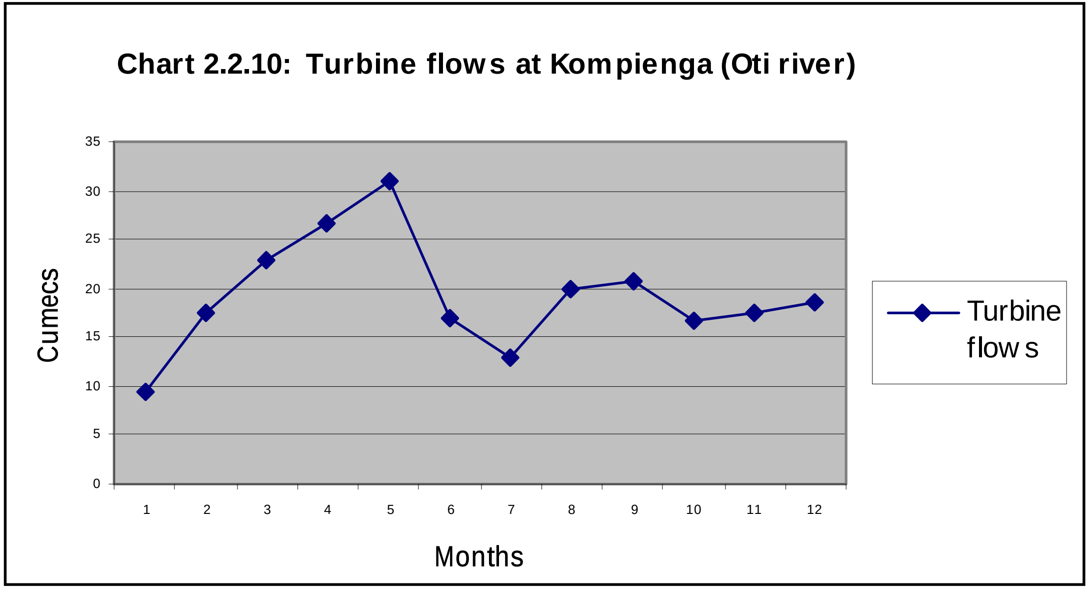
x) The Kompienga Dam

Just as for the Bagré dam, the flows from the Kompienga Dam are the flows through the turbines for hydropower production by SONABEL. This data essentially depends on the demand for hydropower and cannot easily be predicted. This data cannot be simulated using the SMAP model.

Table 2.2- 10: Turbine releases from Kompienga Dam on the Oti River

Turbine flows (m3/s)													
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Annuel**
1995	16.4	20.3	23.5	21.3	29	20.1	20	31.3	35.2	9.03	6.98	16.4	**21.2**
1996	30.1	29.2	25.1	22.5	19.1	22	19.2	14.8	9.05	10.1	9.25	12.6	**18.2**
1997	14.4	7.13	16.2	17.4	13.4	10.4	12	7.76	14.6	18.4	8.88	6.04	**13.3**
1998	6.88	16.2	15.3	25.4	32.1	24.2	9.49	2.31	12.1	14	25.1	23.2	**14.7**
1999	21.5	22.9	30.5	31.8	30.5	31.1		9.56	12	21.7	24.3	19.3	**21**
2000	26.3	27.3	35	23.6	36.4	27.4	20.6	13.8	16.7	17.1	14.9	4.87	**35**
2001													
2002													
2003													
2004	2.4	14.7	18.1	30.9	50.2	8.83	6.79	8.24		33.5	28	17.8	**20**
2005	26.3	28.8	26.7	26.1							27.1	16.1	
2006	11.6	7.68	6.5										
Mean	**9.4**	**17.5**	**23**	**26.6**	**30.9**	**17**	**12.9**	**19.8**	**20.6**	**16.7**	**17.5**	**18.6**	**20.5**

Chart 2.2. 10: Mean monthly turbine flows from Kompienga Dam



2.2 Groundwater – Burkina Faso

Groundwater occurs in crystalline rock formations in almost all the sub-basins in Upper Volta. There is some data about borehole depths, static water levels, borehole yield available.

From the Pre-Audit report, it was stated that the GLOWA-Volta Project has a database on urban and rural boreholes and wells in Burkina Faso and Ghana.
It was also stated that DGIRH runs a monitoring network of observation wells in Burkina Faso, and that 38 of these wells are situated in the Volta Basin. The monitoring was started in the 1980's. Attempts to get data on these wells particularly with regard to groundwater storage capacity, maximum groundwater withdrawals (determined by hydraulic conductivity, aquifer specific yield and hydraulic head) and ground water recharge which are required by the Water Planning Model were not successful. However, the CGIAR Challenge Programme on Water for Food in its Baseline Report No. 8 has an overview assessment of the groundwater resources presented data about some groundwater characteristics of the sub-basins of the Volta viz the Black, White and Oti basins. These are presented in Table 2.3
The results show that the yields are very variable and low.

Table 2.3: Groundwater Characteristics of the Sub-Basins of the Volta

Table 2.3 1: Groundwater Characteristics of the Sub-Basins of the Volta

Basin	Runoff Co-efficient %	Borehole Yield (m^3/h)	Mean Borehole Yields (m^3/h)	Specific Capacities (m^3/h/m)	Depth to Aquifer (m)	Mean Depth to aquifer (m)	Depth of Boreholes (m)	Mean Depth of Borehole (m)
White Volta	10.8	0.03-24.0	21	0.01-21.1	3.7-51.5	18.4	7.4-123.4	24.7
Black Volta	8.3	0.1-36.0	22	0.02-5.28	4.3-82.5	20.6	-	-
Oti	14.8	0.6-36.0	52	0.06-10.45	6.0-39.0	20.6	25.0-82.0	32.9
Lowe Volta	17.0	0.02-36.0	5.7	0.05-2.99	3.0-55.0	22.7	21-29.0	44.5

Source: CGIAR Challenges Programme on Water for Food Baseline Report No. 8. (2006) and That the begin's groundwater resources are not appreciable.

2.3 Water Quality

2.3.1 Surface Water Quality

The water quality considered are both surface and groundwater.
Both Burkina Faso and Ghana have attempted to monitor water quality in the sub-basins. Available data about quality are old and do not reflect the present conditions.
J. M. Goes who was commissioned by PAGEV to carry out the Pre Water Audit provided field test results for selected stations in the two countries at about the same time. The results presented in Table 2.4.1A with explanations in Table 2.4.1B. In the report it was stated that compared with the standards in Table 2.4.1C in some of the samples, the Ph is a bit low (slightly acidic), but besides that all water samples show, for the tested parameters, values that indicate a very low mineral content. Further, no indication for the presence of biological waste (nitrite, nitrate) was found. Special attention was paid to the Bagre Irrigation project on the

White Volta River in the Burkina, since there are some concerns in Ghana that drainage water from the irrigation project may pollute the White Volta River. The EC just downstream of the irrigation project was slightly higher (90 µS/cm, (sample 11) than just upstream of the irrigation project (77 µS/cm (sample12). Still both samples indicated a low mineral content and variation like these are not uncommon between sites along the same river.

2.3.2 Groundwater Quality

Recent data on groundwater quality could not be provided by the time this report was to be finalized.

Table 2.4. 1A: Results of field Water Quality tests in Burkina Faso for selected parameters

No.	Site	Sub-Basin	Country	X-Co-ordinate	Y-Co-ordinate	Date	EC (at 25°C) uS/cm)	Temp. (°C)	NO_3 (mg/l)	NO_2 (mg/l)	Hardness Total (mg/l)	Hardness Carbonate (mg/l)	Ph
1	Road to Bitou (Bridge)	White Volta (Nouhao River)	BF	W0° 15.458′	N11° 12.878′	26-6-05	46	30	<5	<0.5	<107	~53	~6.4
2	Bagre Bridge (downstream of turbine)	White Volta	BF	W0° 32.601′	N11° 28.381′	26-6-05	77	30.6	<5	<0.5	<107	~53	~6.4
3	Bridge just downstream of Bagre Irrig. Proj.	White Volta	BF	W0° 30.963′	N11° 24..554′	26-6-05	90	29.9	<5	<0.5	<107	~53	~6.4
4	Wayen Bridge	White Volta	BF	W1° 04.814′	N12° 22.740′	26-6-05	59	30.4	<5	<0.5	<107	~53	~6.4
5	Boromo Bridge	Black Volta	BF	W2° 54.842′	N11° 46.848′	28-6-05	50	27.5	<5	<0.5	<107	~53	~6.4
6	Saboinse Bridge	White Volta (Red Volta)	BF	W2° 00.355′	N12° 11.633′	28-6-05	21	26.5	<5	<0.5	<107	~53	~6.4
7	Ouagadougou (water from tap in hotel Soritel)	White Volta (Water from tap)	BF			28-6-05	122	27.1	<5	<0.5	<107	~53	~6.5
8	Bossora	Black Volta	BF			8-3-2000	156	24.1	<10	<0.5	<107	53-107	~7.55
9	Samandeni (RRNS2)	Black Volta	BF			29-6-99	41	25.6	2.35				6.62
10	Samandeni	Black Volta	BF			2-3-00	107	21.4	<10	0.44			7.06
11	Noumbiel (RRM(3)	Black Volta	BF			29-6-99	66	25.7	2.62	0.49			6.85
12	Marc aux Hippos	Black Volta	BF			14-3-00	109	25	0	0.21			7.21

Source: J.M. Goes Pre-Audit Report 2005

'Table 2.4.1B 1: Observations on sites and sources of data

NO.	SOURCE	OBSERVATION
1	Pre-Audit Study	PAGEV work to establish a gauging station at this site to monitor flood flows.
2	Pre-Audit Study	No water is being released for hydropower because it is Sunday
3	Pre-Audit Study	Drainage water from the Bagre Irrigation Project passes this site, EC slightly higher than upstream of irrigation project (sample 11)
4	Pre-Audit Study	Automatic water-level recorder (DGIRH), satellite water-level warning system (SONABEL), water level: 1.21 m
5	Pre-Audit Study	Automatic water-level recorder
6	Pre-Audit Study	
7	Pre-Audit Study	
8	Pre-Audit Study	P_2O_5. 1-2.5, 0_2:6 (mg/l)
9	Pre-Audit Study	HCO_3=21.35; CO_3^{2-}=0; Cr=0; PO_4^{3-}=3.24;SO_4^{2-}=0.8; F=0; Ca^{2+}=2.9; Mg^{2+}=2.61; FeTot=1.2; Mn^{2+}=O:K^+=7.5; Zn^+=O; NH_4^+=0.45; Na^+=1 (mg/l)
10	Pre-Audit Study	
11	Pre-Audit Study	HCO_3=30.5; CO_3^{2-}=0; Cr=0; PO_4^{3-}=3.16; SO_4^{2-}=0.16; F=0; Ca^{2+}=5.8; Mg^{2+}=3.28; FeTot=1.9; Mn^{2+}=O:K^+=6.8; Zn^+=O; NH_4^+=0.52; Na^+=3.5 (mg/l)
12	Pre-Audit Study	HCO_3=87.84; CO_3^{2-}=0; Cr=0; PO_4^{3-}=0.04;SO_4^{2-}=0; F=0; Ca^{2+}=10.02; Mg^{2+}=6.55; FeTot=0; Mn^{2+}=0:K^+=21.3; Zn^+=O; NH_4^+=0; Na^+=2.1 (mg/l)

Source: J.M. Goes Pre-Audit Report 2005

Table 2.4.1C 1: Water Quality Parameters tested during the Pre-Audit

Water Quality Parameter ***	Explanation	Results of Field Tests	Accepted Limits
Electrical Conductivity (EC)**	Indication for the amount of ions in the water	21 tot 114 µS/cm	750 to 1500 µS/cm
pH	Acidity of the water, 7 is neutral	6.4 to 6.6	6.5-8.5 (WHO)
Nitrite (NO_2)	Indicates the presence of biological waste such as manure, nitrite is broken down by bacteria into nitrate.	<0.5 mg/l	0 mg/l (WHO) 0.5 mg/l (EU)
Nitrite (NO_3)	Indicates the presence of biological waste such as nanure	< 5mg/l	10 mg/l (WHO) 50 mg/l (EU)
Total Hardness	Sum of ions which can precipitate as 'hard particles', calcium, magnesium and sometimes iron.	<107 mg/l	
Carbonate ($CaCO_3$) Hardness	Sum of calcium ions which can precipitate as 'hard particles', influences pH and CO_2.	<53 to 107 mg/l	500 mg/l (WHO)

* *or roughly 500 to 1000 mg/l Total Dissolved Solids*
** *measured with an EC meter from Hanna Instruments (USA)*
*** *measured with test strips from eSHA (The Netherlands)*

Source: J.M. Goes Pre-Audit Report 2005

3. WATER AVAILABILITY - GHANA

The water availability covers surface and groundwater and their quality. This section however dwells more on surface water because the current groundwater potential was being assessed by the time this report was to be completed.

3.1 Surface Water Availability

The Surface water availability were based on ten gauging stations (namely Bui, Bamboi and Buipe on the Black Volta, Pwalugu and Nawuni on the White Volta; Saboba and Sabari on the Oti; Yagaba on the Kulpawn; Nakong on Sissili, and Prang on the Pru) were selected by PAGEV. An eleventh station which is Yarugu on the White Volta was added at the Tamale meeting in November 2006. This is near the boarder with Burkina Faso. It is to facilitate comparison of flows from the two countries.

3.1.1 Screening of data from the selected stations

Daily discharge data were collected from the Hydrological Services Department (HSD). Data from other sources such as CSIR Water Research and GLOWA sponsored projects were also collected. The data from the HSD are presented on the CD-Rom. The initial step involved the screening of datasets for outliers and comparisons with other databases available for the same stations. Differences in data magnitudes arising out of the use of new rating curves for certain time periods were settled with HSD. Also, as found by the pre-audit the review of the data showed gaps at all stations. It was therefore decided to fill the gaps before they were used for the computation of the long term flow statistics.

3.1.2 Methodology for filling the data gaps

The method selected in filling the gaps were simple and multiple linear regression analysis. A water balance model, WatBal was experimented for use. However, poor data quality in terms of the length of gaps and insufficient representative rainfall data in the catchment of the stations precluded its use. The model has however been used to generate runoffs under changes in rainfall and temperature under climate change scenarios and will be discussed under generation of data under climate change.

For the analysis, data from six selected meteorological stations namely Bole, Kete-Krachi, Tamale, Navrongo, Wa and Yendi were collected from the Ghana Meteorological Agency (GMA). These were later supplemented with data from other meteorological stations within the Upper Volta basin in Ghana. A summary of information about the stations and the supplementary stations are presented in Annexed 3.1 and 3.2. The locations of the stations are shown on Map 1. The raw data are presented on the CD Rom.
The selected river flow stations are shown in Map 2. A summary of the stations providing information about the basins in which they are located, date of establishment, etc. are presented in Annex 3.3.

In the regression analysis for filling the data gaps, correlations among the mean monthly discharges of stations in the sub-basins were estimated and assessed whether they were significant for developing regression equations. The data points were also plotted to check any spurious correlation.

In general the regression analysis was based on the following linear equations:-

$$\mathbf{y = ax + b} \quad \textbf{or} \qquad \textbf{(3.1)}$$

$$\mathbf{y = a_1 x_1 + a_2 x_2 + \ldots\ldots a_n x_n + b} \text{ \textbf{(where the regression are based on multiple stations)}} \qquad \textbf{(3.2)}$$

y being the dependent variable and the x_1 ….. x_n the independent variables.

The coefficients and constant are based on Least Square Estimates as follows:-

$$\mathbf{a = \frac{\Sigma\ (x - \bar{x})\ (y - \bar{y})}{\Sigma\ (x - \bar{x})^2}} \qquad \textbf{(3.3)}$$

$$\mathbf{b = \bar{y} - m\ \bar{x}} \qquad \textbf{(3.4)}$$

Where $\bar{x}$ and $\bar{y}$ are sample means (averages)

To assess the adequacy of the estimates the following validation regression statistics were computed as follows:-

$\mathbf{R^2}$	=	Coefficient of determination to assess how well the dependent variable is determined by the independent variable(s). (The nearer $\mathbf{R^2}$ is to 1, the more it is assumed that the co-relation between the dependent and independent variables is good).
$\mathbf{Se_y}$	=	Standard error of estimate of y value from x value.

3.1.3 Results of Gaps Filling and Data Extension

The results of the analyses are presented in the following paragraphs.

i) *Bui and Bamboi*

The correlation coefficient between the mean monthly discharges of the Bui and Bamboi was 0.844 and was quite significant.

Bui data were regressed over Bamboi data and the Regression equation was

$$Y = 0.7428X + 51.779 \qquad (3.5)$$

where Y is Bui data and X is Bamboi data. R^2 is 0.71.

The regression curve is presented in Fig 3.1.

Bui data were estimated from Bamboi using the above equation. An inverse equation of eqn. (1) was used to estimate the missing data of Bamboi using Bui available data.

In the situation where data were missing from both Bui and Bamboi, another regression equation using data from Bui and Dapola was developed. The latter is a station in Burkina Faso. The R^2 was 0.924. The regression equation is

$$Y = 1.9480\,X + 15.4538 \qquad (3.6)$$

where Y is Bui data and X Dapola data. R^2 is 0.85 and Standard Error 90.4

The completed discharges are presented in Tables 3.1.1 and 3.1.2 for Bui and Bamboi respectively.

ii) *Pwalugu and Nawuni*

Similar approach was used in filling the gaps between Pwalugu and Nawuni datasets. The correlation coefficient between Pwalugu and Nawuni data sets were computed and the regression equations also developed.

Due to the construction of Bagre and Ziga dams, the relationships were investigated over the time period before and after the creation of these dams and used for filling the gaps.

Nawuni (Y) vrs. Pwalugu (X) Discharges

Before Bagre (1953-1990)

$$Y = 1.800X + 57.001, \qquad (3.7)$$
$$R^2 = 0.7392$$

The regression curve is presented in Fig. 3.2.

Before Ziga (1991-2003)

$$Y = 2.5277X + 41.439, \qquad (3.8)$$
$$R^2 = 0.7842$$

After Ziga (2004 – 2006)

$$Y = 2.6306\,X - 38.016, \qquad (3.9)$$
$$R^2 = 0.8192$$

The completed discharges are presented in Tables 3.1.3 and 3.1.4 for Pwalugu and Nawuni respectively.

iii) *Saboba and Sabari*

The correlation coefficient between Saboba and Sabari on Oti was very high with explained variance (R^2) of about 96%.

The regression equation

$Y = 1.1777X – 2.0456,$ (3.10)
$R^2 = 0.9662$

where Y is Sabari and X is Saboba dataset.
The regression curve is presented in Fig. 3.3.

In absence of data from both Sabari and Saboba, investigation indicated that data at Bui on the Black Volta has some significant correlation with the data at Saboba on Oti. The explained variance (R^2) is about 55%.

Yendi rainfall has some significant relationship with Saboba discharges and hence a multiple regression equation was developed between Saboba discharge, Y and discharges at Bui (X_1) and Yendi rainfall (X_2).

The multiple correlation coefficient was 0.80 with explained variance (R^2) of 64%. The multiple regression equation below was developed and used in filling the data gaps.

$Y = 0.970 X_1 + 2.204 X_2 – 116.453,$ (3.11)

Standard error = 361.5

Yendi has no rainfall records earlier than January 1961 and missing records before that date were estimated from Bui discharges alone:

$Y = 1.333 X_1 – 3.081$ (3.12)

$R^2 = 0.55$, Standard error = 402.1

The completed flows are presented in Tables 3.1.5 and 3.1.6 for Saboba and Sabari respectively.

iv) *Yagaba*

Yagaba data was also regressed over the following data sets in various combination: Nawuni, Pwalugu, Nebbou and the best result was the multiple regression of Yagaba over Nawuni and Pwalugu.

$Y = -6.10 + 0.124X_1 + 0.069 X_2$ (3.13)

Multiple $R^2 = 0.709$ Standard error = 42.97
where Y is Yagaba and X_1 and X_2 are Nawuni and Pwalugu data respectively.

The completed flows are presented in Table 3.1.7 for Yagaba.

v) *Nakong*

In filling missing data of Nakong on Sissili river, data from Nebbou station, upstream in Burkina Faso, was found to be of high correlation with the latter. The only limitation was that the data length was only for the period 1974 to 2003. The following results were obtained from the regression analysis.

$$Y = 3.372 + 3.611\,X \qquad (3.14)$$

$R^2 = 0.809$, Standard Error (SE) = 9.05

where Y is Nakong data and X is Nebbou data.

Estimation outside the above period used other dataset. Nakong has some good relations with Nawuni downstream on the White Volta. Nakong is on Sissili river, an upstream tributary of the White Volta.

$$Y = -0.51 + 0.0357X \qquad (3.15)$$

$R^2 = 0.726$ SE = 8.626

where Y is Nakong data and X is Nawuni data.

The completed flows for Nakong are presented in Tables 3.1.8

vi) *Yarugu*

A multiple regression was used in filling gaps of missing data in Yarugu. The regression of Yarugu over Nawuni and Pwalugu data sets gave the best results:

$$Y = 6.44 - 0.0424X_1 + 0.805X_2 \qquad (3.16)$$

Multiple $R^2 = 0.638$ SE =114.82

where Y is Yarugu and X_1 and X_2 are Nawuni and Pwalugu data respectively.

The completed flows for Yarugu are presented in Tables 3.1.9

Tables 3.1.1 to 3.1.9 are presented as follows:-

Table 3.1. 1: Bui on Black Volta- Completed monthly discharges in m^3/s

YEAR	Jan	Feb	March	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	ANNUAL
1951			67.24	65.67	96.15	82.19	198.87	323.47	1019.16	1232.55	891.93	209.72	**418.70**
1952	125.54	77.73	67.31	70.63	76.80	70.24	148.67	267.37	763.05	1270.51	415.57	149.70	**291.93**
1953	127.43	95.43	80.97	69.44	78.08	171.04	227.49	282.42	635.68	499.57	160.23	102.25	**210.84**
1954	0.00	0.00	3.23	3.99	12.98	36.99	28.16	195.61	950.39	866.26	288.43	129.89	**209.66**
1955	83.17	44.23	34.93	17.86	22.65	60.18	178.38	559.24	1092.51	1406.88	353.32	144.23	**333.13**
1956	73.45	40.13	21.68	13.74	25.44	34.96	76.30	124.67	579.32	676.64	317.41	90.20	**172.83**
1957	40.63	14.84	6.24	70.43	52.76	210.46	263.74	536.85	901.53	1132.94	379.65	148.30	**313.20**
1958	72.29	27.14	8.30	11.66	6.60	27.55	42.07	142.49	354.71	389.70	144.76	106.78	**111.17**
1959	59.59	29.33	17.09	8.15	40.67	69.96	105.08	188.10	808.44	495.20	111.85	50.21	**165.30**
1960	12.10	3.19	63.58	7.02	19.47	76.26	168.38	403.86	761.20	610.86	131.16	64.89	**193.50**
1961	16.03	4.45	2.23	5.40	18.10	75.18	89.44	155.86	475.97	293.29	112.58	74.33	**110.24**
1962	33.10	13.54	8.01	29.90	39.83	120.02	218.70	402.40	1017.61	975.99	303.82	92.53	**271.29**
1963	23.97	7.27	4.25	1.66	38.41	27.54	389.90	1291.77	2319.19	1531.77	421.20	126.76	**515.31**
1964	51.16	15.15	8.68	7.33	16.69	91.44	105.02	234.79	1028.04	875.87	214.87	110.17	**229.93**
1965	61.04	27.74	7.53	3.54	7.39	107.12	634.94	721.64	1026.59	806.47	200.03	93.60	**308.14**
1966	39.89	13.31	5.08	5.78	28.02	48.32	64.19	324.18	587.30	802.80	219.11	64.88	**183.57**
1967	14.33	3.65	0.74	1.23	10.15	9.32	50.05	165.41	547.23	510.84	144.32	61.43	**126.56**
1968	17.32	6.95	1.83	6.84	36.57	177.15	377.85	732.21	1439.93	816.49	301.41	120.76	**336.28**
1969	37.83	11.73	5.60	7.83	7.28	27.47	226.70	445.76	938.66	803.52	346.81	100.60	**246.65**
1970	31.27	7.86	2.70	0.68	6.83	16.38	38.42	371.50	873.54	552.08	140.95	83.68	**177.16**
1971	39.17	18.93	9.10	3.62	12.50	20.22	114.06	387.89	704.05	451.56	100.35	36.68	**158.18**
1972	10.39	2.65	1.04	2.32	14.54	129.59	74.48	175.40	335.84	224.55	57.56	7.19	**86.30**
1973	1.06	0.08	0.43	0.43	13.20	23.69	101.20	375.82	415.83	160.92	23.88	1.27	**93.15**
1974	0.09	3.79	7.56	4.28	8.80	19.58	165.69	367.43	875.04	623.95	159.18	45.70	**190.09**
1975	11.70	2.57	4.93	17.86	21.73	62.62	361.36	290.86	805.20	432.17	108.60	55.84	**181.29**
1976	21.50	9.85	6.03	14.53	11.59	81.05	74.27	140.96	198.63	319.60	490.34	77.24	**120.47**
1977	23.90	12.75	5.53	11.37	30.67	65.83	101.58	277.86	883.57	367.58	79.32	19.42	**156.61**
1978	8.49	4.84	7.45	11.24	48.00	51.16	167.89	285.45	405.96	336.56	122.56	50.65	**125.02**
1979	15.85	6.83	3.63	5.70	49.64	305.36	542.29	575.41	1045.75	623.17	271.15	69.69	**292.87**
1980	20.55	13.87	6.12	4.81	18.11	69.17	103.90	456.86	1112.89	406.42	280.38	56.79	**212.49**
1981	21.21	10.56	7.34	8.92	37.63	48.09	167.99	356.70	479.59	265.88	75.26	25.40	**125.38**
1982	11.24	6.62	27.45	37.08	60.06	80.32	113.24	218.04	272.69	374.23	85.00	40.78	**110.56**
1983	27.78	22.14	18.32	17.50	41.17	87.92	119.28	251.16	171.68	74.67	18.10	15.46	**72.10**
1984	15.45	15.45	15.56	15.57	72.72	259.30	329.65	323.97	323.87	321.29	20.67	15.54	**144.09**
1985	15.45	15.45	15.45	16.98	36.30	124.15	375.83	722.57	668.02	264.79	103.50	58.11	**201.38**
1986	18.98	15.45	16.78	18.53	39.02	102.33	130.77	297.91	825.81	266.74	89.48	45.65	**155.62**
1987	23.09	21.10	17.36	20.81	18.94	115.77	119.86	625.17	527.77	163.30	51.30	27.02	**144.29**
1988	19.21	18.03	17.17	27.71	28.33	62.21	197.20	416.74	1092.68	465.43	124.15	83.63	**212.71**
1989	24.98	23.58	24.47	25.60	86.77	153.57	838.13	1232.67	2392.45	1417.56	344.02	237.34	**566.76**
1990	180.85	123.96	97.19	93.47	151.93	239.90	378.91	767.12	755.29	425.12	186.46	122.89	**293.59**
1991	85.78	63.50	67.06	81.87	428.83	810.07	957.59	1293.25	1634.95	959.10	470.72	308.93	**596.80**
1992	183.75	122.39	96.67	80.22	160.18	321.64	443.23	554.01	912.11	526.58	280.76	216.65	**324.85**
1993	136.33	97.91	96.41	90.86	163.67	225.14	294.99	840.39	1224.37	671.07	328.39	257.27	**368.90**
1994	131.55	62.80	68.42	62.55	116.96	255.48	464.32	820.59	1393.16	1520.79	844.30	382.93	**510.32**
1995	320.20	276.00	252.30	159.21	205.65	342.29	559.30	880.54	1024.30	890.58	372.78	186.62	**455.81**
1996	133.22	115.67	0.07	0.46	9.50	54.71	71.24	255.41	626.35	398.72	41.79	4.13	**142.61**
1997	0.48	0.01	0.00	0.38	9.07	161.87	75.95	118.31	375.95	263.07	62.95	5.80	**89.49**
1998	0.54	0.06	0.00	0.00	31.62	24.55	34.52	255.51	294.06	270.88	53.62	6.75	**81.01**
1999	0.60	0.12	0.02	4.74	4.71	22.30	118.80	392.38	1334.10	856.34	142.12	47.75	**243.66**

2000	24.52	6.13	3.19	0.38	121.44	337.63	579.65	545.89	634.30	483.35	107.89	24.52	**239.07**
2001	161.20	103.84	81.45	66.90	8.85	55.93	122.08	207.35	430.47	399.81	54.69	25.45	**143.17**
2002	20.11	19.14	18.61	19.39	14.77	59.75	98.45	313.35	438.55	194.62	17.68	20.77	**102.93**
2003	51.78	0.00	0.00	0.88	7.02	155.81	213.47	530.93	1021.07	582.82	98.72	27.80	**224.19**
2004	8.47	0.89	1.13	7.78	22.58	24.63	107.31	415.09	631.69	187.03	46.95	5.15	**121.56**
2005	1.74	0.14	0.05	0.30	7.03	28.11	106.11	132.78	419.53	329.02	22.39	3.07	**87.52**
MEAN	**49.84**	**30.75**	**25.66**	**24.42**	**50.08**	**118.57**	**226.49**	**428.70**	**814.68**	**601.26**	**206.12**	**86.20**	**223.64**
Max	320.20	276.00	252.30	159.21	428.83	810.07	957.59	1293.25	2392.45	1531.77	891.93	382.93	**596.80**
Min	0.00	0.00	0.00	0.00	4.71	9.32	28.16	118.31	171.68	74.67	17.68	1.27	**72.10**
SD	61.51	48.25	42.42	32.74	69.20	130.26	202.15	286.20	448.79	370.76	183.28	80.60	
CV	**1.23**	**1.57**	**1.65**	**1.34**	**1.38**	**1.10**	**0.89**	**0.67**	**0.55**	**0.62**	**0.89**	**0.94**	

Table 3.1. 2 Bamboi on Black Volta – Completed mean monthly flows in m^3/s

YEAR	Jan	Feb	March	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	ANNUAL
1951			20.81	18.70	59.74	40.94	198.03	365.76	1302.35	1589.62	1131.06	212.63	**493.96**
1952	99.31	34.94	20.91	25.38	33.69	24.86	130.44	290.25	957.56	1640.72	489.76	131.82	**323.30**
1953	101.84	58.76	39.30	23.77	35.40	160.56	236.55	310.50	786.08	602.85	146.01	67.95	**214.13**
1954	0.00	0.00	0.00	0.00	0.00	0.00	0.00	193.48	899.37	902.75	315.19	124.21	**202.92**
1955	80.81	61.35	41.52	17.48	35.28	85.15	274.60	554.70	1076.74	1577.59	424.46	99.43	**360.76**
1956	64.10	33.25	25.74	25.28	45.17	40.56	130.80	126.66	534.70	669.18	119.23	21.20	**152.99**
1957	61.21	36.59	26.34	25.11	65.22	224.14	284.48	542.37	920.41	1244.51	437.63	162.81	**335.90**
1958	113.20	109.46	31.49	28.58	21.75	49.93	58.13	122.79	323.22	454.93	125.18	78.09	**126.40**
1959	10.52	28.10	26.05	22.67	42.73	24.48	110.15	181.36	765.91	635.66	121.58	64.65	**169.49**
1960	30.86	21.03	15.89	32.97	42.41	94.17	176.15	413.45	734.82	699.49	142.75	73.42	**206.45**
1961	32.87	20.32	15.43	24.34	36.98	108.48	91.91	154.94	465.25	335.71	74.50	53.93	**117.89**
1962	0.00	0.00	23.99	40.03	58.60	166.46	271.90	418.18	974.97	979.95	339.88	115.64	**282.47**
1963	43.59	32.29	10.42	11.07	29.06	29.31	385.83	1248.79	2372.33	1545.91	410.82	123.32	**520.23**
1964	0.00	12.54	22.23	19.39	23.62	109.38	96.06	207.32	963.43	790.96	209.36	90.11	**212.03**
1965	59.31	25.72	19.01	17.67	27.03	131.31	607.03	643.44	966.92	811.64	198.69	84.94	**299.39**
1966	70.61	0.00	11.80	12.54	5.04	65.95	86.95	294.85	556.68	1011.06	199.04	55.99	**197.54**
1967	34.59	15.32	8.83	9.72	14.97	17.41	50.57	129.76	489.05	476.31	114.24	44.80	**117.13**
1968	0.00	13.42	7.82	13.59	34.90	198.23	451.09	1016.74	2043.86	1228.60	387.60	107.33	**458.60**
1969	41.13	17.64	12.60	14.18	17.88	30.46	197.43	435.52	1072.13	960.88	405.30	78.02	**273.60**
1970	29.97	13.76	9.43	6.39	16.15	21.01	34.84	365.39	981.40	655.94	107.10	62.57	**191.99**
1971	33.94	20.85	16.05	10.74	20.70	36.33	108.23	433.65	895.65	580.12	78.70	32.56	**188.96**
1972	15.34	8.82	6.96	9.07	22.03	111.20	71.99	107.94	382.41	182.02	45.62	11.30	**81.22**
1973	6.07	4.02	3.22	7.46	13.72	25.59	65.33	304.78	505.97	201.41	31.29	6.39	**97.94**
1974	4.28	2.57	2.28	3.38	10.86	16.62	157.87	414.08	1040.02	890.18	250.05	0.00	**232.68**
1975	6.68	3.03	1.14	7.01	10.43	32.75	234.57	321.86	518.07	320.49	57.30	25.91	**128.27**
1976	10.14	5.10	2.82	0.00	0.00	39.41	30.28	101.61	117.77	360.55	590.41	34.28	**107.70**
1977	0.00	0.00	0.00	0.00	0.00	18.92	67.04	220.32	571.95	329.94	37.08	0.00	**103.77**
1978	0.00	0.00	0.00	0.00	0.00	0.00	156.31	314.59	476.82	383.39	95.29	0.00	**118.87**
1979	0.00	0.00	0.00	0.00	0.00	341.38	660.36	704.94	1338.14	769.24	295.33	24.11	**344.46**
1980	0.00	0.00	0.00	4.80	11.11	23.41	70.17	545.34	1428.53	477.43	307.76	6.74	**239.61**
1981	0.00	0.00	0.00	0.00	0.00	0.00	156.45	410.50	575.94	288.24	31.62	0.00	**121.90**
1982	0.00	0.00	0.00	0.00	11.15	38.43	82.74	223.83	297.40	434.10	44.72	0.00	**94.36**
1983	0.00	0.00	0.00	0.00	0.00	48.65	90.87	268.42	161.42	30.82	0.00	0.00	**50.02**
1984	0.00	0.00	0.00	0.00	28.20	279.38	374.08	366.44	366.31	362.83	0.00	0.00	**148.10**
1985	0.00	0.00	0.00	0.00	0.00	97.43	436.25	903.05	829.62	286.77	69.63	8.53	**219.27**
1986	0.00	0.00	0.00	0.00	0.00	68.06	106.35	331.35	1042.04	289.40	50.75	0.00	**157.33**
1987	0.00	0.00	0.00	0.00	0.00	86.15	91.66	771.93	640.81	150.14	0.00	0.00	**145.06**
1988	0.00	0.00	0.00	0.00	0.00	14.04	195.77	491.33	1401.32	556.89	97.43	42.88	**233.30**
1989	0.00	0.00	0.00	0.00	47.11	137.04	608.34	737.26	3151.14	945.84	212.82	99.10	**494.89**

1990	173.76	97.17	61.13	56.13	52.57	93.00	272.29	963.03	947.11	502.62	94.44	51.47	**280.39**
1991	192.78	393.88	518.26	287.60	219.66	475.40	749.27	1671.34	2131.35	1039.47	900.75	930.91	**792.56**
1992	650.17	479.10	401.63	290.06	221.98	292.72	376.68	407.11	327.94	235.81	97.93	103.60	**323.73**
1993	72.61	62.11	60.08	41.82	41.41	141.09	281.58	275.68	1578.61	833.73	372.39	276.65	**336.48**
1994	107.39	14.84	22.41	19.77	43.37	79.35	239.61	487.56	966.88	1105.76	531.71	445.81	**338.70**
1995	361.36	57.80	57.93	47.64	207.15	119.08	278.73	482.25	678.91	684.96	395.17	186.60	**296.46**
1996	43.95	86.02	0.00	0.00	0.00	3.94	26.20	274.14	773.52	467.07	0.00	0.00	**139.57**
1997	0.00	0.00	0.00	0.00	0.00	148.21	32.53	89.57	436.41	284.46	15.04	0.00	**83.85**
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	274.28	326.17	294.96	2.48	0.00	**74.82**
1999	0.00	0.00	0.00	0.00	0.02	2.63	93.51	980.11	1726.33	1083.14	183.93	10.23	**340.06**
2000	1.93	0.00	0.00	0.00	0.00	36.14	97.68	665.20	2429.55	1623.33	103.77	1.70	**413.27**
2001	0.00	0.00	0.00	0.00	12.06	99.95	179.81	308.04	948.25	468.55	3.92	0.00	**168.38**
2002	0.00	0.00	0.00	0.00	0.13	10.73	129.84	816.31	1389.83	312.04	7.16	0.00	**222.17**
2003	0.00	0.00	0.00	0.00	0.76	408.90	359.40	645.06	1304.92	714.91	85.44	3.05	**293.54**
2004	0.00	0.00	0.00	0.99	5.40	4.64	87.31	1152.74	780.71	182.08	41.32	0.00	**187.93**
2005	0.00	0.00	0.00	0.00	0.09	5.81	55.32	137.06	1105.13	1885.82	13.47	0.00	**266.89**
MEAN		**32.77**	**28.06**	**21.38**	**29.55**	**90.17**	**198.13**	**458.16**	**959.64**	**697.69**	**200.80**	**75.54**	**238.61**
Max		479.10	518.26	290.06	221.98	475.40	749.27	1671.34	3151.14	1885.82	1131.06	930.91	**792.56**
Min		0.00	0.00	0.00	0.00	0.00	0.00	89.57	117.77	30.82	0.00	0.00	**50.02**
SD		84.54	86.91	54.23	49.08	104.11	172.49	327.01	602.48	446.51	225.81	142.75	
CV		**2.58**	**3.10**	**2.54**	**1.66**	**1.15**	**0.87**	**0.71**	**0.63**	**0.64**	**1.12**	**1.89**	

Table 3.1. 3: PWALUGU (White Volta) - Completed mean monthly flows in m^3/s

YEAR	**Jan**	**Feb**	**March**	**April**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**ANNUAL**
1951	-	-	-	-	-	8.88	25.59	436.37	562.50	339.65	41.08	3.42	**202.50**
1952	0.00	0.00	0.00	0.00	3.00	19.04	61.36	292.87	821.00	275.96	7.68	0.06	**123.41**
1953	0.00	0.00	0.00	0.00	32.53	171.46	94.82	238.14	463.34	83.61	7.17	0.00	**90.92**
1954	0.00	0.00	0.00	0.00	6.12	48.29	68.76	198.73	341.47	64.33	10.60	32.42	**64.23**
1955	0.00	0.00	0.00	0.00	55.44	29.26	208.00	433.92	685.02	619.88	35.88	0.00	**172.28**
1956	0.00	0.00	0.00	0.00	0.00	58.08	100.33	234.00	622.07	217.17	5.45	0.00	**103.09**
1957	0.00	0.00	0.00	0.00	210.64	45.50	140.35	277.77	787.79	479.11	37.68	0.00	**164.90**
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	322.98	545.82	222.71	0.00	0.00	**90.96**
1959	0.00	0.00	0.00	0.00	0.00	0.68	17.46	405.54	590.20	28.07	0.00	0.00	**86.83**
1960	0.00	0.00	0.00	0.00	0.00	0.05	19.67	202.67	435.60	44.19	0.00	0.00	**58.51**
1961	0.00	0.00	0.00	0.00	0.00	0.00	100.14	375.59	596.65	243.43	0.00	0.00	**109.65**
1962	0.00	0.00	0.00	0.00	8.15	58.86	98.84	527.85	755.72	230.73	25.67	6.65	**142.71**
1963	0.89	7.63	0.08	10.83	65.94	19.55	183.39	434.13	494.12	134.14	26.42	1.71	**114.90**
1964	0.09	0.00	0.00	0.00	0.00	0.93	251.70	663.36	826.06	180.03	8.31	0.43	**160.91**
1965	0.00	0.00	0.00	13.87	1.46	31.27	59.23	317.24	286.64	80.80	10.04	0.18	**66.73**
1966	0.00	0.00	0.00	6.04	33.22	53.26	46.18	236.66	267.40	107.31	5.16	0.38	**62.97**
1967	0.00	0.00	0.00	0.42	0.77	5.84	56.33	582.05	840.93	160.19	14.96	3.08	**138.71**
1968	0.22	0.00	8.41	2.93	52.13	182.13	375.30	219.21	220.12	43.26	6.68	1.60	**92.66**
1969	0.03	0.00	0.00	2.49	10.86	8.73	150.31	393.73	951.22	99.02	26.07	2.25	**137.06**
1970	1.63	0.00	0.01	0.00	5.91	19.48	64.21	591.52	681.51	100.54	13.77	5.11	**123.64**
1971	2.24	0.93	0.20	0.65	11.84	16.29	114.24	401.11	612.25	80.10	11.01	2.89	**104.48**
1972	0.73	0.06	0.00	13.27	14.27	33.19	100.15	216.07	162.53	32.64	2.31	0.01	**47.94**
1973	0.00	0.00	0.00	0.00	5.09	0.69	138.50	735.90	240.79	27.28	0.00	0.00	**95.69**
1974	0.00	0.00	0.00	0.00	6.01	0.00	278.13	762.90	732.56	329.74	15.44	6.80	**177.63**
1975	0.00	0.00	0.00	0.00	0.00	7.59	114.70	282.85	566.09	87.56	0.00	0.00	**88.23**
1976	0.00	0.00	0.00	0.00	11.21	26.53	65.71	145.55	108.68	141.22	56.59	0.00	**46.29**
1977	0.00	0.00	0.00	0.00	0.00	0.00	6.60	608.82	343.80	38.25	9.19	0.00	**83.89**
1978	0.00	0.00	0.00	0.00	45.33	61.45	110.27	148.49	144.81	38.48	9.86	0.00	**46.56**
1979	0.00	0.00	0.00	0.00	0.00	65.29	120.60	298.37	718.20	220.92	7.18	0.00	**119.21**

1980	0.00	0.00	0.00	0.00	0.00	34.84	91.59	359.81	906.34	78.82	5.82	0.00	**123.10**
1981	0.00	0.00	0.00	0.00	0.00	19.65	46.23	227.21	635.99	202.48	39.73	0.00	**97.61**
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.20	97.52	349.15	143.65	18.61	**53.18**
1983	0.00	0.00	0.00	0.00	0.00	0.00	20.68	114.80	175.03	375.40	89.33	0.00	**64.60**
1984	0.00	0.00	0.00	0.00	0.00	5.60	7.07	65.63	73.15	73.93	0.00	0.00	**18.78**
1985	0.00	0.00	0.00	0.00	0.00	0.00	199.03	528.39	0.00	240.66	6.84	0.00	**81.24**
1986	0.00	0.00	0.00	0.00	0.00	1.21	73.77	278.61	437.18	159.02	8.89	0.00	**79.89**
1987	0.00	0.00	0.00	0.00	0.00	12.91	55.46	397.57	510.76	119.41	0.00	0.00	**91.34**
1988	0.00	0.00	0.00	0.00	0.00	1.85	89.28	443.41	688.25	40.33	0.00	2.60	**105.48**
1989	0.00	0.00	0.00	0.00	0.00	27.39	272.19	703.88	748.19	199.59	32.62	2.74	**165.55**
1990	0.00	0.00	0.00	0.00	0.00	16.93	54.95	141.43	22.12	38.34	0.00	0.00	**22.81**
1991	0.00	0.00	0.00	0.00	40.83	221.36	165.43	656.05	949.50	201.22	18.15	0.00	**187.71**
1992	0.00	0.00	0.00	0.00	0.00	1.95	24.25	90.77	396.57	57.74	0.00	0.00	**47.61**
1993	0.00	0.00	0.00	0.00	2.76	10.01	85.82	391.67	134.47	31.21	0.00	0.00	**54.66**
1994	0.00	0.00	0.00	0.00	5.29	15.78	22.13	358.30	990.38	323.81	127.20	16.47	**154.95**
1995	8.67	0.00	9.91	10.08	11.42	25.46	44.56	363.12	598.03	132.34	0.00	0.00	**100.30**
1996	0.00	2.18	25.88	15.07	28.03	105.69	57.99	272.73	360.28	109.35	40.71	29.14	**87.26**
1997	29.32	0.00	1.70	0.00	5.13	41.62	30.82	83.29	196.02	42.38	17.72	27.93	**39.66**
1998	19.16	26.55	27.18	0.00	65.92	104.00	160.38	211.31	503.76	486.98	46.48	11.45	**138.60**
1999	11.10	13.39	11.55	54.46	54.48	60.07	118.10	537.50	607.37	685.72	67.55	16.85	**186.51**
2000	44.96	38.77	53.50	52.97	46.65	66.38	113.42	343.15	143.13	41.98	20.25	5.04	**80.85**
2001	1.90	12.61	14.55	23.21	22.40	41.62	25.81	36.78	754.71	218.22	9.21	0.00	**96.75**
2002	1.00	2.66	4.56	6.59	1.87	63.53	51.32	177.93	131.36	98.46	38.81	34.48	**51.05**
2003	31.51	36.03	40.90	34.35	39.70	66.17	207.44	375.83	712.84	174.56	59.15	34.48	**151.08**
2004	18.26	32.86	39.03	53.27	66.55	87.06	168.05	271.17	241.59	53.56	28.95	15.96	**89.69**
2005	16.51	31.92	29.08	28.92	42.02	131.59	155.30	254.38	304.38	82.95	45.62	37.70	**96.70**
MEAN	**3.49**	**3.81**	**4.94**	**6.10**	**18.76**	**38.82**	**100.22**	**339.97**	**485.89**	**170.33**	**22.56**	**5.83**	101.54
Maximum	44.96	38.77	53.50	54.46	210.64	221.36	375.30	762.90	990.38	685.72	143.65	37.70	**202.50**
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.20	0.00	27.28	0.00	0.00	**18.78**
SD	9.11	9.93	11.92	13.78	33.91	48.44	78.65	181.56	272.01	148.36	29.87	10.63	
CV	**2.62**	**2.61**	**2.42**	**2.26**	**1.81**	**1.25**	**0.78**	**0.53**	**0.56**	**0.87**	**1.32**	**1.82**	

Table 3.1. 4: Nawuni (White Volta) – Completed mean monthly flows in m^3/s

YEAR	**Jan**	**Feb**	**March**	**April**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**ANNUAL**
1951						70.24	102.45	894.22	1137.34	707.81	132.30	59.71	**443.44**
1952	53.12	53.12	53.12	53.12	58.90	89.83	171.39	617.63	1635.59	585.03	67.92	53.23	**291.00**
1953	53.12	53.12	53.12	53.12	20.76	431.72	460.96	946.94	1334.73	695.46	105.84	14.39	**351.94**
1954	53.12	0.00	2.12	1.14	24.27	109.04	135.41	382.11	1271.66	752.70	82.59	10.96	**235.43**
1955	5.46	3.54	2.15	1.71	2.55	31.32	182.11	875.78	1400.00	1247.95	122.28	23.12	**324.83**
1956	7.01	4.32	3.13	2.51	3.83	3.80	186.76	284.34	1377.19	729.67	45.13	10.17	**221.49**
1957	6.80	4.34	1.35	2.43	69.35	262.83	323.65	588.53	1571.59	963.52	125.75	20.57	**328.39**
1958	4.15	2.77	1.93	2.56	4.04	45.30	34.02	306.23	1279.08	482.39	41.26	6.76	**184.21**
1959	6.24	4.39	2.44	3.34	3.02	63.54	112.36	455.65	1369.87	613.21	34.76	9.81	**223.22**
1960	5.08	3.48	2.47	1.35	3.10	46.39	108.49	515.91	1360.98	890.54	65.85	21.83	**252.12**
1961	5.30	3.80	4.60	3.55	10.94	42.90	246.15	777.08	1203.17	522.33	37.30	13.23	**239.19**
1962	6.76	3.53	1.21	0.69	3.81	73.24	156.91	587.23	1769.36	895.69	97.97	23.24	**301.64**
1963	6.29	2.47	12.72	11.99	32.16	22.27	283.26	1198.10	1816.20	735.17	177.97	24.02	**360.22**
1964	11.97	9.17	6.51	5.14	4.87	14.13	100.70	551.45	1302.80	758.09	54.67	13.24	**236.06**
1965	7.18	6.13	4.20	3.79	7.44	35.04	172.19	664.59	1076.86	399.11	23.32	7.88	**200.64**
1966	6.43	4.83	3.83	2.82	30.92	94.04	86.82	509.29	987.81	485.36	52.47	11.47	**189.67**
1967	6.91	4.54	3.05	3.08	3.69	6.82	41.94	568.08	1526.99	816.33	69.58	10.76	**255.15**
1968	5.09	1.94	3.26	4.13	32.67	167.73	776.51	990.31	1035.51	352.20	51.13	12.15	**286.05**
1969	6.07	4.13	2.25	3.05	10.35	13.44	183.92	474.34	1717.57	717.69	89.92	16.87	**269.97**
1970	5.57	12.82	10.78	11.28	10.41	13.49	66.18	610.45	1602.78	582.40	43.07	17.98	**248.94**
1971	10.11	6.31	4.03	4.26	5.56	23.75	97.82	514.96	1601.75	464.79	36.27	15.31	**232.08**
1972	8.53	7.37	5.58	11.09	19.07	33.86	103.77	205.73	318.41	106.01	27.68	10.67	**71.48**
1973	5.64	3.16	4.03	4.90	10.40	54.46	79.26	793.90	709.80	95.45	25.00	13.16	**149.93**
1974	9.33	6.65	5.19	4.13	5.53	21.69	218.65	813.50	1519.76	688.69	60.11	25.02	**281.52**
1975	14.70	10.47	7.35	9.07	32.48	19.41	274.20	479.21	964.66	530.98	40.05	24.39	**200.58**
1976	19.15	9.25	5.79	5.61	28.85	30.88	79.56	204.48	205.58	250.84	173.04	24.87	**86.49**
1977	14.63	11.91	8.19	5.04	23.80	17.99	65.84	359.17	1026.28	126.85	32.09	6.72	**141.54**
1978	5.19	2.33	2.01	3.30	28.61	124.88	246.66	269.35	332.24	108.46	26.08	8.95	**96.50**
1979	4.74	2.78	1.45	0.69	31.79	178.96	285.59	628.24	1437.45	478.94	66.97	20.67	**261.52**
1980	10.37	5.86	3.41	2.44	9.74	40.26	80.60	626.77	1406.68	205.05	64.34	23.24	**206.56**
1981	13.18	6.11	7.70	10.10	49.30	91.00	142.23	491.08	1279.00	443.40	129.70	35.90	**224.89**
1982	13.42	11.50	2.90	8.60	20.60	45.90	44.20	109.40	241.10	726.10	330.00	89.00	**136.89**
1983	33.70	4.96	3.28	14.40	6.30	18.90	92.99	274.40	390.49	776.70	225.30	27.60	**155.75**
1984	8.10	4.30	3.10	3.03	13.75	63.91	66.75	179.62	194.11	195.63	33.28	11.56	**64.76**
1985	5.64	2.92	1.65	1.28	3.35	47.08	436.75	1071.59	10.58	517.00	66.30	27.60	**182.65**
1986	3.70	1.80	6.62	4.82	6.35	55.46	195.32	590.14	895.79	359.63	70.25	27.04	**184.74**
1987	15.35	10.76	7.83	7.88	6.12	78.01	160.01	819.44	1037.61	283.28	66.10	25.38	**209.81**
1988	13.60	8.87	6.36	5.40	20.80	40.52	197.96	594.32	1461.11	693.77	86.86	58.13	**265.64**
1989	45.65	27.28	19.91	18.02	16.79	60.80	393.17	1123.36	2065.89	1135.94	116.00	58.41	**423.43**
1990	45.84	30.43	21.23	17.65	19.14	66.92	183.83	506.32	466.73	127.03	25.70	15.60	**127.20**
1991	14.23	22.55	10.62	23.14	131.82	479.79	371.99	1317.66	1883.28	440.97	88.11	37.18	**401.78**
1992	24.18	16.04	12.67	16.60	29.69	56.88	99.86	228.09	817.51	164.41	40.44	20.40	**127.23**
1993	13.21	10.27	6.71	19.64	58.45	72.42	218.53	808.06	1465.52	359.49	77.28	48.82	**263.20**
1994	35.68	29.45	23.52	51.36	63.32	83.54	141.50	743.75	2010.25	1355.08	298.30	84.86	**410.05**
1995	69.83	52.44	72.22	72.55	75.14	102.19	139.02	982.83	1205.83	308.21	59.59	37.30	**264.76**
1996	44.79	46.48	43.18	41.65	50.67	125.34	164.90	442.08	1394.25	995.19	106.90	54.52	**292.50**
1997	51.22	51.01	56.39	50.91	63.00	133.36	112.52	213.67	430.95	176.15	69.81	48.54	**121.46**
1998	23.98	30.47	25.38	29.02	68.69	114.79	140.62	460.43	1024.13	991.79	142.71	75.20	**260.60**
1999	74.52	78.94	75.38	81.58	88.26	101.81	280.77	1365.10	2095.66	1374.85	183.32	85.60	**490.48**

2000	69.87	64.99	55.67	71.88	76.01	164.04	271.73	515.42	731.43	401.53	76.13	30.05	**210.73**
2001	16.62	19.28	20.31	38.31	37.52	74.42	94.10	382.54	1507.83	473.74	70.87	51.84	**232.28**
2002	55.05	58.25	61.92	65.83	56.73	78.14	94.91	490.24	592.22	274.88	109.19	66.83	**167.02**
2003	54.63	55.89	67.42	60.38	58.86	135.22	469.92	713.97	1868.60	1095.12	147.34	72.54	**399.99**
2004	58.71	24.21	67.97	80.04	91.29	120.36	263.73	722.60	968.48	218.92	43.49	83.88	**228.64**
2005	35.83	50.11	55.68	51.82	56.71	168.40	280.15	368.26	816.99	271.25	141.06	66.77	**196.92**
MEAN	**22.31**	**17.92**	**17.72**	**19.76**	**31.51**	**86.59**	**191.30**	**603.78**	**1166.45**	**566.34**	**88.67**	**32.64**	**240.28**
Max	74.52	78.94	75.38	81.58	131.82	479.79	776.51	1365.10	2095.66	1374.85	330.00	89.00	**490.48**
Min	3.70	0.00	1.21	0.69	2.55	3.80	34.02	109.40	10.58	95.45	23.32	6.72	**64.76**
SD	21.07	20.38	22.80	24.21	28.88	89.09	134.23	291.32	519.75	329.04	63.78	23.95	
CV	**0.94**	**1.14**	**1.29**	**1.23**	**0.92**	**1.03**	**0.70**	**0.48**	**0.45**	**0.58**	**0.72**	**0.73**	

Table 3.1. 5: Saboba (Oti River) - Completed mean monthly flows in m^3/s

TABLE 3.1.5: SABOBA												
YEAR	**Jan**	**Feb**	**March**	**April**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**ANNUAL**
1951													
1952													
1953			0.58	0.45	18.20	289.43	436.66	651.80	1932.17	1109.00	128.76	22.14	**458.92**
1954	0.00	0.00	4.81	4.06	17.94	96.40	94.19	164.67	693.33	709.84	105.34	22.93	**159.46**
1955	4.25	1.80	0.64	0.48	5.87	27.03	546.94	1573.33	2261.93	1872.78	468.02	33.55	**566.38**
1956	12.86	4.26	2.40	1.68	1.48	20.20	68.54	253.13	1037.71	845.02	120.20	13.32	**198.40**
1957	12.31	4.26	0.35	5.30	67.27	277.54	235.52	793.84	2248.61	1812.86	265.79	194.65	**493.19**
1958	93.31	33.11	7.99	12.47	5.72	30.92	19.10	58.48	160.53	154.87	61.05	28.36	**55.49**
1959	9.02	3.84	4.04	19.16	28.72	29.76	131.89	492.28	1613.55	1103.55	67.88	10.80	**292.87**
1960	3.35	18.82	15.94	19.02	8.30	65.31	216.82	309.57	1422.75	1508.92	114.39	16.08	**309.94**
1961	5.72	1.75	2.93	3.16	12.14	47.83	294.57	314.40	912.29	438.17	22.15	4.78	**171.66**
1962	0.90	0.47	0.36	1.47	5.03	113.19	245.37	821.18	2387.72	1232.21	146.48	48.87	**416.94**
1963	7.29	3.88	2.57	2.48	10.35	6.65	496.34	1306.49	2273.08	1292.74	305.97	39.72	**478.96**
1964	12.00	5.29	2.72	5.43	8.18	15.97	96.02	544.05	1653.83	1226.49	101.26	17.28	**307.38**
1965	10.82	7.10	6.37	6.06	8.70	39.30	128.96	442.18	822.96	356.27	31.37	3.47	**155.30**
1966	3.78	1.67	3.41	9.76	16.12	60.80	72.61	524.24	957.15	818.98	186.02	24.81	**223.28**
1967	5.98	2.00	0.95	19.82	20.56	23.18	122.52	781.34	1211.81	899.44	410.78	199.33	**308.14**
1968	29.72	23.67	8.52	18.85	60.30	157.84	659.60	1235.76	1522.41	741.59	216.36	48.94	**393.63**
1969	0.00	28.16	4.03	15.52	11.60	21.41	146.40	602.65	2113.20	1161.26	259.33	45.48	**367.42**
1970	19.41	10.68	7.09	3.55	9.86	9.85	52.18	819.51	2403.83	1439.37	87.87	22.70	**407.16**
1971	11.50	7.09	4.92	9.18	9.85	19.10	229.31	1090.14	1818.58	385.73	37.58	15.58	**303.21**
1972	7.68	3.64	1.78	3.29	17.20	34.38	122.71	323.23	1153.36	767.11	63.17	16.19	**209.48**
1973	11.32	4.26	1.92	1.69	5.49	20.96	54.69	726.84	950.86	356.31	0.00	9.74	**178.67**
1974	4.64	2.26	1.14	1.15	10.14	47.96	150.05	731.83	1762.15	802.42	312.38	22.67	**320.73**
1975	9.73	5.99	3.82	11.53	38.00	36.74	324.01	618.47	961.35	807.90	112.35	22.34	**246.02**
1976	8.82	4.88	2.45	3.35	13.61	77.78	149.44	332.90	395.64	439.72	219.71	31.40	**139.97**
1977	13.42	7.29	4.71	4.51	7.65	21.45	76.29	330.57	799.37	213.91	38.80	21.75	**128.31**
1978	17.44	15.59	4.23	8.60	23.57	39.42	554.80	581.42	820.34	301.82	80.96	16.89	**205.42**
1979	8.65	4.30	14.96	2.73	19.69	72.96	296.82	721.82	1794.02	633.51	102.22	30.85	**308.54**
1980	14.56	8.02	4.41	3.26	18.48	37.41	40.84	476.37	1399.92	327.52	75.42	21.12	**202.28**
1981	9.52	4.30	2.87	3.59	33.84	51.26	145.84	807.11	852.31	321.83	47.60	23.33	**191.95**
1982	17.79	15.70	15.26	11.83	27.10	33.07	93.86	142.80	292.93	285.92	83.28	26.42	**87.16**
1983	4.53	3.68	11.20	12.32	12.52	40.06	147.19	190.85	374.74	156.36	28.99	0.00	**81.87**
1984	0.00	10.28	3.89	9.15	13.34	34.09	40.83	150.20	358.66	562.10	37.17	17.50	**103.10**
1985	13.10	10.17	3.29	5.09	6.72	14.07	149.74	728.06	914.70	482.17	30.73	10.01	**197.32**
1986	5.24	3.69	2.67	3.78	5.00	19.00	73.55	433.28	950.15	297.84	70.99	14.47	**156.64**

1987	7.34	4.13	2.82	2.43	1.72	16.31	123.48	507.80	1223.53	431.03	45.21	12.19	**198.17**
1988	5.94	3.66	2.58	2.41	5.78	23.84	161.82	417.97	1831.39	572.34	99.71	0.00	**260.62**
1989	6.36	5.31	4.47	3.39	4.69	28.59	225.23	862.36	1958.35	781.68	73.56	23.45	**331.45**
1990	13.67	21.27	8.19	14.49	17.18	29.29	161.99	617.21	654.79	497.96	64.48	29.02	**177.46**
1991	21.44	0.00	18.82	18.01	50.81	162.14	585.24	848.12	1448.82	1160.70	340.33	183.33	**403.15**
1992	28.71	22.17	17.20	21.79	38.79	58.43	216.70	428.10	777.05	262.76	52.98	19.91	**162.05**
1993	12.07	5.66	17.14	20.10	28.07	28.13	182.90	983.63	1372.31	379.08	72.96	27.18	**260.77**
1994	12.50	11.96	11.66	20.98	33.70	74.17	163.28	1110.04	1854.12	1970.11	360.59	61.46	**473.71**
1995	32.22	29.48	36.73	53.87	50.76	53.32	136.34	1383.64	1857.94	1170.69	196.99	53.45	**421.29**
1996	58.03	60.50	37.57	46.15	48.65	131.24	154.92	649.27	2091.22	1014.12	177.11	46.23	**376.25**
1997	28.08	12.88	20.62	41.27	74.68	107.65	252.76	605.00	1157.15	456.84	107.68	36.34	**241.75**
1998	22.61	26.75	25.49	22.56	60.96	166.17	493.71	1046.15	2132.97	1954.77	361.90	91.23	**533.77**
1999	56.48	52.25	49.49	51.58	52.46	57.03	167.29	902.62	2780.27	1148.26	21.46	0.00	**444.93**
2000	38.10	37.10	54.78	47.85	60.56	83.35	156.20	719.96	903.29	764.20	100.98	36.48	**250.24**
2001	27.79	42.76	40.17	51.49	55.30	54.23	177.73	693.71	1457.51	782.87	70.57	42.40	**291.38**
2002	0.00	0.00	33.77	39.74	28.46	34.49	105.22	317.65	740.06	603.85	99.65	0.00	**166.91**
2003	12.21	5.77	26.69	45.31	36.55	162.93	262.30	787.70	1761.49	1262.47	169.52	54.38	**382.28**
2004	26.05	24.37	33.10	49.91	47.78	49.07	370.81	875.93	1415.51	459.77	136.63	49.68	**294.88**
2005	47.64	49.15	44.02	32.46	33.87	141.51	459.07	690.89	1057.15	694.93	91.58	48.14	**282.53**
MEAN	16.27	13.02	12.16	15.65	24.70	64.04	212.66	651.37	1352.88	796.87	133.67	36.08	**278.84**
Max	93.31	60.50	54.78	53.87	74.68	289.43	659.60	1573.33	2780.27	1970.11	468.02	199.33	**566.38**
Min	0.00	0.00	0.36	0.45	1.48	6.65	19.10	58.48	160.53	154.87	0.00	0.00	**55.49**
SD	17.19	14.59	14.17	16.30	19.71	61.26	155.71	328.90	627.93	476.87	110.36	42.56	
CV	**1.06**	**1.12**	**1.17**	**1.04**	**0.80**	**0.96**	**0.73**	**0.50**	**0.46**	**0.60**	**0.83**	**1.18**	

Table 3.1. 6: Sabari (Oti River) - Completed mean monthly flows in m^3/s

YEAR	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	ANNUAL
1953			0.00	0.00	19.38	338.71	512.03	765.31	2272.70	1303.57	149.54	24.02	**538.53**
1954	0.00	0.00	3.61	2.74	19.08	111.45	108.84	191.82	814.21	833.65	121.97	24.95	**186.03**
1955	2.96	0.07	0.00	0.00	4.86	29.77	641.87	1850.23	2660.92	2202.78	548.96	37.45	**664.99**
1956	13.09	2.96	0.78	0.00	0.00	21.73	78.65	295.96	1219.66	992.80	139.47	13.64	**231.56**
1957	12.45	2.97	0.00	4.19	77.15	324.70	275.23	932.54	2645.25	2132.24	310.87	227.12	**578.73**
1958	107.81	36.93	7.36	12.64	4.68	34.36	20.44	66.80	186.94	180.28	69.83	31.34	**63.28**
1959	8.58	2.47	2.70	20.51	31.77	32.99	233.95	410.42	1758.95	1297.16	77.87	37.09	**326.21**
1960	26.01	20.11	16.72	20.34	28.16	59.67	216.22	403.38	1646.70	1774.40	132.62	45.88	**365.85**
1961	29.08	21.61	17.35	19.39	28.24	67.13	325.34	407.80	971.47	571.80	53.19	28.45	**211.74**
1962	21.23	18.27	13.07	15.83	31.25	156.84	312.74	1009.41	2809.01	1896.87	192.26	63.73	**545.04**
1963	34.69	26.49	24.56	0.87	43.99	34.34	498.75	1372.40	2943.81	1644.39	358.17	44.72	**585.60**
1964	12.08	4.18	1.15	4.35	7.58	16.76	110.99	515.85	1760.29	1441.90	117.17	18.29	**334.22**
1965	10.69	36.21	30.08	29.80	42.53	67.85	157.27	451.35	1054.00	397.09	34.88	2.04	**192.82**
1966	19.93	16.31	12.54	11.55	21.61	79.84	119.90	581.12	1150.87	871.65	188.23	27.17	**258.39**
1967	4.99	0.31	15.50	21.29	22.16	55.99	142.20	1029.94	1493.91	1056.86	481.57	51.38	**364.67**
1968	32.94	25.82	29.39	20.15	68.95	201.07	774.51	1452.81	1790.29	871.03	252.67	55.57	**464.60**
1969	0.00	31.11	24.35	37.56	45.14	48.35	254.50	583.74	2658.28	1604.62	303.26	51.50	**470.20**
1970	42.90	10.52	24.05	18.21	26.24	29.36	66.34	737.31	2827.98	1692.53	101.41	24.67	**466.79**
1971	29.23	23.45	3.75	26.81	26.81	41.12	268.85	1144.03	2269.55	452.08	42.20	16.30	**362.01**
1972	28.01	21.46	16.23	18.22	35.35	61.02	142.42	352.41	1237.30	901.08	72.32	22.86	**242.39**
1973	17.47	15.53	7.99	7.37	11.61	26.41	52.37	721.92	1094.69	450.84	0.00	30.04	**203.02**
1974	22.46	17.95	14.97	12.58	21.91	54.42	181.35	859.54	1924.56	942.64	365.72	55.64	**372.81**
1975	33.86	25.00	19.28	24.45	42.70	36.15	379.41	655.15	1129.76	949.10	130.22	45.50	**289.21**
1976	27.07	22.29	16.90	14.98	25.88	120.59	176.86	320.27	335.05	536.56	294.58	50.34	**161.78**
1977	27.93	20.38	16.17	13.51	18.23	41.54	80.81	327.00	873.93	267.74	43.63	23.56	**146.20**
1978	18.49	16.31	14.93	20.55	42.78	90.26	357.76	523.66	878.00	321.64	126.70	35.82	**203.91**
1979	24.74	3.01	15.56	13.99	28.66	83.85	326.33	831.57	1973.59	700.10	118.21	51.13	**347.56**
1980	32.34	18.75	14.05	9.76	19.71	41.99	46.04	423.04	1646.08	383.54	86.75	22.82	**228.74**
1981	23.68	19.13	15.44	17.35	37.80	58.30	169.65	948.16	1001.38	376.85	53.99	25.42	**228.93**
1982	18.90	16.44	15.92	11.88	29.86	36.89	87.53	166.07	342.82	334.57	96.00	29.06	**98.83**
1983	19.57	15.39	11.15	12.46	12.69	45.12	171.24	222.64	439.13	182.04	32.09	0.00	**96.96**
1984	0.00	10.06	10.41	13.69	30.14	45.45	50.55	174.78	362.20	286.65	41.72	18.55	**87.02**
1985	13.37	9.93	8.05	3.95	14.91	27.00	174.24	855.10	906.21	565.61	48.66	22.49	**220.79**
1986	14.62	2.30	1.10	2.40	3.85	20.32	84.54	408.63	1116.56	348.61	81.54	14.99	**174.95**
1987	19.54	2.82	1.28	0.81	0.00	28.91	143.33	396.35	1438.41	505.40	51.18	12.31	**216.69**
1988	4.95	2.27	10.84	9.64	15.68	51.36	188.46	490.03	2154.05	671.77	115.35	0.00	**309.53**
1989	5.44	18.13	17.64	14.62	18.47	39.58	225.10	1013.20	2303.52	918.23	84.55	40.20	**391.56**
1990	28.32	32.55	20.12	29.43	31.43	43.00	154.35	555.03	694.29	584.20	73.87	32.12	**189.89**
1991	23.19	0.00	20.11	19.16	57.77	188.84	686.95	996.45	1703.65	1364.45	398.62	213.78	**472.75**
1992	31.75	24.06	33.27	40.29	55.75	77.68	187.92	353.52	690.09	304.99	60.33	21.39	**156.75**
1993	29.06	21.02	34.45	38.23	44.60	46.49	149.92	1155.98	1613.57	354.60	83.85	29.95	**300.14**
1994	12.67	12.03	11.68	22.66	37.63	85.28	190.19	1304.81	2180.81	2317.37	422.48	70.31	**555.66**
1995	35.89	32.66	41.20	61.37	57.72	60.73	158.47	1289.99	1661.89	1003.43	166.38	60.88	**385.88**
1996	66.28	69.18	42.19	25.12	55.23	152.46	186.66	801.76	2459.95	1191.88	206.46	52.38	**442.46**
1997	31.01	19.23	17.89	37.39	91.16	120.11	307.55	715.81	1668.31	690.87	123.70	42.61	**322.14**
1998	18.36	24.93	20.36	28.58	56.12	200.89	506.68	1122.72	2509.10	2299.30	424.02	105.36	**609.70**
1999	64.45	59.46	41.98	46.80	46.51	58.36	150.60	956.51	3271.17	1349.80	23.21	0.00	**505.74**
2000	42.81	41.63	51.35	50.87	52.11	76.28	160.20	1090.72	1277.51	1202.13	96.31	50.45	**349.36**
2001	30.68	34.39	34.44	42.02	49.67	61.80	152.76	756.96	1973.54	919.63	64.46	32.30	**346.05**
2002	0.00	0.00	29.59	34.88	31.47	31.02	98.13	426.58	1084.75	841.31	115.27	0.00	**224.42**
2003	23.66	28.11	23.35	34.64	28.77	149.22	283.11	890.13	2525.93	1682.77	197.53	51.37	**493.22**
2004	25.19	16.29	25.26	41.46	39.93	37.25	376.22	1124.03	2144.50	539.25	137.82	39.64	**378.90**
2005	40.96	40.30	35.23	36.17	37.83	122.74	497.49	758.05	1358.11	945.11	91.83	40.94	**333.73**
MEAN	24.33	19.09	17.69	20.33	32.71	78.74	234.03	720.58	1602.06	951.92	154.82	40.93	**326.40**
Max	107.81	69.18	51.35	61.37	91.16	338.71	774.51	1850.23	3271.17	2317.37	548.96	227.12	**664.99**
Min	0.00	0.00	0.00	0.00	0.00	16.76	20.44	66.80	186.94	180.28	0.00	0.00	**63.28**
SD	18.47	14.71	12.32	14.48	19.31	68.71	168.17	382.07	768.60	585.84	129.56	41.03	
CV	**0.76**	**0.77**	**0.70**	**0.71**	**0.59**	**0.87**	**0.72**	**0.53**	**0.48**	**0.62**	**0.84**	**1.00**	

Table 3.1. 7: Yagaba (White Volta) - Completed mean monthly flows in m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1957			0.00	0.00	4.84	36.19	46.05	88.96	248.25	149.72	13.98	0.00	
1958	0.00	0.23	0.66	0.56	1.33	2.29	0.79	1.01	50.26	23.43	0.73	0.27	**6.80**
1959	0.00	0.00	0.05	1.13	0.22	3.30	8.68	10.63	138.34	13.22	0.96	0.37	**14.74**
1960	0.00	0.00	0.00	0.00	0.00	1.12	7.91	87.60	250.40	52.88	3.78	1.04	**33.73**
1961	0.19	0.40	0.00	0.00	0.00	0.56	33.49	119.51	188.55	78.24	0.00	0.00	**35.08**
1962	0.00	0.00	0.00	0.12	1.57	2.32	8.27	54.80	312.04	19.67	7.10	1.42	**33.94**
1963	0.38	0.12	0.18	0.08	0.32	0.56	15.89	350.92	548.09	365.14	212.38	0.00	**124.50**
1964	0.00	0.00	0.00	4.61	5.51	4.38	3.81	16.74	182.41	33.45	4.80	2.02	**21.48**
1965	1.47	3.11	0.58	0.63	0.49	8.58	58.66	227.29	464.18	51.44	3.77	2.17	**68.53**
1966	1.40	1.02	0.48	0.98	3.54	1.10	1.76	95.77	90.27	61.48	2.41	0.45	**21.72**
1967	0.54	0.47	0.36	0.00	0.43	0.00	2.98	8.86	186.64	22.55	3.55	0.00	**18.87**
1968	0.47	0.34	0.13	1.65	1.56	14.14	136.81	196.76	243.78	41.95	0.69	3.67	**53.50**
1969	1.64	0.00	0.35	1.15	0.67	0.63	19.66	150.88	268.95	67.96	6.84	0.00	**43.23**
1970	0.00	0.00	0.00	0.00	0.21	0.25	1.64	73.30	207.61	23.53	2.27	0.62	**25.78**
1971	0.00	0.12	0.05	0.23	0.16	0.34	4.41	123.01	243.78	23.64	3.49	0.95	**33.35**
1972	0.36	0.00	0.04	0.02	0.29	2.55	2.92	12.44	15.08	6.40	0.81	0.08	**3.41**
1973	0.01	0.00	0.00	0.00	0.00	2.43	0.82	7.42	32.54	7.83	0.00	0.00	**4.25**
1974	0.00	0.00	0.00	0.00	0.00	0.00	29.03	73.65	239.85	105.19	3.34	0.00	**37.59**
1975	0.00	0.00	0.00	0.00	0.00	0.50	19.14	52.12	149.91	79.64	0.09	0.00	**25.12**
1976	0.00	0.00	0.00	0.00	0.00	0.00	8.29	29.29	26.88	34.74	19.25	0.00	**9.87**
1977	0.00	0.00	0.00	0.00	0.08	1.05	14.76	35.57	159.89	30.41	0.00	0.00	**20.15**
1978	0.00	0.00	0.00	0.00	0.08	1.05	14.67	12.75	88.77	13.39	1.29	0.42	**11.04**
1979	0.11	0.02	0.00	0.00	13.28	10.98	89.07	95.40	226.51	71.21	4.46	0.00	**42.59**
1980	0.00	0.00	0.00	0.00	0.00	0.13	6.66	95.16	221.53	26.83	4.03	0.00	**29.53**
1981	0.00	0.00	12.71	12.71	12.71	12.71	16.65	73.17	12.71	12.71	12.71	12.71	**15.96**
1982	12.71	12.71	0.00	12.71	12.71	26.47	27.17	48.15	47.19	14.60	12.83	12.71	**19.99**
1983	12.71	0.00	0.00	12.71	15.33	53.71	8.67	12.71	56.88	12.71	12.71	12.71	**17.57**
1984	12.71	12.71	12.71	0.00	0.00	3.96	4.42	22.71	25.06	25.30	0.00	0.00	**9.96**
1985	0.00	0.00	0.00	0.00	0.00	1.23	64.37	167.23	37.98	13.71	12.71	12.71	**25.83**
1986	12.71	12.71	12.71	0.00	0.00	2.59	25.25	89.22	138.75	51.88	4.99	0.00	**29.23**
1987	0.00	0.00	0.00	0.00	0.00	6.24	19.53	126.38	161.73	39.50	4.31	0.00	**29.81**
1988	0.00	0.00	0.00	0.00	0.00	0.00	24.60	98.19	222.56	106.01	7.68	3.02	**38.51**
1989	1.00	0.00	0.00	0.00	0.00	3.32	61.43	181.76	301.69	177.66	12.40	3.07	**61.86**
1990	1.03	0.00	0.00	0.00	0.00	3.36	20.48	66.43	53.29	12.71	12.71	12.71	**15.23**
1991	0.00	12.71	0.00	0.00	3.92	0.18	11.79	191.42	272.13	8.39	0.00	0.00	**41.71**
1992	0.00	0.00	0.00	0.00	0.00	0.43	19.30	86.14	32.26	0.01	0.00	0.00	**11.51**
1993	0.00	0.00	0.00	0.00	0.00	0.00	3.46	124.53	231.06	51.85	6.13	1.52	**34.88**
1994	0.00	0.00	0.00	1.93	3.87	7.14	16.53	114.11	319.32	213.16	41.94	7.35	**60.45**
1995	4.92	2.10	5.31	5.36	5.78	10.16	16.13	140.82	97.48	43.54	3.26	0.00	**27.91**
1996	0.86	0.00	1.03	0.10	2.11	16.73	0.00	56.86	224.27	115.58	30.08	2.66	**37.52**
1997	2.27	1.87	2.74	1.85	3.81	15.21	11.84	28.23	63.43	55.22	37.85	1.47	**18.82**
1998	0.00	0.00	0.00	0.00	4.73	12.20	16.39	95.32	131.56	101.69	16.73	5.79	**32.03**
1999	5.68	6.40	5.82	6.82	7.91	10.10	39.10	214.79	333.16	216.37	23.31	7.47	**73.08**
2000	5.66	4.63	4.49	6.46	5.92	20.18	86.14	152.10	156.54	103.15	45.80	34.37	**52.12**
2001	0.00	0.00	0.00	0.00	0.00	12.71	8.85	43.86	237.91	70.36	5.09	2.00	**31.73**
2002	12.71	3.04	3.64	4.27	2.80	0.00	1.57	4.80	79.19	38.14	11.30	4.43	**13.82**
2003	2.46	2.66	0.00	0.00	0.00	10.75	39.50	272.17	279.01	141.73	55.91	14.26	**68.20**
2004	20.84	1.68	1.15	1.28	2.47	14.83	48.42	137.19	75.88	10.69	3.50	0.87	**26.57**

2005	0.07	0.00	0.00	0.00	0.35	1.64	11.90	20.05	86.44	15.27	1.53	0.26	**11.46**
2006	0.00	0.00	0.00	0.00	0.00								
Mean	**2.34**	**1.61**	**1.33**	**1.58**	**2.33**	**6.34**	**22.78**	**93.73**	**171.12**	**60.54**	**13.78**	**3.45**	**31.76**
SD	**4.79**	**3.62**	**3.27**	**3.36**	**3.94**	**9.43**	**27.12**	**76.61**	**117.74**	**68.15**	**31.96**	**6.27**	**22.03**
Cv	**2.04**	**2.24**	**2.46**	**2.13**	**1.69**	**1.49**	**1.19**	**0.82**	**0.69**	**1.13**	**2.32**	**1.82**	**0.69**

Table 3.1. 8: Nakong (White Volta) - Completed mean monthly flows in m^3/s

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
1966	0.18	0.12	0.09	0.05	5.84	4.09	7.84	28.91	20.95	10.44	1.83	0.36	**6.72**
1967	0.20	0.11	0.06	0.06	0.08	0.77	2.72	21.43	40.26	11.41	1.10	0.33	**6.54**
1968	0.13	0.02	0.07	1.33	2.60	3.10	14.88	13.34	7.84	1.69	0.67	0.38	**3.84**
1969	0.17	0.10	0.00	0.00	0.57	1.00	17.84	27.09	78.02	28.18	5.40	0.38	**13.23**
1970	0.00	0.00	0.33	0.35	1.03	1.37	0.35	21.78	27.97	6.47	0.11	0.59	**5.03**
1971	0.31	0.17	0.09	0.10	0.15	0.80	6.09	49.79	64.71	11.28	1.30	0.08	**11.24**
1972	0.00	0.21	0.00	0.00	0.33	1.47	5.32	9.58	6.60	0.32	0.00	0.00	**1.99**
1973	0.00	0.00	0.00	0.00	0.00	5.56	9.81	45.99	7.80	2.21	0.00	0.00	**5.95**
1974	0.00	0.00	0.00	0.00	0.00	0.00	21.12	43.21	35.67	9.01	0.80	0.00	**9.15**
1975	0.00	0.00	0.00	0.00	0.00	0.00	8.60	18.87	42.98	3.91	0.07	0.00	**6.20**
1976	0.00	0.00	3.37	3.37	3.37	3.66	26.08	4.64	2.34	12.07	2.83	3.37	**5.42**
1977	3.37	3.37	0.00	0.00	0.00	0.00	15.11	56.29	47.88	5.34	3.45	3.37	**11.52**
1978	3.37	3.37	3.37	3.37	3.37	4.78	20.04	1.50	1.59	0.32	3.37	3.37	**4.32**
1979	3.37	3.37	3.37	0.00	1.09	6.35	21.14	18.90	12.36	5.50	3.38	3.37	**6.85**
1980	3.37	3.37	3.37	3.37	3.37	1.78	10.93	22.36	16.91	3.70	3.37	3.37	**6.61**
1981	3.37	3.37	3.37	3.37	3.37	3.37	5.03	33.85	28.83	3.73	3.37	3.37	**8.20**
1982	3.37	3.37	3.37	1.45	3.08	6.50	6.66	0.00	11.21	3.80	3.40	3.37	**4.13**
1983	3.37	3.37	3.37	3.37	3.97	12.69	13.88	4.51	3.58	3.39	3.37	3.37	**5.19**
1984	3.37	3.37	3.37	3.37	4.12	4.28	18.21	7.52	5.72	4.01	3.37	3.37	**5.34**
1985	3.37	3.37	3.37	3.37	4.69	6.68	31.64	29.62	9.11	3.60	3.37	3.37	**8.80**
1986	3.37	3.37	3.37	3.81	6.49	15.32	11.24	21.90	53.56	4.10	3.37	3.37	**11.11**
1987	3.37	3.37	3.37	3.37	3.37	7.85	10.23	25.87	8.39	3.97	3.37	3.37	**6.66**
1988	3.37	3.37	3.37	3.37	3.37	6.45	5.39	12.51	19.69	3.38	3.05	3.37	**5.89**
1989	3.37	3.37	3.37	3.37	3.37	3.38	20.49	19.66	12.51	4.56	3.73	3.37	**7.05**
1990	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	**3.37**
1991	3.37	3.37	3.37	3.37	3.37	7.16	5.40	47.06	20.56	15.72	3.37	3.37	**9.96**
1992	3.37	3.37	3.37	3.37	3.37	9.66	7.38	5.85	29.18	3.37	3.37	3.37	**6.59**
1993	3.37	3.37	3.37	3.37	3.37	3.39	12.90	28.84	13.09	3.42	3.37	3.37	**7.10**
1994	3.37	3.37	3.37	3.37	3.37	5.35	33.81	75.95	78.48	19.77	6.88	3.37	**20.04**
1995	3.37	3.37	3.37	3.37	5.84	5.91	4.92	9.94	43.06	10.97	3.37	3.37	**8.41**
1996	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	**3.37**
1997	3.37	3.37	3.37	6.49	6.65	8.36	13.95	21.10	22.91	6.15	3.61	3.37	**8.56**
1998	3.37	3.37	3.37	3.37	3.37	3.37	4.98	16.41	36.57	35.41	3.37	3.37	**10.03**
1999	3.37	3.37	3.37	3.37	3.37	3.37	40.56	45.98	64.76	9.47	6.29	3.37	**15.89**
2000	3.37	3.37	3.37	3.37	3.37	3.37	10.88	18.38	11.82	6.33	2.67	3.37	**6.14**
2001	3.37	3.37	3.37	3.37	3.37	7.09	16.08	13.41	53.86	16.89	3.37	3.37	**10.91**
2002	3.37	3.37	3.37	3.37	3.37	8.50	5.42	40.16	17.77	10.00	0.03	0.00	**8.23**
2003	0.00	0.00	0.00	0.00	2.37	12.75	40.04	52.59	90.18	17.82	0.85	0.00	**18.05**
2004	0.00	0.00	0.00	0.00	1.54	6.43	16.91	46.87	34.58	7.78	0.00	0.00	**9.51**
2005	0.00	0.00	0.00	0.00	0.06	2.95	8.39	9.18	31.51	0.79	0.24	0.00	**4.43**

Mean	**2.16**	**2.16**	**2.15**	**2.15**	**2.71**	**4.86**	**13.47**	**24.44**	**28.04**	**7.92**	**2.64**	**2.25**	**7.94**
SD	**1.60**	**1.60**	**1.61**	**1.74**	**1.84**	**3.56**	**9.94**	**17.91**	**23.47**	**7.40**	**1.71**	**1.56**	**3.87**
Cv	**0.74**	**0.74**	**0.75**	**0.81**	**0.68**	**0.73**	**0.74**	**0.73**	**0.84**	**0.93**	**0.65**	**0.70**	**0.49**

Table 3.1. 9: Yarugu (White Volta) - Completed mean monthly flows in m^3/s

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
1963	3.57	54.34	0.00	0.00	14.69	50.03	172.00	757.21	218.83	36.04	4.76	0.43	**109.33**
1964	0.00	0.00	0.00	0.00	55.76	51.82	1051.99	920.92	323.38	47.58	1.17	0.00	**204.39**
1965	0.00	0.00	0.00	2.87	3.84	45.54	74.00	503.24	248.28	115.01	19.14	2.86	**84.56**
1966	0.18	0.00	0.00	0.00	17.39	57.69	32.92	147.50	175.31	52.99	1.81	0.20	**40.50**
1967	0.00	0.00	0.00	0.00	0.00	5.78	56.68	571.60	517.60	90.59	8.23	1.67	**104.34**
1968	0.07	0.00	5.33	3.23	33.31	113.72	227.15	100.56	122.08	14.14	1.49	2.66	**51.98**
1969	0.65	0.00	0.00	5.41	16.93	9.93	46.90	291.13	624.34	44.26	8.06	1.61	**87.43**
1970	0.08	0.00	0.51	1.32	2.01	10.42	87.04	93.82	459.73	5.49	3.25	0.95	**55.38**
1971	0.46	0.49	1.04	0.67	10.22	11.57	108.01	264.21	403.27	56.18	3.99	0.36	**71.71**
1972	0.07	0.00	0.00	6.49	13.25	14.48	81.04	176.26	97.36	15.12	0.52	0.38	**33.75**
1973	0.22	0.00	0.00	0.00	1.96	47.66	84.01	97.89	127.22	16.90	1.78	0.00	**31.47**
1974	0.00	0.00	6.22	6.27	11.05	12.45	71.07	463.45	531.64	242.65	7.62	2.64	**112.92**
1975	0.75	0.27	0.10	0.03	10.05	2.72	184.32	244.50	707.28	50.04	5.83	1.78	**100.64**
1976	0.56	0.14	0.00	0.00	31.13	1.51	47.72	121.87	93.59	32.51	14.34	1.02	**28.70**
1977	0.00	0.00	6.10	6.23	5.43	5.68	8.96	481.30	145.16	31.87	6.97	6.16	**58.65**
1978	6.22	6.34	6.36	6.30	41.71	50.61	84.74	114.55	108.91	32.81	13.28	6.06	**39.82**
1979	6.24	6.32	6.38	6.41	5.09	51.40	91.40	219.96	523.57	163.95	9.38	5.57	**91.31**
1980	6.00	6.19	6.30	6.34	6.03	32.78	76.75	269.48	676.34	61.19	8.39	5.46	**96.77**
1981	5.88	6.18	6.12	6.01	4.35	18.40	37.62	168.50	464.12	150.62	32.92	4.92	**75.47**
1982	5.87	5.95	6.32	6.08	5.57	4.49	4.57	25.30	74.71	256.68	108.07	17.65	**43.44**
1983	5.01	6.23	6.30	5.83	6.18	5.64	19.14	87.21	130.76	275.67	68.79	5.27	**51.84**
1984	6.10	6.26	6.31	6.31	5.86	8.24	9.30	51.65	57.08	57.65	5.03	5.95	**18.81**
1985	6.20	6.32	6.37	6.39	6.30	4.44	148.12	386.31	5.99	178.23	9.13	5.27	**64.09**
1986	6.29	6.37	6.16	6.24	6.17	5.06	57.54	205.67	320.35	119.19	10.61	5.29	**62.91**
1987	5.79	5.99	6.11	6.11	6.18	13.52	44.29	291.70	373.55	90.54	3.64	5.37	**71.07**
1988	5.87	6.07	6.17	6.21	5.56	6.21	69.91	338.16	498.46	9.46	2.76	6.07	**80.07**
1989	4.50	5.28	5.60	5.68	5.73	25.91	208.87	542.06	250.88	118.89	27.78	6.17	**100.61**
1990	4.50	5.15	5.54	5.69	5.63	22.81	12.29	42.55	3.02	31.92	5.35	5.78	**12.52**
1991	5.84	5.49	5.99	5.46	33.71	164.27	123.82	478.63	690.84	149.70	17.31	4.86	**140.49**
1992	5.42	5.76	5.90	5.74	5.18	5.60	21.72	69.83	290.98	45.94	4.73	5.58	**39.36**
1993	5.88	6.01	6.16	5.61	6.19	11.43	66.25	287.43	52.48	16.30	3.16	4.37	**39.27**
1994	4.93	5.19	5.44	4.26	8.01	15.60	18.25	263.30	718.36	209.58	96.18	16.10	**113.77**
1995	10.46	4.22	11.35	11.48	12.45	22.60	36.42	257.03	436.67	99.89	3.91	4.86	**75.94**
1996	4.54	6.23	25.44	16.80	26.86	86.20	46.13	207.22	237.28	52.22	34.68	27.59	**64.27**
1997	27.87	4.28	5.41	4.28	7.89	34.29	26.47	64.42	145.94	33.08	17.74	26.87	**33.21**
1998	20.85	26.52	27.24	5.21	56.59	85.29	129.58	157.01	368.50	356.36	37.80	12.47	**106.95**
1999	12.22	13.87	12.54	46.82	46.55	50.47	89.60	381.18	406.41	500.09	53.04	16.37	**135.76**
2000	39.67	34.89	47.14	46.03	40.77	52.92	86.21	260.80	90.62	23.19	19.51	9.22	**62.58**
2001	7.26	15.78	17.29	23.50	22.88	36.79	23.23	19.81	549.98	162.00	10.85	4.24	**74.47**
2002	4.91	6.11	7.49	8.95	5.54	54.27	43.73	128.87	87.04	74.03	33.05	31.36	**40.45**
2003	29.49	33.07	36.51	31.53	35.90	53.97	153.48	278.68	500.96	100.47	47.81	31.12	**111.08**
2004	18.65	31.87	34.98	45.93	56.14	71.42	130.53	194.06	159.81	40.27	27.90	15.73	**68.94**
2005	18.21	30.01	27.49	27.52	37.86	105.22	119.57	195.58	216.79	61.71	37.18	33.96	**75.93**

Mean	7.26	8.82	8.95	9.84	17.79	36.16	99.45	260.99	307.80	100.53	19.51	8.19	**73.65**
SD.	8.73	11.93	10.96	12.24	16.63	35.21	158.48	195.01	211.91	102.22	24.30	9.25	**37.26**
Cv	1.20	1.35	1.22	1.24	0.94	0.97	1.59	0.75	0.69	1.02	1.25	1.13	**0.51**

3.1.4 Flow Statistics and water availability scenarios

After the estimation of the missing flows, statistics were computed for each of the stations for the months of January to December for the mean, maximum and extreme flows over the periods of data. The coefficients of variation were also computed. As can be expected of flows in this climatic region, the flows are very variable in the dry season months of November to June, but less variable in the wet season months of July to October.

For the purposes of assessing the feasibility of meeting present and future water demand, under extreme conditions the extremes were determined by dividing the flow data over the periods into percentiles for the months and annuals and defining the:-

i) 10th percentile as Very low flow
ii) 25th " " Low flow
iii) 75th " " High flow
iv) 90th " " Very High flow.

The Water availability scenarios for the various stations are presented in Tables 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.7, 3.2.8 and 3.2.9 for Bui, Bamboi, Pwalugu, Nawuni, Saboba, Sabari, Yagaba, Nankong and Yarugu respectively.

The scenarios for each station are compared in charts 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.7, 3.2.8 and 3.2.9 for Bui, Bamboi, Pwalugu, Nawuni, Saboba, Sabari, Yagaba, Nankong and Yarugu respectively.

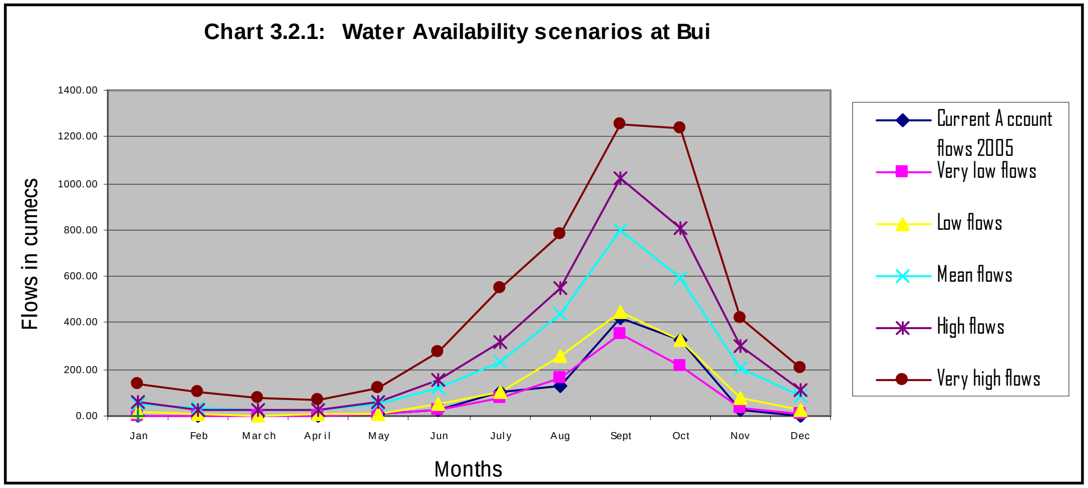
i) Bui

The long-term annual mean over 45 years (1951-2005) at 223.6 **m^3/s** with a coefficient of variation of 0.57%.

Table 3.2. 1: Water Availability scenarios at Bui (m^3/s)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANNUAL
Cur. Act 05	1.74	0.14	0.05	0.30	7.03	28.11	106.11	132.78	419.53	329.02	22.39	3.07	87.52
10%	1.26	0.13	0.21	0.55	7.32	24.03	67.01	159.68	343.38	239.96	43.86	6.92	74.53
25%	14.61	4.547	3.21	4.13	12.74	42.54	101.39	253.28	477.78	325.15	82.16	26.24	112.31
MEAN	49.84	30.75	25.66	24.42	50.08	118.57	226.49	435.84	814.68	601.26	206.12	86.20	223.64
75%	60.68	27.59	23.08	26.65	51.20	154.69	312.32	549.95	1022.69	811.48	302.61	115.47	288.20
90%	132.72	97.17	75.95	70.55	119.65	257.77	511.10	799.20	1290.20	1192.71	401.21	200.48	398.78

Chart 3.2. 1: Water availability scenarios at Bui



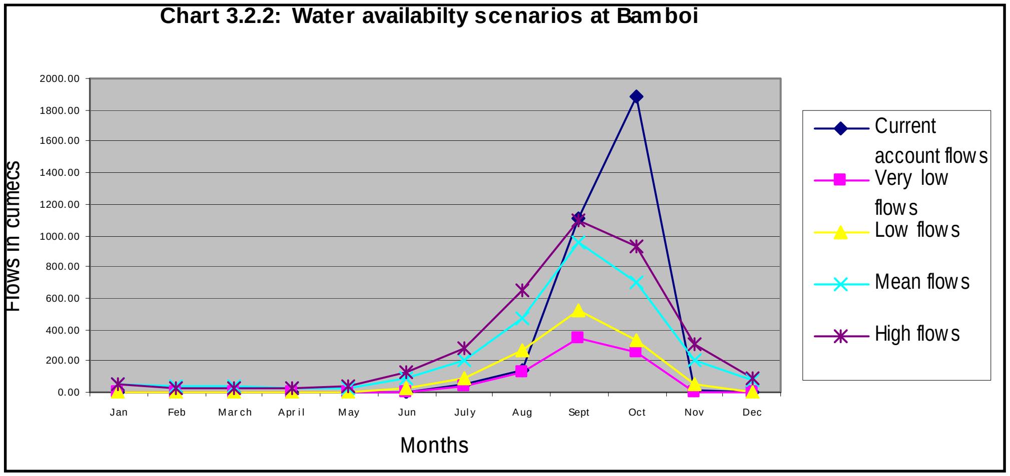
ii) Bamboi

The data completed is over the 45 year period (1951-2005). The annual mean flow over the period is 238.6 **m^3/s** with a coefficient of variation of 0.58.

Table 3.2. 2: Water availability scenarios at Bambio (m^3/s)

	Jan	Feb	March	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	ANNUAL
Cur.act 05	0.00	0.00	0.00	0.00	0.09	5.81	55.32	137.06	1105.13	1885.82	13.47	0.00	266.89
10%	0	0	0	0	0	4.22	41.13	132.68	343.29	255.27	5.21	0.00	65.15
25%	0	0	0	0	0	22.21	84.84	271.28	526.38	332.83	45.17	0	106.89
MEAN	54.18	38.37	36.60	21.38	29.55	90.17	198.13	465.80	959.64	697.69	200.80	75.54	238.61
75%	53.31	30.20	23.20	22.03	36.19	125.19	276.66	644.25	1090.93	924.29	301.55	87.53	301.28
90%	105.73	61.88	40.63	37.21	56.19	213.77	416.08	939.04	1667.24	1425.35	432.36	150.41	392.27

Chart 3.2. 2: Water availability scenarios at Bomboi



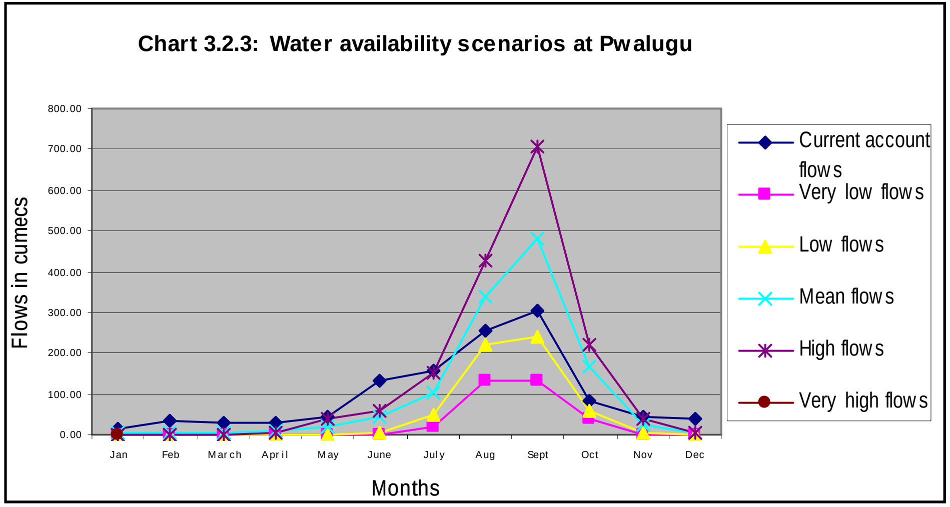
iii) Pwalugu

Data constituted covers the 45 year period (1951-2005). The estimated annual mean over the period is 101.5 **m^3/s** with a coefficient of variation of 0.44.

Table 3.2. 3: Water availability scenarios at Pwalugu- White Volta, m^3/s

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	ANNUAL
Cur.acut.05	16.51	31.92	29.08	28.92	42.02	131.59	155.30	254.38	304.38	82.95	45.62	37.70	96.70
10%	0	0	0	0	0	0	20.07	125.45	132.6	38.40	0	0	26.38
25%	0	0	0	0	0	3.77	46.20	217.64	241.19	61.03	3.737	0	47.80
MEAN	3.49	3.81	4.94	6.10	18.76	38.82	100.22	339.97	485.89	170.33	22.56	5.83	101.54
75%	0.60	0.00	0.06	2.82	31.40	58.47	139.43	434.02	700.54	221.81	34.25	5.07	135.71
90%	14.89	13.16	22.48	20.77	53.77	97.22	204.07	601.90	824.04	345.35	52.54	24.20	165.29

Chart 3.2. 3: Water availability scenarios at Pwalugu



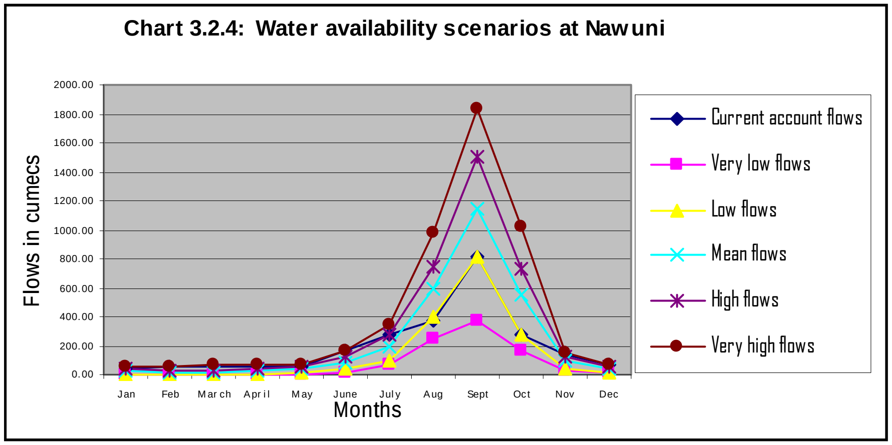
iv) Nawuni

The data completed covers 1951 – 2005. The 45 year mean annual flow is 240.3 **m^3/s** with a coefficient of variation of 0.39.

Table 3.2. 4: Water availability scenarios at Nawuni (m^3/s)

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	ANNUAL
Cur.Act. 05	35.83	50.11	55.68	51.82	56.71	168.40	280.15	368.26	816.99	271.25	141.06	66.77	196.92
10%	5.22	2.77	2.04	1.93	3.81	18.27	70.51	240.46	349.72	167.93	32.45	10.32	75.45
Lower Quartile(25%)	6.32	4.17	3.11	3.13	6.62	34.45	98.84	412.31	856.65	295.74	43.28	13.24	148.15
MEAN	22.31	17.92	17.72	19.76	31.51	86.59	191.30	603.78	1166.45	566.34	88.67	32.64	240.28
Upper Quartile(75%)	35.79	26.51	21.00	27.55	55.20	105.61	255.19	785.49	1513.79	743.93	112.60	50.33	311.08
90%	54.18	52.92	56.18	58.20	69.15	166.25	352.65	987.32	1797.47	993.83	162.76	70.26	384.08

Chart 3.2. 4: Water availability scenarios at Nawuni- White Volta



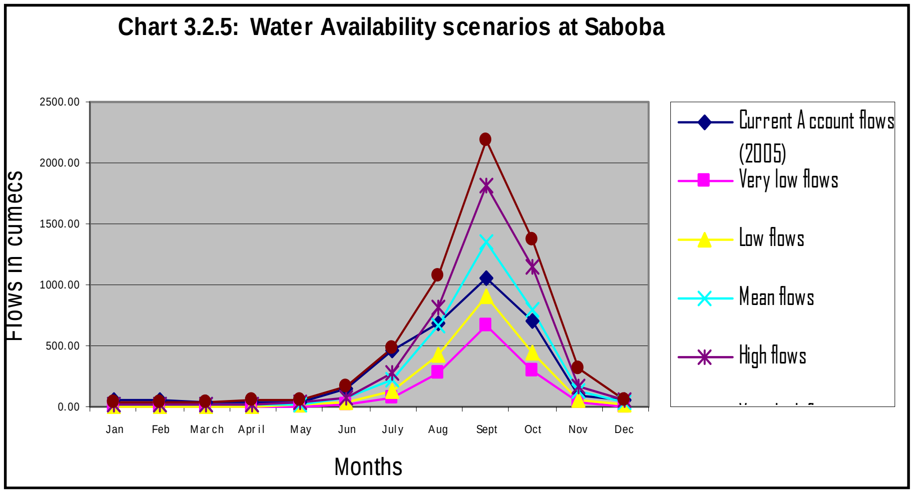
v) Saboba

Data constituted covers 43 years from 1953 to 2005. The long-term mean annual flow is estimated at 278.8 **m^3/s** with a coefficient of variation of 0.45.

Table 3.2. 5: Water availability scenarios at Saboba on Oti River- m^3/s

	Jan	Feb	March	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	ANNUAL
Cur.act 05	47.64	49.15	44.02	32.46	33.87	141.51	459.07	690.89	1057.15	694.93	91.58	48.14	282.53
Low(10%)	3.40	1.75	1.27	1.83	5.54	19.02	69.36	264.41	662.50	298.64	32.53	5.77	113.83
1st Quartile(25%)	5.97	3.80	2.72	3.35	8.70	27.03	122.52	428.10	903.29	431.03	63.17	16.08	167.98
MEAN	16.27	13.02	12.16	15.65	24.70	64.04	212.66	651.37	1352.88	796.87	133.67	36.08	278.84
3rd Quartile(75%)	19.91	19.43	17.14	20.10	36.55	74.17	252.76	819.51	1831.39	1148.26	177.11	42.40	371.56
90%	31.97	32.74	36.14	45.98	54.74	154.58	486.78	1081.34	2225.49	1410.05	311.10	54.19	456.12

Chart 3.2. 5: Water availability scenarios at Saboba on Oti



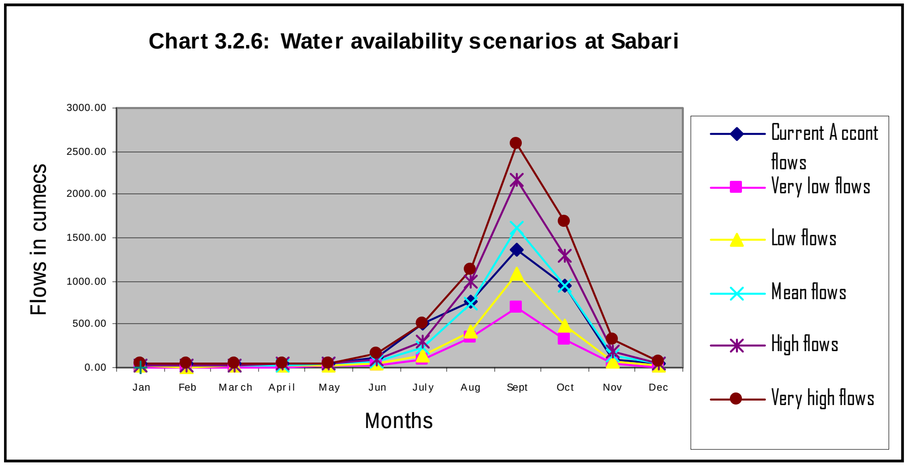
vi) Sabari

The reconstituted flow is from 1953 to 2005 a period of 43 years. The mean annual flow is 326.4 m³/s with a coefficient of variation of 0.46.

Table 3.2. 6: Water availability scenarios at Sabari on Oti River- m³/s

	Jan	Feb	March	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	ANNUAL
Cur. Act.05	40.96	40.30	35.23	36.17	37.83	122.74	497.49	758.05	1358.11	945.11	91.83	40.94	333.73
Low(10%)	4.95	2.27	1.18	2.47	8.39	29.00	79.08	300.82	690.93	324.23	42.49	12.57	124.86
1st Quartile(25%)	12.99	8.49	10.41	11.55	19.38	36.89	142.20	408.63	1054.00	452.08	69.83	22.82	187.44
MEAN	24.33	19.09	17.69	20.33	32.71	78.74	234.03	720.58	1602.06	951.92	154.82	40.93	326.40
3rd Quartile(75%)	30.76	25.20	24.35	29.43	43.99	85.28	307.55	996.45	2180.81	1303.57	192.26	50.45	439.18
90%	40.45	36.03	34.45	39.88	56.04	155.96	498.50	1153.59	2655.67	1758.03	364.21	59.83	543.74

Chart 3.2. 6: Water availability scenarios at Sabari on Oti River



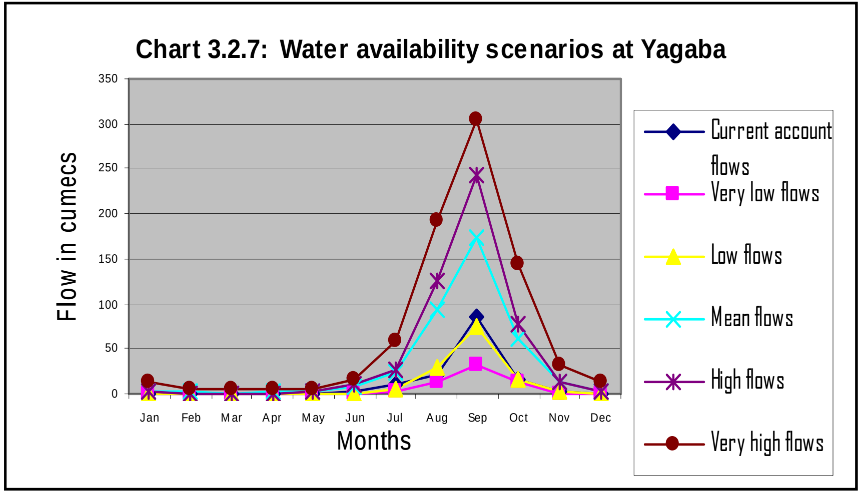
vii) Yagaba

The reconstituted flow is from 1953 to 2005 a period of 43 years. The mean annual flow is 31.8 m^3/s with a co-efficient of variation of 0.69.

Table 3.2. 7: Water availability scenarios at Yagaba on Kulpawn River- m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cur. Act. 2005	0	0	0	0	0.35	1.64	11.90	20.05	86.44	15.27	1.53	0.26	11.46
10%	0	0	0	0	0	0	1.74	12.07	32.49	12.30	0	0	10.71
25%	0	0	0	0	0	0.56	6.66	29.29	75.88	15.27	1.53	0	17.17
Mean	2.39	1.65	1.33	1.58	2.43	6.94	23.26	93.64	172.69	62.36	13.79	3.38	31.76
75%	1.51	1.19	0.48	1.15	3.81	10.75	27.17	126.38	243.78	78.24	12.71	3.07	37.82
90%	12.71	5.16	4.65	5.58	6.32	15.52	59.22	192.49	303.76	143.33	31.63	12.71	60.87

Chart 3.2. 7: Water availability scenarios at Yagaba on Kulpawn River



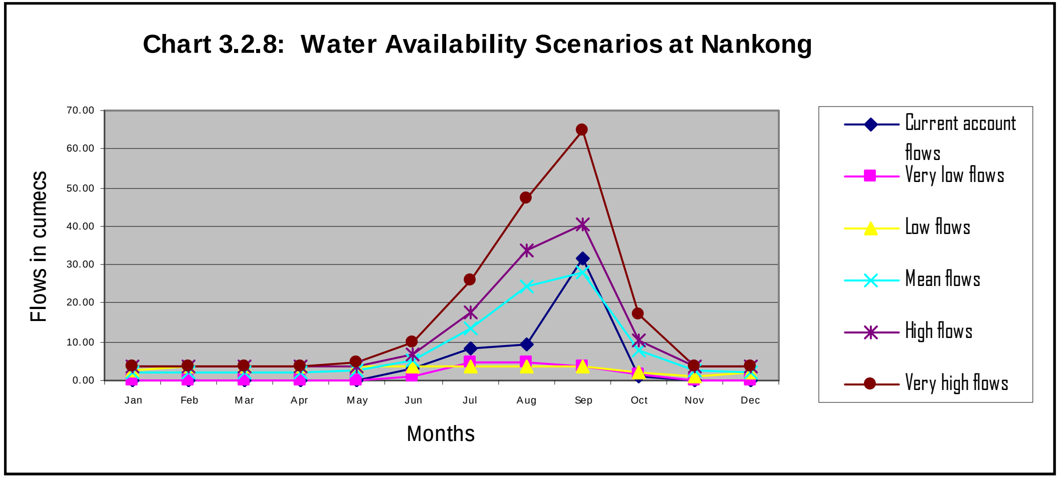
viii) Nakong

The reconstituted flow is from 1953 to 2005 a period of 43 years. The mean annual flow is 7.9 m^3/s with a coefficient of variation of 0.49.

Table 3.2. 8: Water availability scenarios at Nakong on Sissili River- m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cur. Act. 2005	**0.00**	**0**	**0**	**0**	**0.06**	**2.95**	**8.39**	**9.18**	**31.51**	**0.79**	**0.24**	**0**	**4.43**
10%	**0**	**0**	**0**	**0**	**0.06**	**0.80**	**4.92**	**4.51**	**3.58**	**1.69**	**0.03**	**0**	**4.10**
25%	**2.43**	**3.37**	**3.37**	**3.37**	**3.37**	**3.37**	**3.37**	**3.37**	**3.37**	**2.21**	**0.96**	**1.99**	**3.37**
Mean	**2.22**	**2.21**	**2.16**	**2.14**	**2.72**	**5.03**	**13.30**	**24.59**	**27.97**	**7.74**	**2.58**	**2.20**	**7.94**
75%	**3.37**	**3.37**	**3.37**	**3.37**	**3.37**	**6.68**	**17.84**	**33.85**	**40.26**	**10.44**	**3.37**	**3.37**	**9.62**
90%	**3.37**	**3.37**	**3.37**	**3.37**	**4.69**	**9.66**	**26.08**	**47.06**	**64.71**	**16.89**	**3.61**	**3.37**	**11.69**

Chart 3.2. 8: Water availability scenarios at Nakong on Sissili River



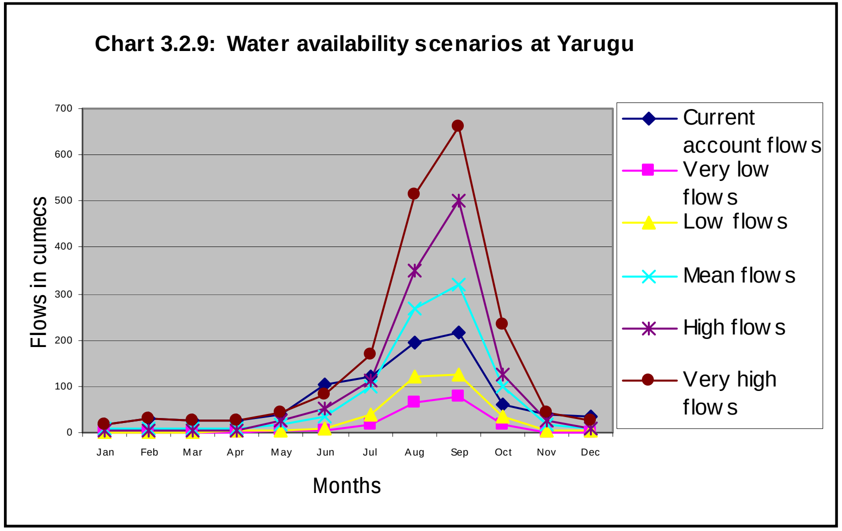
ix) Yarugu

The reconstituted flow is from 1953 to 2005 a period of 43 years. The mean annual flow is 73.7 m^3/s with a coefficient of variation of 0.51.

Table 3.2. 9: Water availability scenarios at Yarugu on White Volta- m^3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Curr. Act. 2005	18.21	30.01	27.49	27.52	37.86	105.22	119.57	195.58	216.79	61.71	37.18	33.96	75.93
10%	0.01	0	0	0	4.00	5.22	18.52	66.05	78.41	16.48	2.09	0.40	33.32
25%	0.51	0.07	0.41	3.14	5.57	9.51	37.32	120.04	125.94	33.01	4.54	2.42	41.97
Mean	6.91	8.45	8.54	9.12	16.82	35.98	99.61	266.92	321.64	99.93	19.27	8.29	73.65
75%	6.23	6.32	6.37	6.39	27.93	51.51	110.90	348.92	499.08	126.82	27.81	10.00	98.69
90%	18.56	29.31	26.70	26.32	41.43	81.13	166.44	516.34	660.74	232.73	44.81	24.10	112.55

Chart 3.2. 9: Water availability scenarios at Yarugu on White Volta



3.2 Groundwater Resources

The groundwater information presented in Table 2.3 under Burkina Faso are applicable to the Ghana portion of the Sub-basins.
However, in Ghana as a result of efforts made since the 1990's to drill wells to provide drinking water for rural communities, small towns and some urban centres in the northern parts of the country (UE, UW and NR regions) many boreholes have been drilled. These were with the assistance of various development partners Prominent among them are CIDA, AfD, World Bank and the World Vision International. Data from these boreholes are being collected for analysis to assess the groundwater resources in the three regions.

This is being carried out under a Hydrogeological Assessment Project for the Water Resources Commission by the Water Research Institute of the Council for Scientific and Industrial Research (CSIR) and CIDA. Preliminary results obtained under the project for the three regions are that:-

Annual abstraction = 40 Mm^3/year
Annual groundwater recharge = 1,500 – 13,000 Mm^3/year
% groundwater abstraction = 0.3 – 3.0%

These will later be disaggregated into sub-basin values.

3.3 Water Quality

3.3.1 Surface Water

The situation about water quality as described for Burkina Faso applies to Ghana. Recent data is that provided by J.M. Goes, in the Pre-Audit study. The results of the field tests are presented in Tables 3.3.1A, 3.3.1B and 3.3.1C. The report stated that in some of the samples, the Ph is a bit low (slightly acidic), but besides that all water samples show, for the tested parameters, values that indicate a very low mineral content. Further, no indication for the presence of biological waste (nitrite, nitrate) was found.

3.3.2 Groundwater quality

Data requested for this section had not been supplied by the time this report had to be finalized.

Table 3.3.1A 1: Results of field water quality tests in Ghana for selected Quality Parameters

No.	Site	Sub-Basin	Country	X-Co-ordinate	Y-Co-ordinate	Date	EC (at 25°C) uS/cm)	Temp. (°C)	NO_3 (mg/l)	NO_2 (mg/l)	Hardness Total (mg/l)	Hardness Carbonate (mg/l)	Ph
1	Bui Bridge	Black Volta	GH	W1° 27.255′	N8° 45.921′	25-6-05	92	29.5	<5	<0.5	<107	<53	6.6
2	Yapei Bridge	White Volta	GH	W1° 09.535′	N9° 08.436′	25-6-05	51	28.1	<5	<0.5	<107	<53	6.5
3	Nabogo Bridge	White Volta (small tributary)	GH	W0° 49.443′	N9° 44..439′	26-6-05	43	27.4	<5	<0.5	<107	<53	~6.4
4	Nasia Bridge	White Volta (Nasia River)	GH	W0° 4.8.224′	N10° 09.315′	26-6-05	55	28.3	<5	<0.5	<107	<53	6.5
5	Pwalugu Bridge	White Volta	GH	W0° 50.499′	N10° 35.140′	26-6-05	57	28.4	<5	<0.5	<107	18-53	~6.4
6	Bolgatanga-Bawku Road (Bridge)	White Volta (Tributary)	GH	W0° 50.295′	N10° 47.200′	26-6-05	73	28.2	<5	<0.5	<107	~53	~6.4
7	Nangodi – Tilli Road (Bridge)	White Volta (Red Volta)	GH	W0° 36.422′	N10° 52.698′	26-6-05	41	28.4	<5	<0.5	<107	~53	~6.4
8	Kobore Bridge (Zebilla-Bawku Road)	White Volta	GH	W0° 23.421′	N10° 58.989′	26-6-05	55	28	<5	<0.5	<107	~53	~6.4
9	Between Bawku & Border (bridge)	White Volta (small tributary to Nouhao)	GH	W0° 12.207′	N10° 07.998′	26-6-05	114	30.9	<5	<0.5	<107	53-71	26.4

Source: J.M. Goes Pre-Audit Report 2005

Table 3.3.1B 1: Some observation on the Sites and Sources of Data

NO.	SOURCE	OBSERVATION
1	Pre-Audit Study	
2	Pre-Audit Study	
3	Pre-Audit Study	Stage Board
4	Pre-Audit Study	Automatic water-level recorder, meteo-station
5	Pre-Audit Study	Old automatic water-level recorder, diver, meteo-station (GLOWA)
6	Pre-Audit Study	River coming from urban area
7	Pre-Audit Study	
8	Pre-Audit Study	Old automatic water-level recorder, water level: 73 cm
9	Pre-Audit Study	

Source: J.M. Goes Pre-Audit Report 2005

Table 3.3.1C: 1Water Water Quality Parameters Tested for the Pre-Audit

Water Quality Parameter ***	Explanation	Results of Field Tests	Accepted Limits
Electrical Conductivity (EC)**	Indication for the amount of ions in the water	21 tot 114 µS/cm	750 to 1500 µS/cm
pH	Acidity of the water, 7 is neutral	6.4 to 6.6	6.5-8.5 (WHO)
Nitrite (NO_2)	Indicates the presence of biological waste such as manure, nitrite is broken down by bacteria into nitrate.	<0.5 mg/1	0 mg/1 (WHO) 0.5 mg/1 (EU)
Nitrite (NO_3)	Indicates the presence of biological waste such as manure	< 5mg/1	10 mg/1 (WHO) 50 mg/1 (EU)
Total Hardness	Sum of ions which can precipitate as 'hard particles', calcium, magnesium and sometimes iron.	<107 mg/1	
Carbonate ($CaCO_3$) Hardness	Sum of calcium ions which can precipitate as 'hard particles', influences pH and CO_2.	<53 to 107 mg/1	500 mg/1 (WHO)

* *or roughly 500 to 1000 mg/l Total Dissolved Solids*
** *measured with an EC meter from Hanna Instruments (USA)*
*** *measured with test strips from eSHA (The Netherlands)*

Source: J.M. Goes (July 2005): Pre-Audit Report for PAGEV Project

3.4 Climate Change Impact on Water Resources

Available potential water resources in the basin may be a limiting factor for development. Hence, the assessment of impacts of climate change on the water resources of the basin is crucial for its socio-economic development.

Climate change is a global phenomenon associated with emission of greenhouse gasses into the atmosphere with the resultant effect of rising mean temperatures. The emissions are associated with human activities such as burning of fossil fuels.

Assessment of impact of climate change on water resources of Burkina Faso and Ghana including the Volta River basin were carried out in 2001 as preliminary studies for the preparation of Burkina Faso and Ghana National communications for the United Nations Framework Convention on Climate Change. In carrying out the water audit in the Volta basin including assessment of impacts of climate change on water resources, the results of the studies in the two countries were used.

In Burkina Faso, the climate predictions were based on numeral experimental model of the Meteorological Research Institute of the Japanese Meteorological Agency. (viz General Circulation Models of the Ocean and Atmosphere developed by the Institute). The predictions were based on transient concentrations of CO_2 in the atmosphere at the rate of 0.5% per year and secondly on a stationery or constant concentration of CO_2 in the atmosphere. These predicted rainfall in Ouagadougou of 730 ±182 mm for the transient CO_2 concentration and 750 ± 182 mm for the constant CO_2 concentration in year 2025. The predicted rainfall without climate change in Ouagadougou in 2025 would be 650 mm. The hydrological consequence is that rainfall could increase to 730 + 182 = 912 mm or decrease to 703 – 182 = 548 mm. On the basis that there are no significant differences in the two scenarios. Water Demand in Ouagadougou in 2025 is projected to 39 million m^3. Consequently:-

i) without climate change only 26% of the demand can be met.
ii) with climate change resulting in increased rainfall, 61.3% of the demand can be met.
iii) with climate change resulting in decreased rainfall only 12.3% of the demand can be met.

In the case of Ghana, the predictions of rainfall were based on General Circulation Models (GCMs) developed by the European Centre-Hamburg Model and the Commonwealth Scientific and Industrial Research Organisation model. A climate change model for the assessment of Greenhouse Gas Induced Climate Change generated the inputs changes in temperature into the GCM models which then predicted the resulting rainfalls. To predict the resulting runoff, a water balance model WATBAL was used. The results of the simulation studies shows that, for 1°C rise in temperature due to Greenhouse gases would lead to 10% to 23% change in rainfall, while a 10% change in rainfall at constant temperature would lead to 10% to 22% change in runoff. The forecasts for Ghana shows that runoff could be expected to reduced by 16% in year 2020 and by 37% in year 2050 over the base period of 1961 to 1990.

Combining the results of the two studies for the water audit, it is recommended that since Ghana covered a wider area of the White Volta basin and the results more general, the coping measures or mechanisms be developed to deal with a reduction of runoff by 16% by 2020 and 37% by year 2050 over the 1961-1990 base period.

The summary of the study reports for the two countries are presented in Annexes 3.5.1 and 3.5.2 for Burkina Faso and Ghana respectively.

4. CURRENT AND PROJECTED WATER DEMANDS

The water demand covers domestic and industrial water supply, irrigation, livestock watering and environmental needs and hydropower generation. The demands are based on population per capita water demand which account for various population activities, crops and sizes irrigated land water consumption for animals, reservoir storage and head on turbines, etc.

4.1 Burkina Faso

The rate of water used for various categories of consumers, (domestic, irrigation livestock, etc.) is presented in Annex 4.1.1 to be provided. The population projection for areas served by ONEA are presented in Table 4.1.1A and the water demand for projection for areas served by ONEA is presented in Table 4.1.1B. The status of water and sanitation coverage (2003) for the major towns is presented in Table 4.1.2. The water demand by sub-basins is presented in Table 4.1.3A. The summary of projected water demand to 2010 is presented in Table 4.1.3B. The major towns are shown in Map 3.

The locations of existing dams for various purposes are shown in Map 3 and the information about the dams are presented in Annex 4.1.2. With regard to planned dams/reservoir these are shown in Map 4 and the information about them in Annex 4.1.3.

Irrigation and Hydropower at Bagré

Information about irrigation and hydropower at Bagré are presented in Tables 4.1.4A and 4.1.4B.

Irrigation at Bagré

Past and projected areas to be brought under irrigation.

Table 4.1.4A 1Projected area to be irrigated at Bagré

Year	Area to be irrigated
2005	1,800
2015	7,400
2020	13,000
2030	30,000

Hydropower generation at Bagré

In addition to irrigation, the Bagré dam is also used to generate electricity. The following table shows the discharge of water and for power generation, the plant factor, the generating efficiency and the tail water level as a function of turbine flow.

Table 4.1.4B 1Hydropower information at Bagré Dam

i) Minimum and maximum turbine flows (per turbine)

Hauteur de chute (m)	Minimum Power (kW)	Minimum flow (m³/s)	Maximum Power (kW)	Maximum Flow (m³/s)
*25,5	2240	14,89	8360	35,73
22	2190	16,41	7980	40
20	2880	16,37	7190	40
*16	2120	15,5	5300	37,8

ii) Plant factor (%) of each month that hydropower plant is ran): 2006

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plant factor (%)	95.9	95.7	95,4	96,1	96.0	96.1	96.0	96.7	95.6	96.7	96.6	96.3

Generating efficiency (electricity generated divided hydropower input): 8,1/8,36 = 0,968

iii) Tail water elevation as a function of turbine discharge

Turbine Discharge (m³/sec)	0	20	40	60	80
Downstream Level (m)	207,6	208,5	209	209,35	209,70

4.2 Ghana

Population and Water Demand Projections

Population and water demand projections for settlements depending on surface water systems. Population figures were obtained from the 2000 population census data of the Ghana Statistical Service (GSS). Growth rates were computed and compared with those adopted for various population sizes as provided by the Strategic Investment Programme (SIP) for the Regions as presented in Annex 4.2.2. It was decided to use the SIP figures. The population sizes for the various settlements served by the systems were projected from 2005 to 2030. The systems and the basins in which they are located are shown in Annex 4.2.1 and in Map 3.

Using the per capita consumption (l/c/d) for the listed population sizes adopted by the SIP, the water demand from the year 2005 to 2030 were projected. The per capita consumption rates are shown in Annex 4.2.3. The population projections were updated with the 2000 population Census results.

The results of the population and water demand projections for the various systems are presented in Table 4.2.1.

Irrigation and Livestock

There are many dugouts and small dams in the Volta Basin, Ghana which lie in the Upper East, Upper West and Northern region which are used for irrigation, livestock and domestic purposes. Most of these are in the upper East region lying in the White Red Volta Sissili and Kulpawn sub-basins. The most significant ones are the Tono and Vea dams in the Upper East and Bontongo in the Northern Region.
The location of the dams in the Upper East are shown in Map 5 while the information about them are in Annex 4.2.4. The Tono and Vea irrigation schemes had a total of 2420 ha under irrigation in 2000, out of a total planned area of 3200 ha. Information about future irrigation water at these sites had not been provided by the time this report had be finalized.

Hydropower Generation in Ghana

There are no hydropower stations in the sub-basins in Ghana currently. However, two have been planned, one on the Black Volta at Bui and the other on the White Volta at Pwualugu.
The sod for the Bui Project was cut on 24th August, 2007. It was originally designed to have an installed capacity of 450 MW. The expected annual inflow is 6850 Mm^3. It is to have live storage at full supply level of 14,000 Mm^3. The elevation at full supply level is 198.0 m. The minimum operating level is 184.0 m and tailwater level (under rated conditions is 96.8 m.

Pwalugu on the other hand is yet to be started.

4.3 Environmental Flow Demand

This is the flow required to maintain the flora and fauna in the aquatic (river/lake reservoir and terrestrial (flood plain) ecosystems throughout the year (low and high flow period) and which also ensure that the livelihoods of people who depend upon them are sustained.

The most critical period above the Lower Volta are from November to April.

To sustain river flows for environmental purposes, minimum flow requirements have been defined downstream of all existing and proposed water intakes and dam sites. The assessment of the minimum flow requirements have been based on a low flow and frequency analyses on the monthly flow time series and have been determined as the 95-percentile flow in each calendar month. The 95-percentile flow equals a 20-year return period minimum flow.

Table 4.1.1A: 1Population projections for areas served by ONEA

Centres				Growth Rate (% annum)						
	1998	'99-2000	2001-2010	2011-2020	1999	2000	2005	2010	2015	2020
Ouagadougou	942 000	4,7	4,5	3,0	986 274	1 032 629	1 286 843	1 603 641	1 859 060	2 155 160
Ziniare	4300	2,5	2,5	2,5	4 408	4 518	5 111	5 783	6 543	7 403
Bobo-Dioulasso	506 000	4,0	3,5	2,5	526 240	547 290	650 008	772 006	873 454	988 233
Banfora	58 000	3,5	3,5	3,5	60 030	62 131	73 792	87 642	104 091	123 628
Gaoua	18 300	4,5	4,0	4,0	19 124	19 984	24 314	29 581	35 990	43 788
Niangoloko	13 800	3,5	3,0	3,0	14 283	14 783	17 137	19 867	23 031	26 700
Leguema	4 500	2,5	2,5	2,5	4 613	4 728	5 349	6 052	6 847	7 747
Orodara	23 500	4,0	4,0	4,0	24 440	25 418	30 924	37 624	45 776	55 693
Diébougou	4 800	2,5	2,5	2,5	4 920	5 043	5 706	6 455	7 304	8 264
Arbinda	5 800	3,0	3,0	3,0	5 974	6 153	7 133	8 269	9 587	11 113
Bogande	7 500			4,0 3,0 3,0	7 800	8 112	9 404	10 902	12 638	14 651
Boromo	13 600			4,0 3,5 3,5	14 144	14 710	17 471	20 750	24 644	29 269
Boulsa	14 000			3,0 3,0 2,5	14 420	14 853	17 218	19 961	22 584	25 551
Dedougou	33 100			4,0 3,5 3,5	34 424	35 801	42 520	50 501	59 979	71 236
Diapaga	17 200			2,5 2,5 2,5	17 630	18 071	20 445	23 132	26 172	29 611
Djibo	27 000			4,0 3,0 3,0	28 080	29 203	33 855	39 247	45 498	52 744
Dori	18 200			4,0 3,0 3,0	18 928	19 685	22 820	26 455	30 669	35 554
Fada N'Gourma	37 000			5,0 3,5 3,5	38 850	40 793	48 449	57 542	68 342	81 168
Garango	20 000			4,0 3,0 3,0	20 800	21 632	25 077	29 072	33 702	39 070
Gorom-Gorom	4 900			3,0 3,0 2,5	5 047	5 198	6 026	6 986	7 904	8 943
Gourcy	23 900			3,0 3,0 2,5	24 617	25 356	29 394	34 076	38 554	43 620
Kaya	39 700			3,5 3,5 3,0	41 090	42 528	50 509	59 989	69 544	80 621
Kombissiri	20 700			4,0 4,0 3,0	21 528	22 389	27 240	33 141	38 420	44 539
Kompienga	4 950			2,5 2,5 2,5	5 074	5 201	5 884	6 657	7 532	8 522
Kongoussi	10 750			3,5 3,5 3,5	11 126	11 516	13 677	16 244	19 293	22 914
Koudougou	82 340			4,0 3,5 3,5	85 634	89 059	105 774	125 626	149 205	177 208
Koupela	17 000			4,0 3,5 3,5	17 680	18 387	21 838	25 937	30 805	36 587
Leo	18 200			4,0 3,0 3,0	18 928	19 685	22 820	26 455	30 669	35 554
Manga	17 100			4,0 3,0 3,0	17 784	18 495	21 441	24 856	28 815	33 405
Nouna	21 000			3,5 2,5 2,5	21 735	22 496	25 452	28 796	32 581	36 862
Ouahigouya	69 800			4,5 4,0 4,0	72 941	76 223	92 737	112 829	137 274	167 015
Po	23 000			3,0 3,0 3,0	23 690	24 401	28 287	32 793	38 015	44 070
Poura	7 900			2,5 2,5 2,5	8 098	8 300	9 391	10 625	12 021	13 600
Pouytenga	41 400			4,5 4,0 4,0	43 263	45 210	55 005	66 922	81 420	99 060
Reo	25 700			3,0 2,5 2,5	26 471	27 265	30 848	34 902	39 488	44 677
Sabou	6 600			2,5 2,0 2,0	6 765	6 934	7 656	8 453	9 332	10 304
Tenkodogo	32 500			3,5 3,5 2,5	33 638	34 815	41 349	49 110	55 563	62 865
Tougan	19 000			4,0 3,5 3,5	19 760	20 550	24 407	28 988	34 429	40 891
Yako	18 400			3,0 3,0 2,5	18 952	19 521	22 630	26 234	29 681	33 582
Zabre	13 000			2,5 2,5 2,5	13 325	13 658	15 453	17 484	19 781	22 380
Zorgho	16 100			2,5 2,5 2,5	16 503	16 915	19 138	21 653	24 498	27 717
Total	2 228 00			4,3 3,9 3,1	2 399 027	2 499 636	3 020 535	3 653 237	4 230 734	4 901 517

Source : ONEA

Table 4.1.1B: 1Projection of Water Demand for areas served by ONEA

Centres	**1999**	**2000**	**2005**	**2010**	**2015**	**2020**
Ouagadougou	12 483 220	13 159 280	18 762 355	23 595 878	27 997 961	32 762 639
Ziniare	-	-	-	-	-	-
Bobo-Dioulasso	5 221 914	5 759 814	7 466 911	9 352 035	11 373 742	12 999 878
Banfora	534 472	552 425	652 155	770 869	912 328	1 081 060
Gaoua	168 589	177 229	219 601	272 598	336 551	416 693
Niangoloko	78 279	82 853	107 186	138 888	179 903	233 413
Leguema	6 740	7 379	11 670	18 629	29 991	48 662
Orodara	72 671	77 052	103 903	141 588	192 945	266 250
Diébougou	-	-	-	-	-	-
Arbinda	5 042	5 688	10 563	20 399	40 982	86 032
Bogande	43 398	45 008	52 116	60 503	70 410	82 121
Boromo	40 738	43 008	55 418	72 372	95 716	128 085
Boulsa	-	-	-	-	-	-
Dedougou	173 349	180 938	215 889	260 330	313 541	382 466
Diapaga	-	-	-	-	-	-
Djibo	99 813	106 328	138 474	180 813	235 764	308 447
Dori	205 932	213 476	245 254	282 082	324 782	374 312
Fada N'Gourma	140 918	150 591	199 579	267 445	361 714	492 945
Garango	48 421	51 469	66 825	87 760	116 680	157 638
Gorom-Gorom	39 642	40 893	47 404	54 952	62 050	70 068
Gourcy	42 169	45 207	63 849	90 691	126 239	176 469
Kaya	249 597	261 424	325 853	406 930	495 792	605 340
Kombissiri	58 623	62 780	88 335	124 556	167 686	226 153
Kompienga	33 844	34 757	39 702	45 500	52 334	60 436
Kongoussi	68 080	70 584	85 105	103 641	127 339	157 680
Koudougou	862 378	898 741	1 080 674	1 304 035	1 578 894	1 917 859
Koupela	175 094	182 177	216 564	257 581	306 524	364 944
Leo	66 352	69 574	85 384	105 700	131 811	165 374
Manga	54 916	58 044	73 612	93 700	119 739	153 652
Nouna	62 146	65 492	80 702	99 661	123 334	152 939
Ouahigouya	560 930	587 930	720 930	885 060	1 082 773	1 327 055
Po	104 221	107 472	125 639	147 462	173 683	205 193
Poura	88 684	90 426	99 828	110 530	122 749	136 746
Pouytenga	291 168	305 748	383 431	487 442	631 004	836 643
Reo	35 062	37 263	49 558	66 739	90 854	124 829
Sabou	20 316	21 498	27 755	35 893	46 401	60 102
Tenkodogo	200 162	208 508	253 164	307 868	358 749	418 347
Tougan	100 197	104 862	127 558	155 234	188 140	228 256
Yako	103 381	106 264	122 238	141 179	160 156	182 186
Zabre	22 389	23 527	30 890	42 800	63 902	104 777
Zorgho	-	-	-	-	-	-
Total	22 562 846	23 995 708	32 436 078	40 589 345	48 793 165	57 495 687

(-) : The centre lite: Ziniare, Diebougou, Boulsa, Diapaga and Zorgho have ther autonomous water supply assess and the data is not available

Source : ONEA

Table 4.1.2: 1Status of Water and Sanitation Coverage in the major cities (2003)

Town	Total Population	Total Annual Consumption of Potable Water (m^3)	Source	Number of Connections	Distribution Company	Meeting of Demand	Type of Water Supply System
Ouagadougou	1.187.429	17.910.666	Surface water from the Nakanbe (White Volta) basin (dams of Ziga, Loumbila and Ouagadougou) + Groundwater (boreholes)	46.973	ONEA	Sufficient	Collectif et Autonome
Bobo-Dioulasso	604.798	6.731.998	Groundwater from the Mouhoun (Black Volta) basin	16.877	ONEA	Sufficient	Collectif et Autonome
Banfora	74.126	698.117	Surface water from the Comoe basin (River Camoe)	2554	ONEA	Sufficient	
Koudougou	84.856	945.790	Surface water from the Mouhoun (Black Volta) basin	2783	Idem	Sufficient	
Ouahigouya	71.011	717.000	Surface water from the Nakanbé basin (Goinré dam + Groundwater (boreholes)	1525	Idem	Insufficient	
Fada N'Gourma	35.490	144.092	Surface water from the Nakanbé basin (Tandjali dam) + Groundwater (boreholes)	289	Idem	Insufficient	
Kaya	41.627	307.195	Surface water from the Nakanbé basin (lake Dem) + Groundwater (boreholes)	844	Idem	Insufficient	
Koupéla	16.721	218.061	Surface water from the Nakanbé basin(Itengué dam) + Groundwater (boreholes)	545	Idem	Insufficient	
Tenkodogo	39.091	258.768	Groundwater from the Nakanbé basin (boreholes)	456	Idem	Insufficient	
Gaoua	17.471	236.642	Groundwater from the Mouhoun basin (boreholes)	428	Idem	Sufficient	
Dédougou	34.941	212.792	Groundwater from the Mouhoun basin (boreholes)	450	Idem	Sufficient	
Pouytenga	20.786	350.107	Surface water from the Nakanbé basin (Itengué dam) + Groundwater (boreholes)	216	Idem	Sufficient	
Yako	22.339	134.067	Groundwater from the Nakanbé basin (boreholes)	169	Idem	Sufficient	
Manga	16.760	71.776	Groundwater from the Nakanbé basin (boreholes)	120	Idem	Sufficient	
Dori	19.604	186.387	Surface water from the Niger basin (boreholes) + Groundwater	443	Idem	Sufficient	
Djibo	29.287	131.906	Groundwater from the Nigerbasin (boreholes)	147			
TOTAL	**2.316.037**	**29.255.364**		**77.819**			

Source: National Office for Water and Sanitation(ONEA)

Table 4.1.3A: 1Water demand for 2000 in m^3

National Sub-basins	Domestic Demand	Irrigation Demand	Livestock water Demand	Industrial Demand	Mining Water Demand	Consumptive Demand	Hydropower Demand
Comoé-Léraba	3,31	107,9	3,02	3,52	0	117,75	91
Mouhoun Supérieur	13,11	46,43	5,52	1,14	0	66,2	0
Sourou	4,34	67,14	3,55	0	0	75,03	0
Mouhoun inférieur	17,43	19,19	12,53	0,17	0	49,32	0
Nakanbé	38,42	66,24	16,29	1,31	0	122,26	1 300
Nazinon	4,98	2,61	3,93	0	0	11,52	0
Sissili	1,55	0,84	1,25	0	0	3,64	0
Pendjari-Kompienga	2,98	-	3,32	0	0	6,3	700
Banifing	1,17	-	1,30	0	0	2,47	0
Béli	2,45	1,86	2,88	0	0,35	7,19	0
Gourouol	1,67	5,16	1,86	0	0	9,04	0
Dargol	0,34	-	0,67	0	0	1,01	0
Faga	6,29	3,56	8,75	0	0	18,6	0
Sirga-Gouroubi	3,24	0,57	4,58	0	0	8,39	0
Bonsoanga	1,39	0,58	1,11	0	0	3,08	0
Dymangou	0,52	-	0,45	0	0	0,97	0
Tapoa-Mekrou	0 ,79	0,56	0,72	0	0	2,07	0
River Basin/Catchment							
Comoé	3,31	107,9	3,02	3,52	0	117,75	91
Mouhoun	34,89	133,17	21,60	1,31	0	190,97	0
Nakanbé	47,93	69,68	24,80	1,31	0	143,72	2 000
Niger	17,82	12,30	22,32	0	0,35	52,79	0
TOTAL BURKINA	103,95	323	72	6	0,35	505	2 091

Table 4.1.3B: 1Summary of Projected Demand for 2010 in m^3

TYPE OF DEMAND	**SUB - BASINS**		
	BLACK VOLTA	**WHITE VOLTA**	**TOTAL**
POTABLE WATER	44 296 000	61 867 000	106 163 000
IRRIGATION	160 375 000	105 500 000	265 875 000
LIVESTOCK	22 800 000	34 000 000	56 800 000
INDUSTRIES	2 000 000	2 000 000	4 000 000
MINES	-	3 700 000	3 700 000
TOTAL 1	**229 471 000**	**207 067 000**	**436 538 000**
HYDROELECTRICITY	-	2 000 000 000	2 000 000 000
TOTAL 2	**229 471 000**	**2 207 067 000**	**2 436 538 000**

Table 4.2.1: Population and Water Demand Projectionsz for major settlements in the White Volta and Oti River Basins of Ghana.

5. ASSESSMENT OF THE ADEQUACY OF THE WATER AVAILABILITY TO MEET PRESENT AND PROJECTED WATER DEMAND

The above assessment was carried out using the Water Evaluation and Planning Tool (WEAP) developed by the Stockholm Environmental Institute. In essence the tool assesses how the water availability under long term mean, extreme and climate change conditions as scenarios can meet the current and future demand under various assumptions. The demand is expected to include environmental (ecosystems) needs, in addition to sectoral needs. Assumptions include policy changes and socio-economic changes. As a policy tool WEAP evaluates a full range of water development and management options and takes account of multiple and comparing uses of water system.

5.1 The WEAP Approach

Operating on the basic principle of water balance accounting, WEAP is applicable to municipal and agricultural systems, single sub-basins or complex river systems. Moreover, WEAP can address a wide range of issues, e.g., sectoral demand analyses, water conservation, water rights and allocation priorities, groundwater and streamflow simulations, reservoir operations, hydropower generation, pollution tracking, ecosystem requirements, and project benefit-cost analyses.

The analyst represents the system in terms of its various supply sources (e.g., rivers, creeks, groundwater, and reservoirs); withdrawal, transmission and wastewater treatment facilities; ecosystem requirements, water demands and pollution generation. The data structure and level of detail may be easily customized to meet the requirements of a particular analysis, and to reflect the limits imposed by restricted data.

WEAP applications generally include several steps. The study definition sets up the time frame, spatial boundary, system components and configuration of the problem. The Current Accounts provide a snapshot of actual water demand, pollution loads, resources and supplies for the system. Alternative sets of future assumptions are based on policies, costs, technological development and other factors that affect demand, pollution, supply and hydrology. Scenarios are constructed consisting of alternative sets of assumptions or policies. Finally, the scenarios are evaluated with regard to water sufficiency, costs and benefits, compatibility with environmental targets, and sensitivity to uncertainty in key variables.

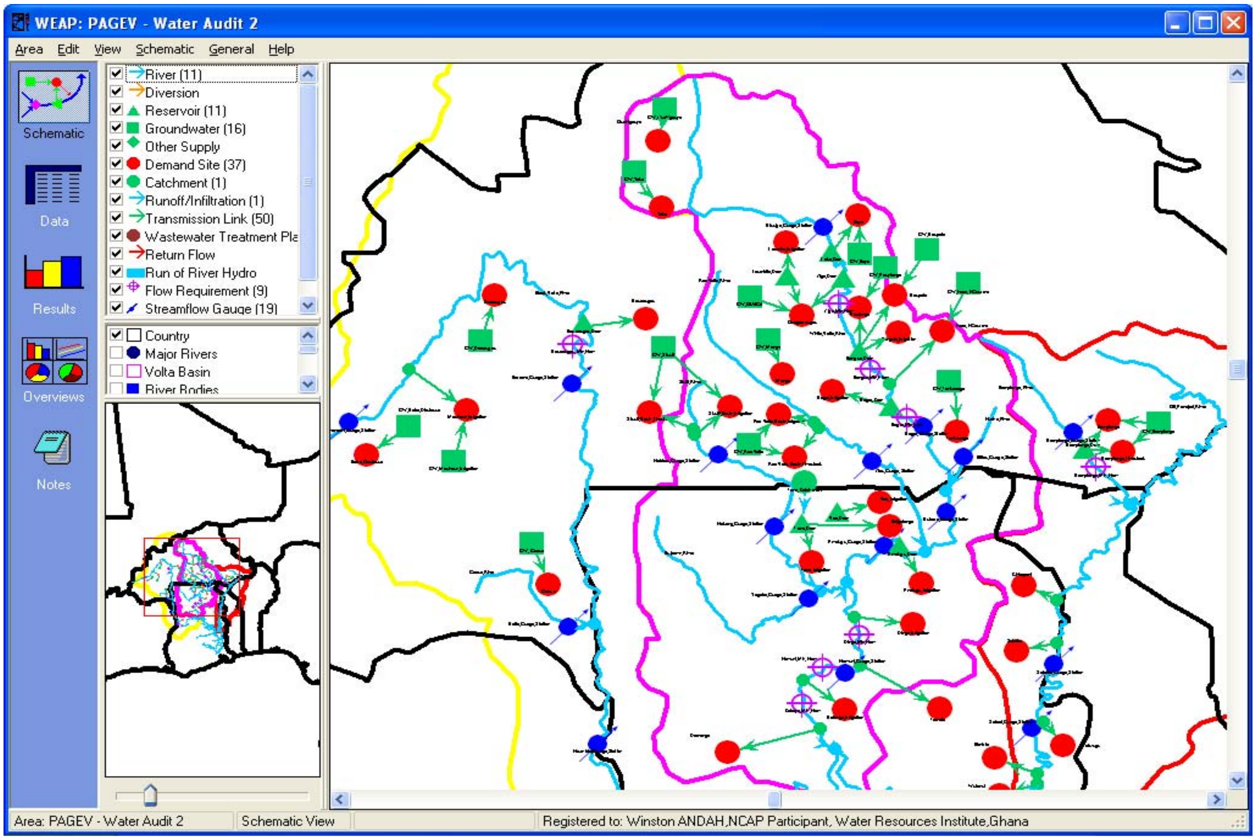
A brief description of the tool is presented in Annex 5.1.

5.2 Structure of Programme to Volta Basin

As described in the above annex, the WEAP consists of five main views: Schematic, Data, Results, Overviews and Notes. For the Volta Basin project area these are described in the paragraphs that follow.

5.3 The Schematic for the Volta Basin

The Schematic View is the starting point for the modeling.
In the case of the Volta Basin, it is the study area within Ghana and Burkina Faso and consists of a set of demand sites defined by geographic boundaries. The schematic is conceived as both a set of demand and supply sites in the Volta river system. This schematic view is presented in Fig. 5.1.



☑ River (11)
☑ Diversion
☑ Reservoir (11)
☑ Groundwater (16)
☑ Other Supply
☑ Demand Site (37)
☑ Catchment (1)
☑ Runoff/Infiltration (1)
☑ Transmission Link (50)
☑ Wastewater Treatment Pla
☑ Return Flow
☑ Run of River Hydro
☑ Flow Requirement (9)
☑ Streamflow Gauge (19)

☑ Country
☐ Major Rivers
☐ Volta Basin
☐ River Bodies

Area: PAGEV - Water Audit 2
Schematic View
Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig. 5. 1: Schematic View of Demand and Supply sites

GIS layers were used as backgrounds on the Schematic. These background maps were developed in ArcView (GIS) imported into the software. They are the hydrological maps mentioned in sections 2 and 3 and the maps of the water systems for domestic, irrigation, livestock and hydropower uses mentioned in Section 4.

5.4 Data Input

In the Data View the modeling of the Basin was built by entering the data structures, data, assumptions, modeling relationships and documentation for the Current Accounts and for each scenario.

In the model, data were organized under six major categories; Key Assumptions, Demand Sites, Hydrology and Supply and Resources. See Fig. 5.2 for the key Assumptions and Demand sites.

5.4.1 Key Assumptions

Under this, independent variables like domestic and irrigation water supply and their monthly variations were created and organized. These are variables that references will be made to elsewhere in the analysis. These are monthly share in percentages of the annual demand at all demand sites. This is shown in Table 5.1A. The appropriate groundwater data was not available as earlier stated. Generally, groundwater is for small communities except Ouagadougou and Pouytenga which happen to be supplemented with surface water. For the small communities it is assumed that the available groundwater will be adequate.

Table 5.1A: 1Monthly variation of water at site

Demand Type	**Percentage of Annual Demand in**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Domestic Water Supply	7.92	9.0	9.6	9.2	8.75	8.0	7.5	7.5	7.58	8.3	8.5	8.0
Irrigation	26.1	19.5	14.0	7.1	2.9	2.0	2.4	2.5	2.8	2.9	2.7	14.3

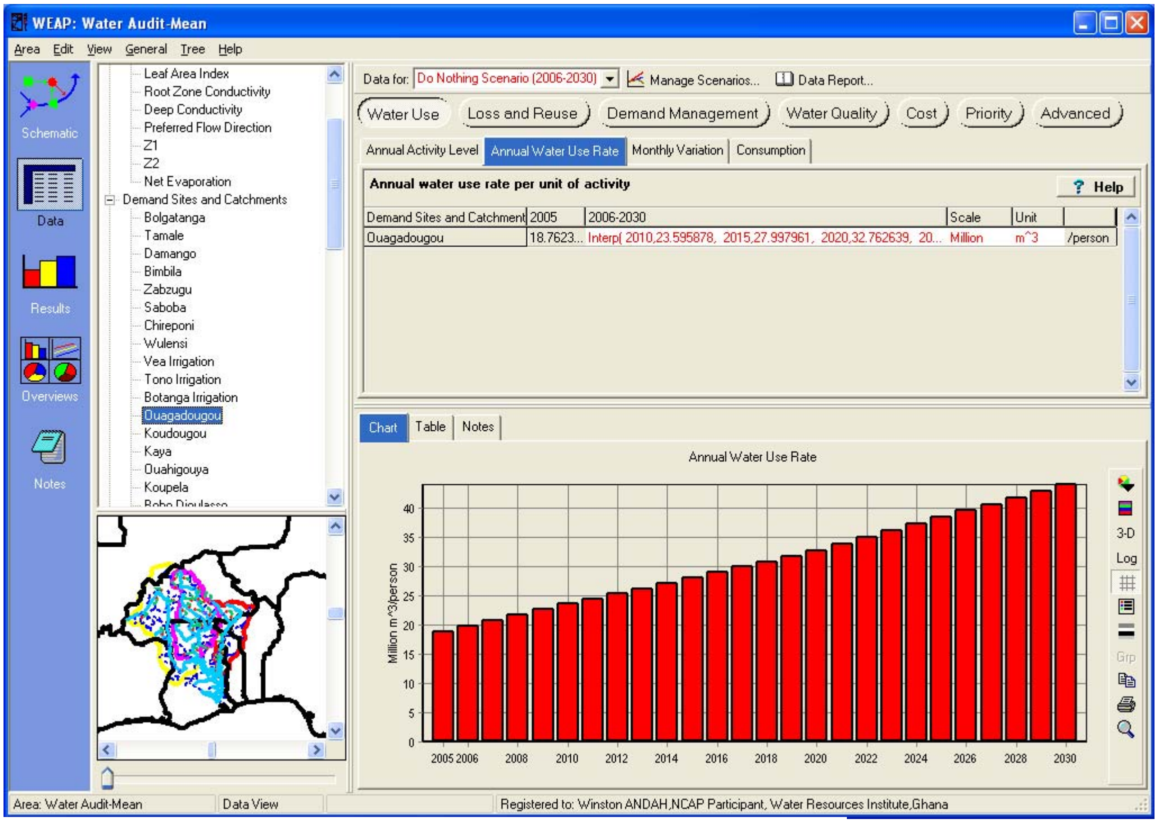
5.4.2 Demand Sites:

Demand sites were aggregated for water consumption in the study. It could have been disaggregated if there was enough time. Examples are the towns shown in Table 4.2.1 for the towns which depend on the various systems. The Tamale system could have been disaggregated into 25 demand sites.

Demand analysis in the model was end-use based approach for modeling the requirements for water consumption in the study. Demographic and water-use information were applied to construct alternative scenarios that examine how total and disaggregated consumption of water evolve over time for domestic, irrigation and livestock. Demand analysis in WEAP was also the starting point for conducting integrated water planning analysis, since all Supply and Resource calculations in WEAP were driven by the levels of final demand calculated in the demand analysis. This is exemplified by Tables 4.1.1A and 4.2.1.

The model provided a lot of flexibility in how to structure the demand data. These could range from highly disaggregated end-use oriented structures to highly aggregate analyses. Typically a structure would consist of sectors including households, livestocks and agriculture, each of which might be broken down into different sub-sectors, end-uses and water-using devices. The structure of the data adapted to the purposes of the study, based on the availability of data and also the time available for the study. Some of the irrigation and livestock demands were aggregated into sub-basins. Examples are Yaaran irrigation demand and Sissili livestock demands at Po.

In each case, demand calculations were based on various measures of social and economic activity (number of households, hectares of irrigated agriculture, industrial and commercial value added, etc.). In the simplest cases, these activity levels are multiplied by the water use rates of each activity (water use per unit of activity). Each activity level and water use rate was individually projected into the future using a variety of techniques.



Data for: Do Nothing Scenario (2006-2030)

Annual water use rate per unit of activity

Demand Sites and Catchment	2005	2006-2030	Scale	Unit	
Ouagadougou	18.7623...	Interp(2010,23.595878, 2015,27.997961, 2020,32.762639, 20...	Million	m^3	/person

Fig. 5. 2: Demand Site - Ouagadougou

Demand sites considered in the study included Bobo Dioulasso, Dedougou, Koudougou, Goua and Yaaran Irrigation, all in Black Volta sub basin. In the White Volta sub-basin, the demand sites considered included Ouagadougou, Kaya, Poutenga, Manga, Tenkodogo, Koupela, Tamale, Bolgatanga, Bimbila, Botanga Irrigation, Vea Irrigation and Tono Irrigation. In Oti Pendjari sub-basin, the demand sites were considered were Kompienga, Cheriponi and Saboba.

The complete list is presented in Table 5.1B.

Table 5.1B: 1Water Demand Sites in the Study Area

DOMESTIC & INDUSTRIAL		IRRIGATION		LIVESTOCK		HYDROPOWER	
Burkina Faso	**Ghana**	**Burkina Faso**	**Ghana**	**Burkina Faso**	**Ghana**	**Burkina Faso**	**Ghana**
Ouagadougou	Tamale	Yaara	Vea	Po		Bagre	(Bui construction just started)
Bobo-Dioulasso	Bolgatanga	Lac Bam	Tono	Kopienga			
Dedougou	Damongo	Bagre	Bontanga				
Fada N'Goutina	Bimbila	Itengule					
Kaya	Salaga						
Koudrougou	Zabzugu						
Kompela	Saboba						
Mando	Wulensi						
Pouytenga	Chereponi						
Ouahigouya							
Tenkodogo							
Yako							

5.4.3 Hydrologic Inflows

The following types of data were used in the model:

- Streamflow guage records and their locations (see Tables 2.1.1 to 2.1.10 and Tables 3.1.1 to 3.1.9 and in Map 2.
- Reservoir storage levels, volume-elevation relationships, net monthly evaporation rates, operating rules for fish and wildlife, recreation, water supply and other conservation purposes. The data on hydropower were inadequate and so the model was not run for hydropower.
- Instream flow requirements for recreation, water quality, fish and wildlife, navigation, other conservation purposes, and any downstream obligations

The model utilized long-term mean of streamflow records to project surface water hydrology over the study period. This included river and tributary headflows, surface water inflows to river reaches and local reservoirs.

5.4.4 Supply and Resources

Given the monthly supply requirement from Demand and defining the hydrology, the Supply and Resources section determines the amounts, availability and allocation of supplies, simulates monthly river flows, including surface/groundwater interactions and in stream flow requirement and also tracks reservoir and groundwater storage.

5.5 Results of the Model Run

Once the data had been entered, the model was run. The model, WEAP, ran its monthly simulation and reported projections of all aspects of the water system, including demand site requirements and coverage, streamflow, instream flow requirement satisfaction, reservoir and groundwater storage.

5.5.1 The "Do Nothing" Scenario for mean flows

This Scenario assumes the "*status quo*" situation regarding the resource capacity, which implies that no new dams or additional sources will be introduced. Likewise, the existing water abstraction and other facilities will be maintained as they are, but expanded in step with the increase in demand up to the limit of the present resource capacity.

The results obtained from the running of the model indicate that for:-

i) *Domestic Water Supply;*

This scenario results in:-

a. pronounced water shortages during the dry months for Ouagadougou,

b. sufficiency of water resources to meet the requirements in Bolgatnaga, Bimbila, Wulensi, Chereponi, Saboba, Pouytenga, Ouahigouya and Bobo Dioulasso throughout the plan period. These demand sites will have 100% demand coverage.

Ouagadougou

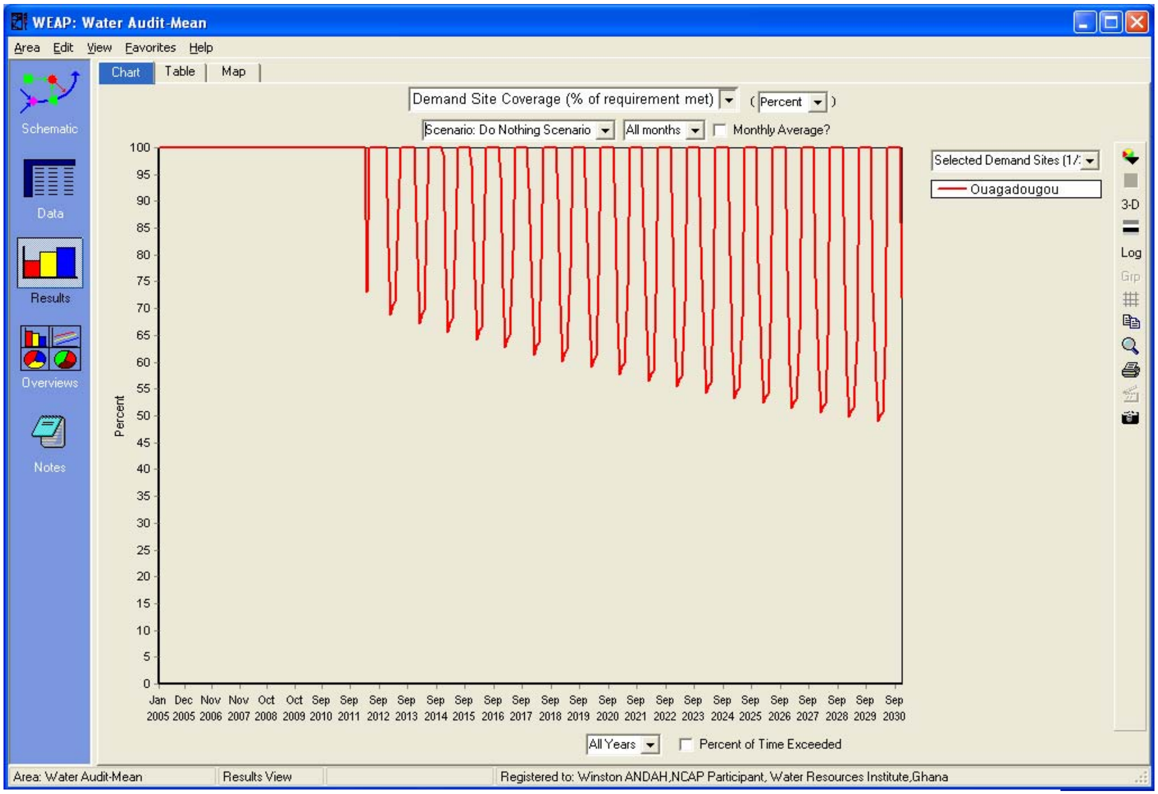


Fig. 5. 3: demand Coverage - Ouagadougou

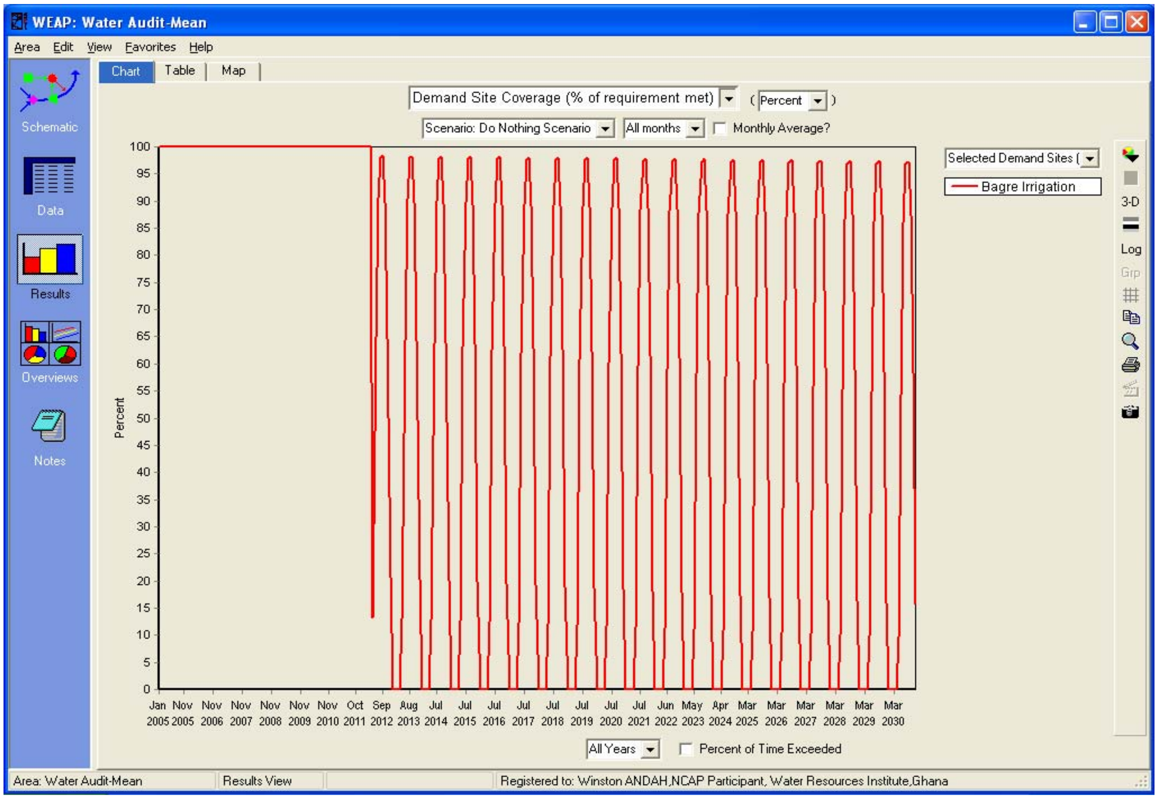
From 2007 to 2012, the Ouagadougou water demand will be 100 percent met. The shortfall will start in 2013. The water demand coverage will be about 88%, 84% and 78% of the water demand in 2015 and 2030 respectively will be met. Thus, groundwater will contribute 10% of the total supply, Loumbila Dam 20% and the rest of 70% will be contributed by Ziga Dam.

In 2015, Ouagadougou will need a top up of about 389,875 m^3 of water to meet the yearly demand and 1.11 million m^3 will be needed to make up for the deficit in 2030. The deficit usually occurs from December to May.

ii) *Irrigation Water Supply;*

This scenario results in pronounced water shortages during the dry months for Bagre and Lac Bam Irrigations.

Bagre Irrigation



WEAP: Water Audit-Mean

Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (

Bagre Irrigation

All Years | ☐ Percent of Time Exceeded

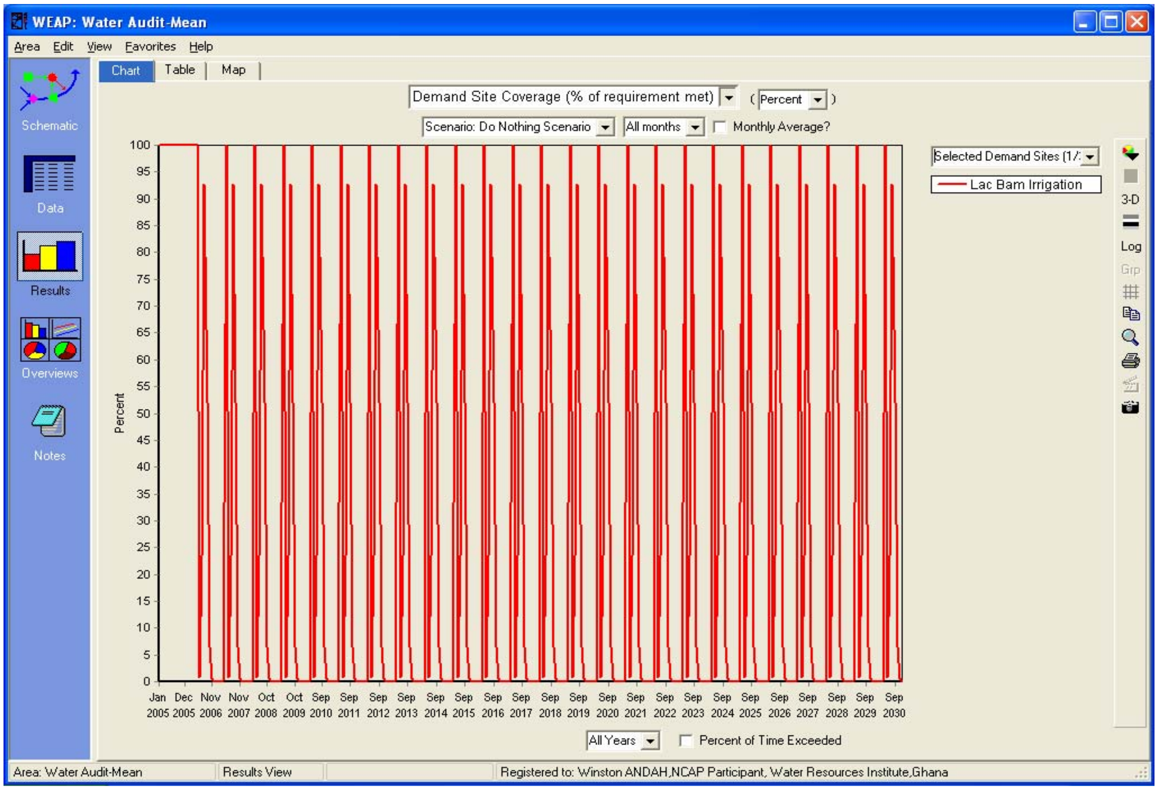
Area: Water Audit-Mean | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig. 5. 4: Demand coverage - Bagre irrigation scheme

From the results, the Bagre Irrigation water demand will be 100 percent met during the period 2007 to 2012. The shortfall will begin in 2013. The water demand coverage will be around 44.5% in 2015, 43.8% in 2020 and in 2030 only 42.1% of the water demand will be met. January to April are the months that will be severely hit. In 2015, Bagre Irrigation project will need a top up of about 1.45 million m^3 of water to meet irrigation water requirement and 1.5 million m^3 will be needed to make up the deficit in 2030. The deficit usually occurs from December to May.

Lac Bam Irrigation

Irrigation project which will be severely affected in the ensuing years is Lac Bam Irrigation. The irrigation water demand coverage will be around 23% in 2010, 2015, and 2020 through to 2030. The results indicate that 254,314 m^3 of water will require every year supplement the irrigation water demand. In December, January, February and March, there will be barely water to irrigate the crops. The water demand coverage for Lac Bam Irrigation is shown in the Fig 5.3 below.



Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (1/

Lac Bam Irrigation

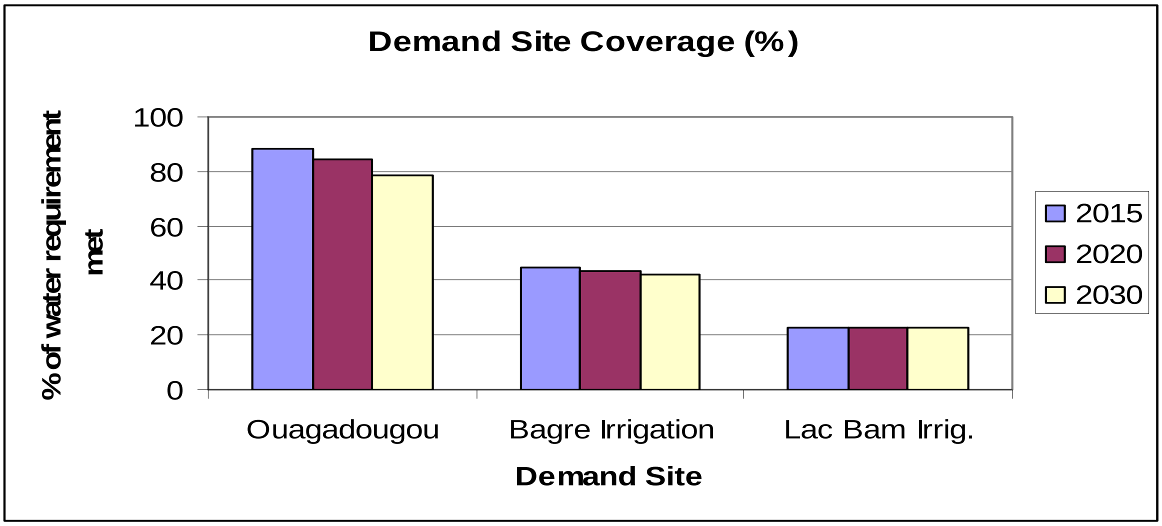
All Years | ☐ Percent of Time Exceeded

Area: Water Audit-Mean | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5.5: Demand Coverage – Lac Bam Irrigation

Table 5.2: Demand Site Coverage under mean flow scenario (% of water requirement met)

Demand Site	2015	2020	2030
Ouagadougou	88.3	84.4	78.4
Bagre Irrigation	44.5	43.8	42.1
Lac Bam Irrig.	23.0	23.0	23.0



5.5.2 The "Very Dry" Scenario (10 Percentile).

This Scenario examines the effects of very dry spells on the water resources in meeting increasing water demands in the basin.

The preliminary results obtained from the running of the model indicate that for:-

i) *Domestic Water Supply;*

This scenario results in:-

- pronounced water shortages during the dry months for these demand sites i.e. Ouagadougou, Tamale and Damango,
- sufficiency of water resources to meet the requirements in Bolgatnaga, Bimbila, Wulensi, Chereponi, Saboba, Poutenga, Ouahigouya and Bobo Dioulasso throughout the plan period. These demand sites will have 100% demand coverage.

Ouagadougou

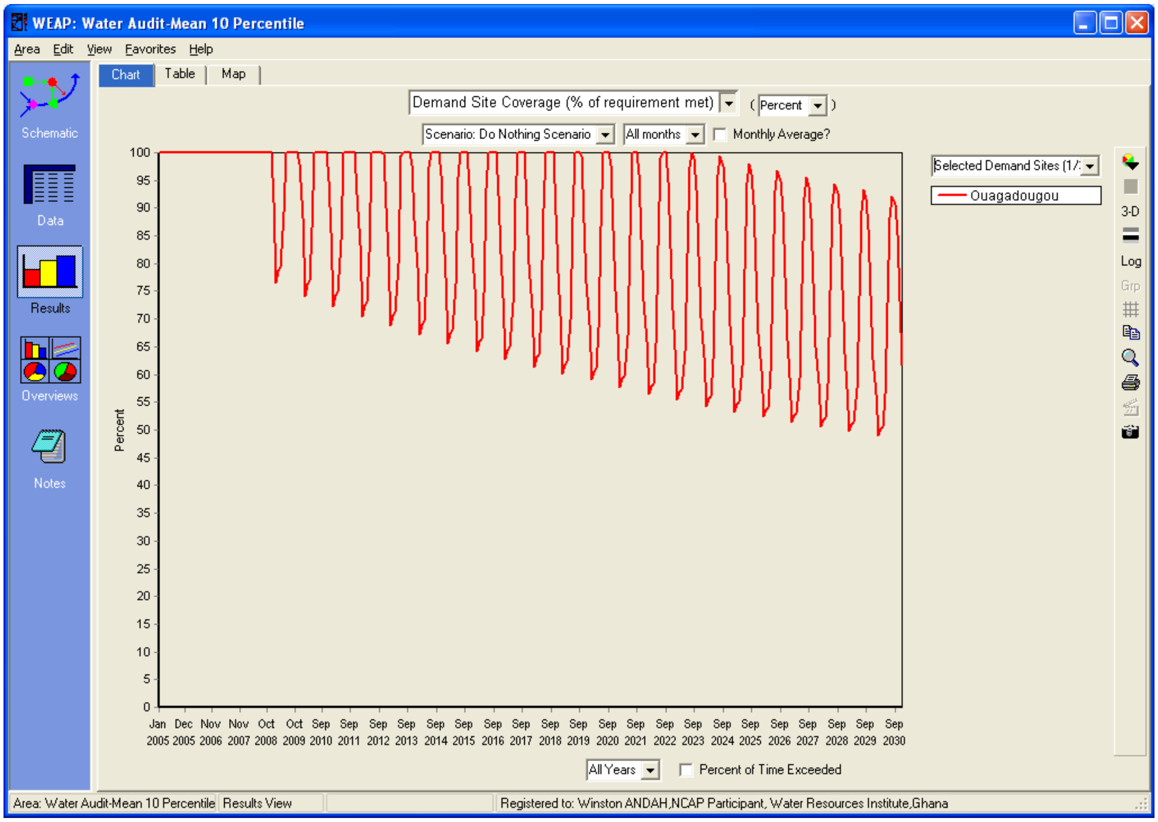


Fig 5.6: Demand Coverage - Ouagadougou

In a very dry situation, Ouagadougou will experienced water shortages right from 2009. The water demand coverage will be around 85.7% in 2015, 80.32% in 2020 and in 2030 only 68.9% of the water demand will be met. Thus, if composition of various sources is unchanged, i.e. groundwater contributing 10% of the total supply, Loumbila Dam 20% and the rest of 70% contributes by Ziga Dam. During very dry periods, Ouagadougou will need a top up of about 471,488 m^3 of water to meet the yearly demand and 1.57 million m^3 will be needed to make up the deficit in 2030. The deficit usually occurs from December to May.

Tamale

In this very dry situation, Tamale will experience water shortages especially during months of January, February and March. Water demand coverage in 2015 will be 99.8%, 98.3% in 2020 and 90.7% in 2030. Thus, 4,336 m^3 will be needed to supplement demand requirement in 2015, 40,126 m^3 will be required to supplement demand in 2020 and in 2030, 325,876 m^3 will be needed.

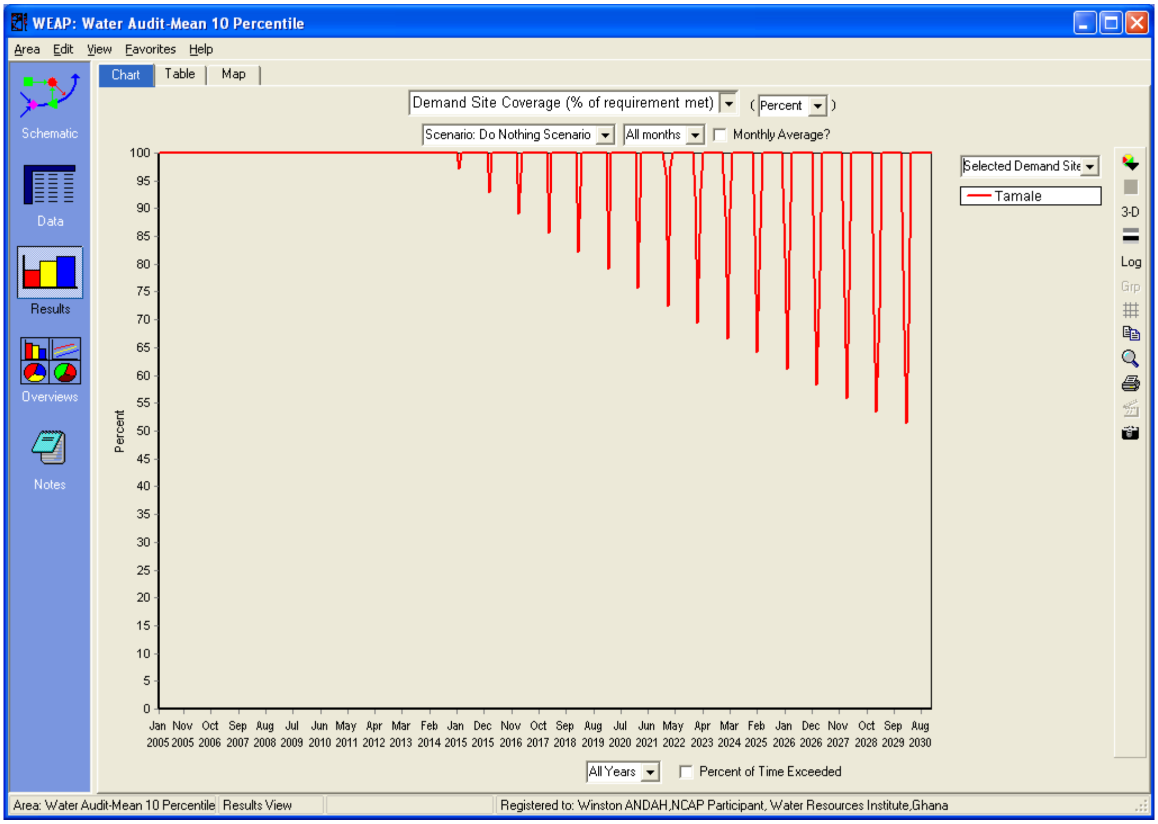


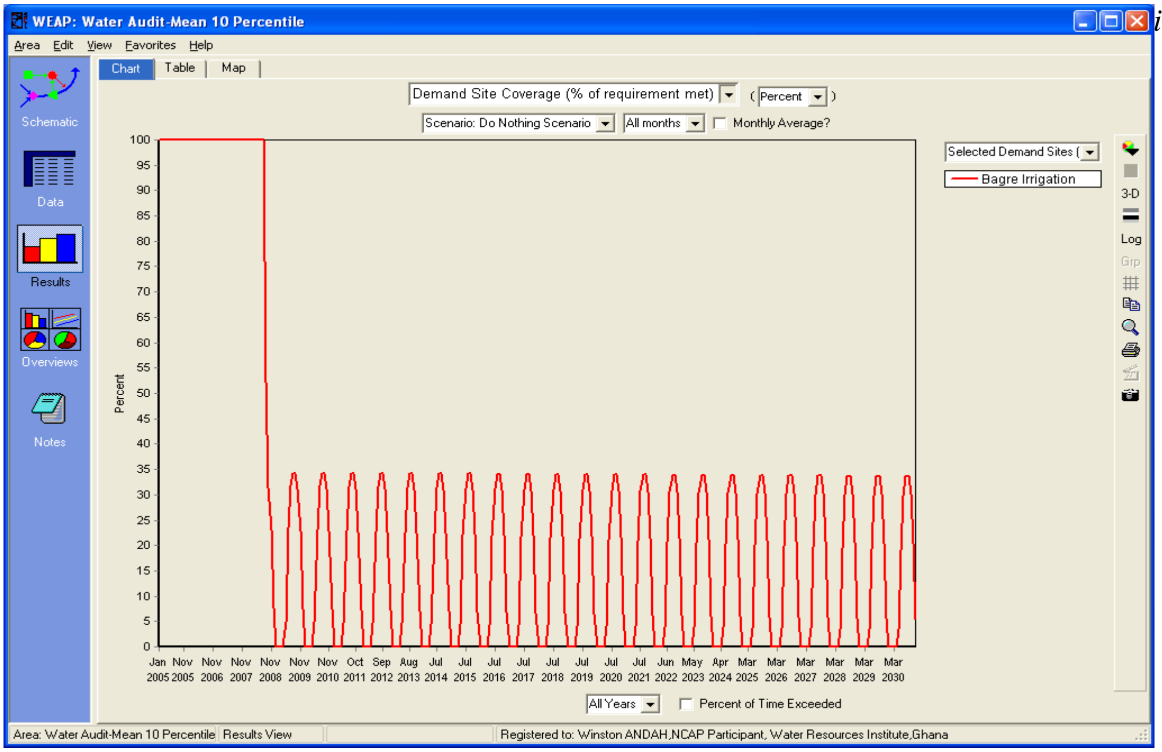
Fig 5.7: Demand Coverage - Tamale

ii) *Irrigation Water Supply;*

This scenario results in pronounced water shortages during the dry months for Bagre and Lac Bam Irrigations.

Bagre Irrigation

From the results, the Bagre Irrigation project will be severely hit during very dry events. The water demand coverage will be around 15.5% in 2015, 15.2% in 2020 and in 2030 only 14.6% of the water demand will be met. January to April are the months that will be severely hit as shown by the figure 5.2 above. In 2015, Bagre Irrigation project will need a top up of about 1.95 million m^3 of water to meet irrigation water requirement and 2 million m^3 will be needed to make up the deficit in 2030. The deficit usually occurs from December to May.



Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (

Bagre Irrigation

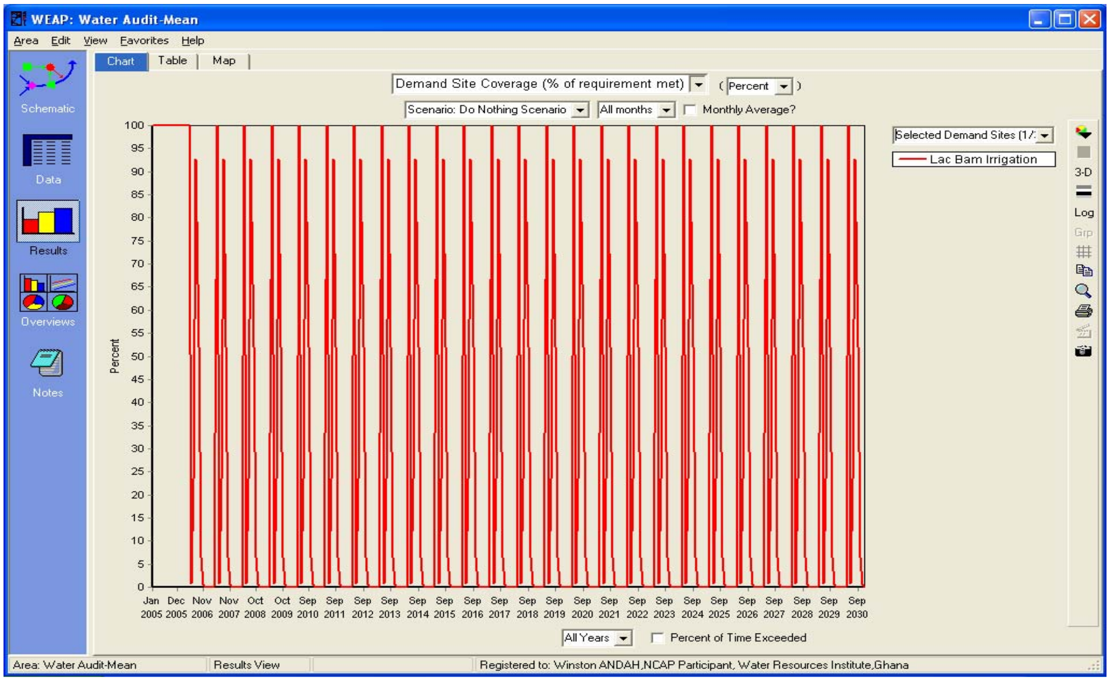
All Years | ☐ Percent of Time Exceeded

Area: Water Audit-Mean 10 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5:8: Demand Coverage – Bagre Irrigation

Lac Bam

Lac Bam Irrigation project will be severely affected during very dry seasons. The irrigation water demand coverage will be around 13% in 2010, 2015, and 2020 through to 2030. The results indicate that 274,338 m3 of water will require every year supplement the irrigation water demand. In December, January, February and March, there will be barely water to irrigate the crops. The water demand coverage for Lac Bam Irrigation as depicted in the Fig 5.9.



Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (1/

Lac Bam Irrigation

All Years | ☐ Percent of Time Exceeded

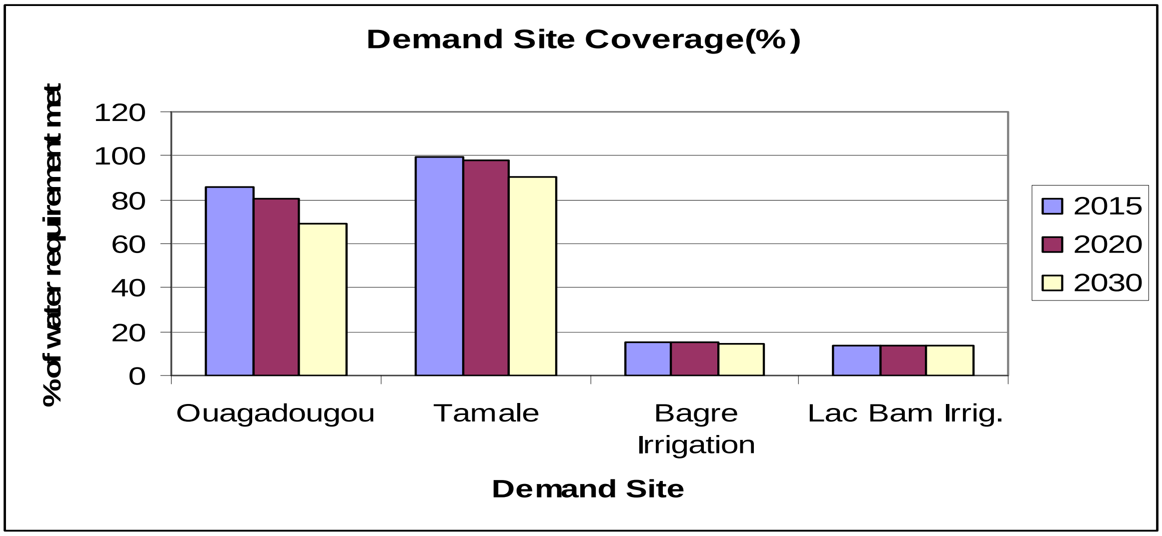
Area: Water Audit-Mean | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5.9: Demand Coverage – Lac Bam Irrigation

Table 5.3: Demand Site Coverage Very Dry Year scenario

(% of water requirement met)

Demand Site	2015	2020	2030
Ouagadougou	85.7	80.2	68.9
Tamale	99.8	98.3	90.7
Bagre Irrigation	15.5	15.2	14.6
Lac Bam Irrig.	13.47	13.47	13.47



5.5.3 The "Dry" Scenario (25 Percentile)

This Scenario examines the effects of dry spells on the water resources in meeting increasing water demands in the basin.

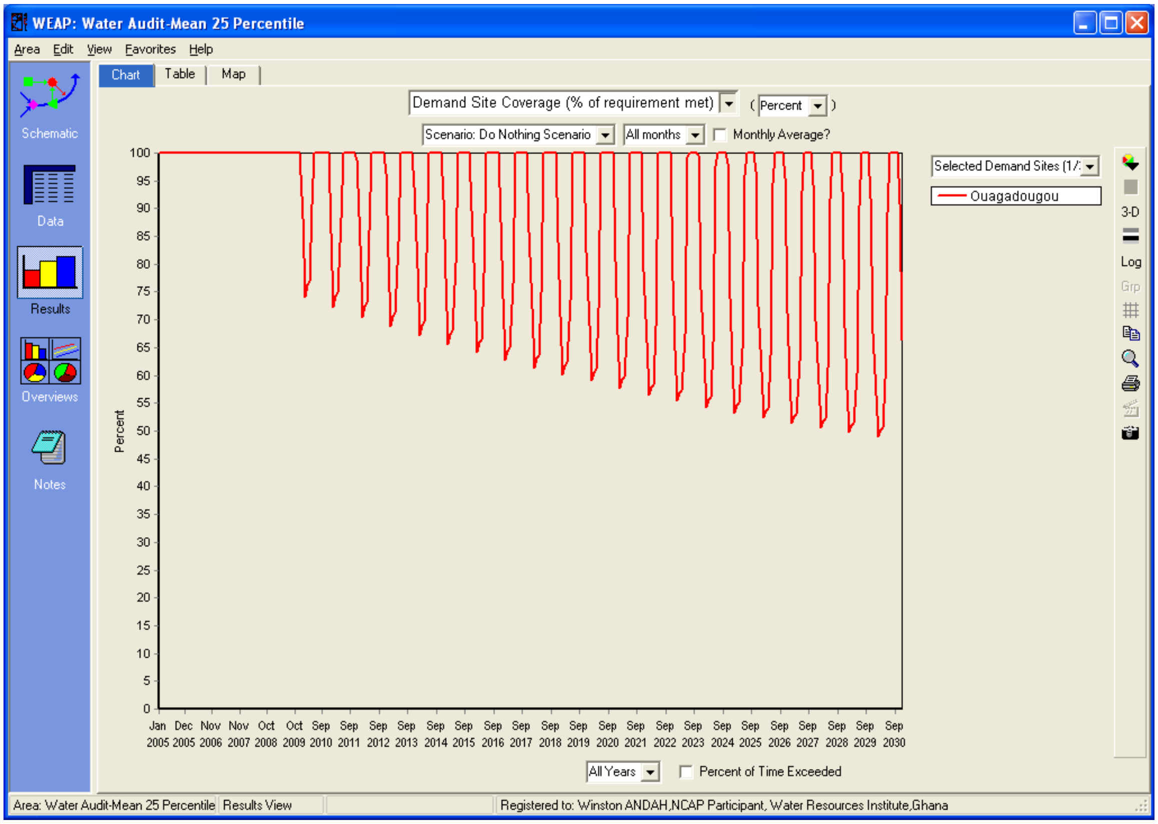
The results obtained from the running of the model indicate that for:-

i) *Domestic Water Supply;*

This scenario results in:-

- pronounced water shortages during the dry months for these demand sites i.e. Ouagadougou, Tamale and Damango,
- sufficiency of water resources to meet the requirements in Bolgatnaga, Bimbila, Wulensi, Chereponi, Saboba, Poutenga, Ouahigouya and Bobo Dioulasso throughout the plan period. These demand sites will have 100% demand coverage.

Ouagadougou



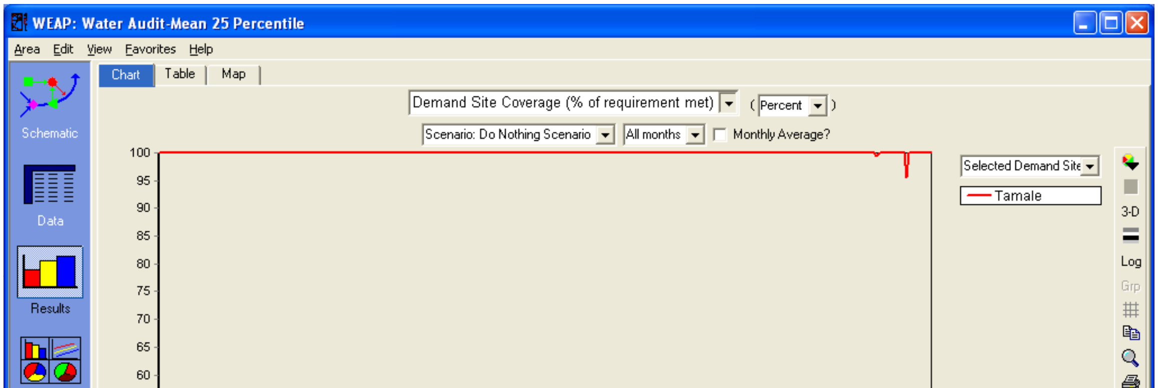
Demand Site Coverage (% of requirement met) (Percent)
Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?
Selected Demand Sites (1/
All Years | ☐ Percent of Time Exceeded
Area: Water Audit-Mean 25 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5.10: Demand Coverage - Ouagadougou

During dry events, Ouagadougou will experienced water shortages right from 2009. The water demand coverage will be around 87.4% in 2015, 83.5% in 2020 and in 2030 only 76.0% of the water demand will be met. Thus, if composition of various sources is unchanged, i.e. groundwater contributing 10% of the total supply, Loumbila Dam 20% and the rest of 70% contributes by Ziga Dam. During very dry periods, Ouagadougou will need a top up of about 419,154 m^3 of water to meet the yearly demand and 1.2 million m^3 will be needed to make up the deficit in 2030. The deficit usually occurs from December to May.

Tamale

In this dry situation, Tamale will experience water shortages especially during months of January, February and March. Water demand coverage in 2015 will be 100%, and 99.6% in 2030. Thus, 13,543 m^3 will be needed to supplement demand requirement in 2030.



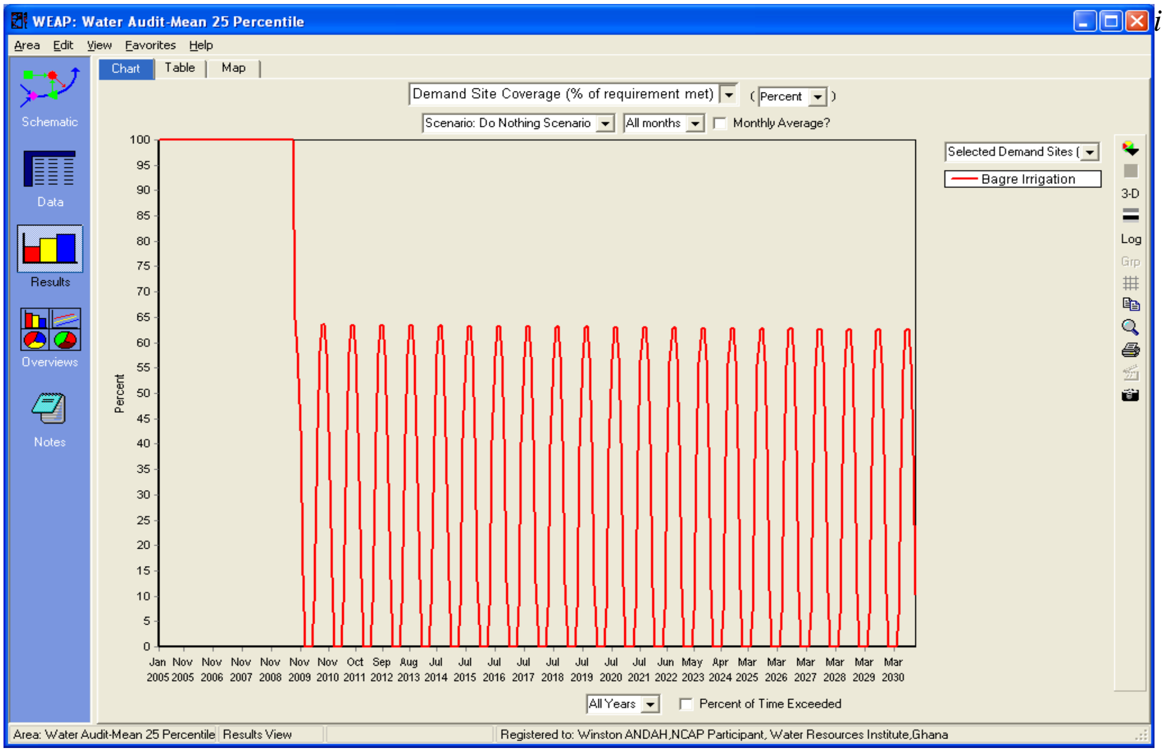
Demand Site Coverage (% of requirement met) (Percent)
Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?
Selected Demand Site

Fig 5.11: Demand Coverage - Tamale

ii) *Irrigation Water Supply;*
This scenario results in pronounced water shortages during the dry months for Bagre and Lac Bam Irrigations.

Bagre Irrigation

From the results, the Bagre Irrigation project will be severely hit during dry events. The water demand coverage will be around 28.8% in 2015, 28.2% in 2020 and in 2030 only 27.1% of the water demand will be met. January to April are the months that will be severely hit as shown. In 2015, Bagre Irrigation project will need a top up of about 1.72 million m^3 of water to meet irrigation water requirement and 1.8 million m^3 will be needed to make up the deficit in 2030. The deficit usually occurs from December to May.



WEAP: Water Audit-Mean 25 Percentile

Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites | Bagre Irrigation

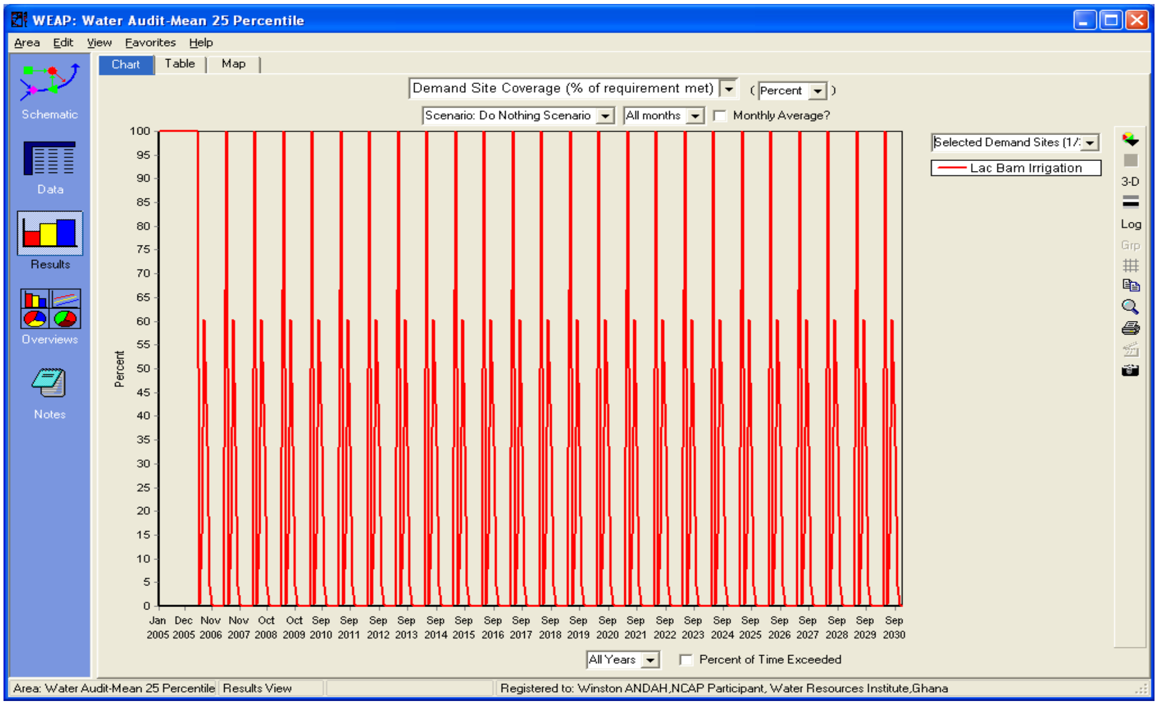
All Years | ☐ Percent of Time Exceeded

Area: Water Audit-Mean 25 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5:12: Demand Coverage – Bagre Irrigation

Lac Bam

Lac Bam Irrigation project will be severely affected during dry seasons. The irrigation water demand coverage will be around 17.9% in 2010, 2015, and 2020 through to 2030. The results indicate that 265,096 m^3 of water will require every year supplement the irrigation water demand. In December, January, February and March, there will be barely water to irrigate the crops. The water demand coverage for Lac Bam Irrigation as depicted in the Fig 5.13.



WEAP: Water Audit-Mean 25 Percentile

Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (1/ | Lac Bam Irrigation

All Years | ☐ Percent of Time Exceeded

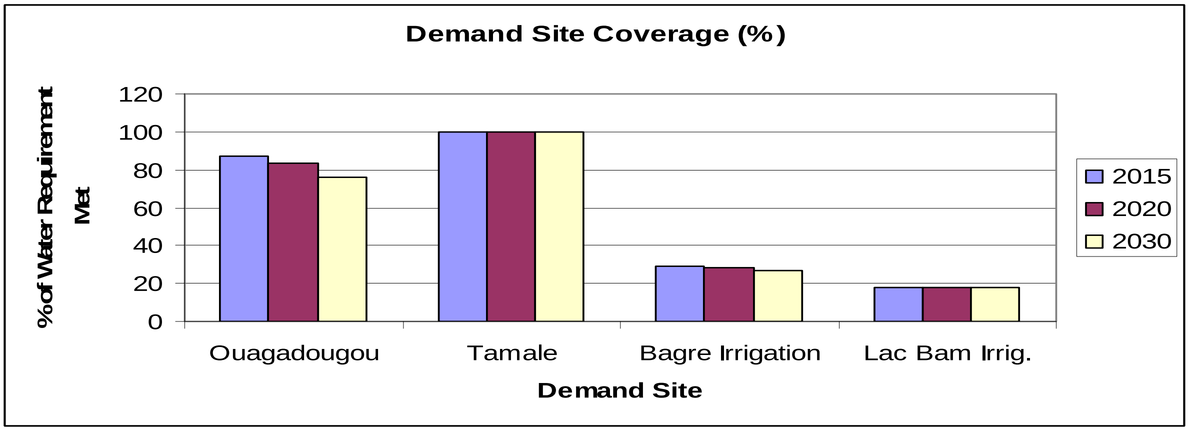
Area: Water Audit-Mean 25 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5.13: Demand Coverage – Lac Bam Irrigation

Table 5.4: Demand Site Coverage Dry Year scenario

(% of water requirement met)

Demand Site	2015	2020	2030
Ouagadougou	87.4	83.5	76.0
Tamale	100	100	99.6
Bagre Irrigation	28.8	28.2	27.1
Lac Bam Irrig.	17.9	17.9	17.9



5.5.4 The "Wet" Scenario (75 Percentile).

This Scenario examines the effects of wet seasons on the water resources in meeting water demands in the basin.

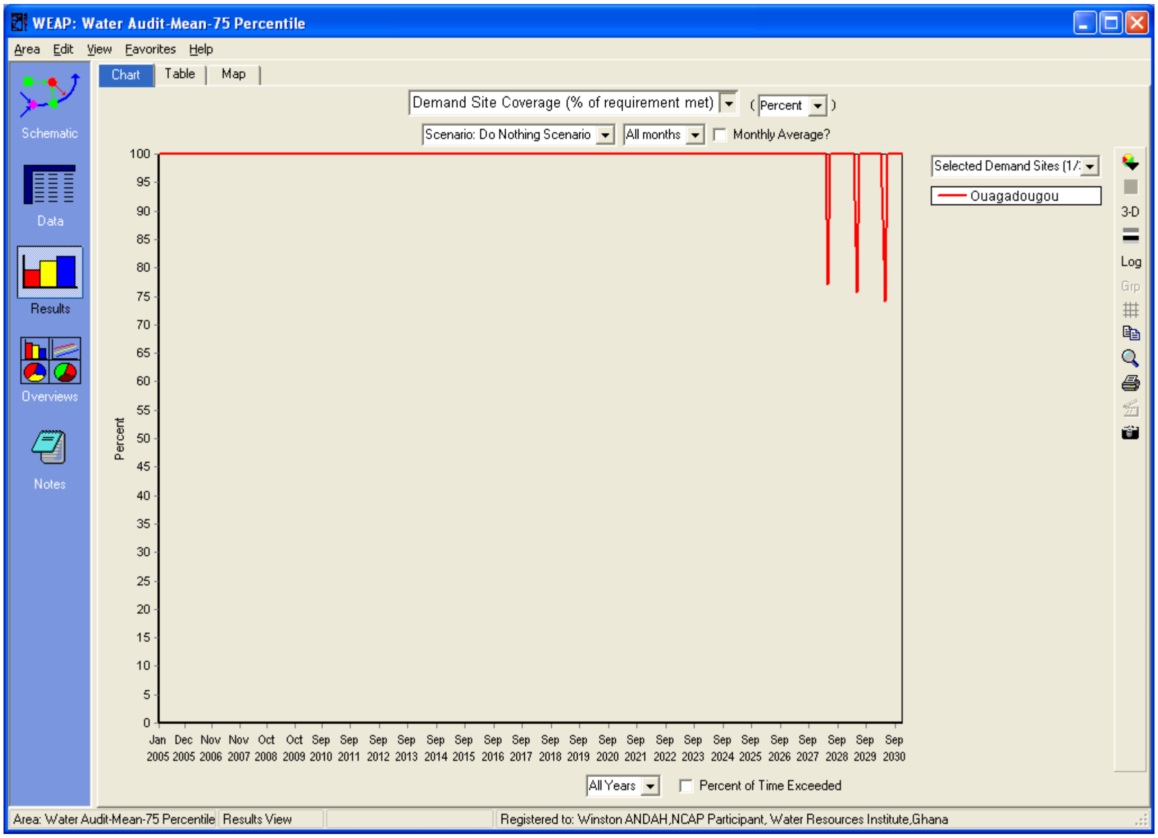
The results obtained from the running of the model indicate that for:-

i) *Domestic Water Supply;*

This scenario results in:-

- Ouagadougou will experience few water shortages during the year 2030.
- sufficiency of water resources to meet the requirements in Bolgatnaga, Bimbila, Wulensi, Chereponi, Saboba, Poutenga, Ouahigouya and Bobo Dioulasso throughout the plan period. These demand sites will have 100% demand coverage.

Ouagadougou



WEAP: Water Audit-Mean-75 Percentile

Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (1/

All Years | ☐ Percent of Time Exceeded

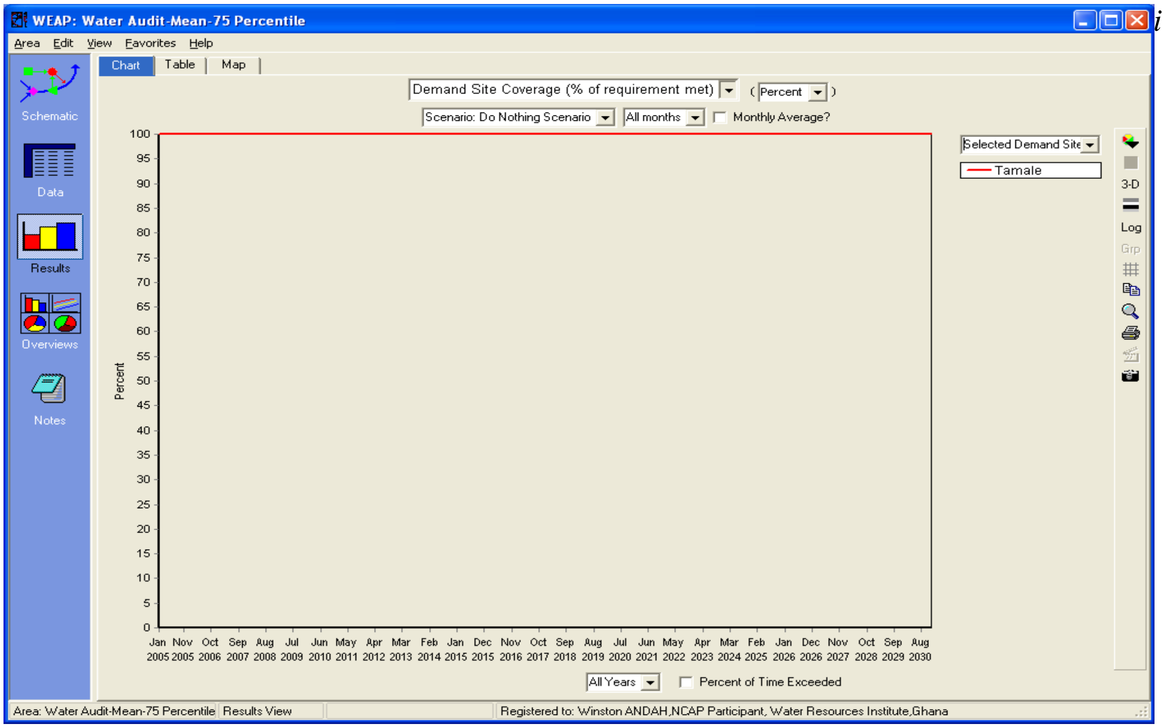
Area: Water Audit-Mean-75 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5.14: Demand Coverage - Ouagadougou

During high flows, Ouagadougou will experience few water shortages. But the overall demand coverage for the period is encouraging. The coverage for 2015 and 2020 will be 100%. The overall water demand coverage for year 2030 is 96.9%. During 2030, all the months will experience 100% coverage with the exception of April and May whose coverage will be 88.6% and 74.2% respectively. Thus, if composition of various sources is unchanged, i.e. groundwater contributing 10% of the total supply, Loumbila Dam 20% and the rest of 70% contributes by Ziga Dam.

Tamale

During high flows, Tamale will have enough water to meet its demand requirements in 2015, 2020 and 2030.



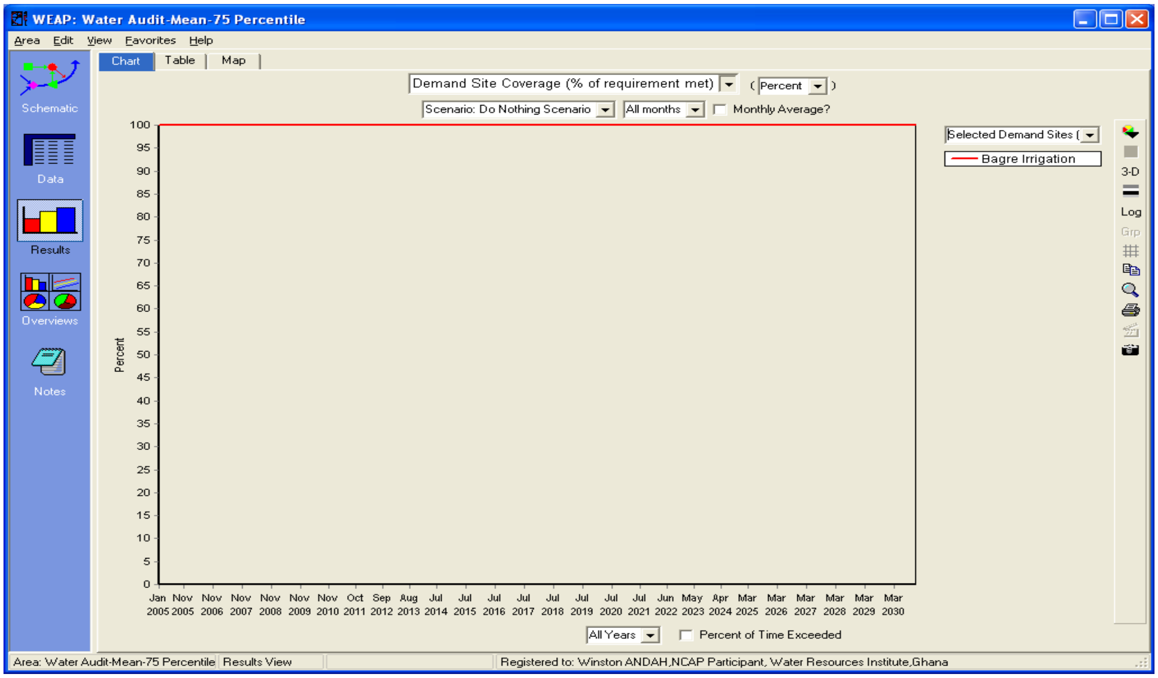
Demand Site Coverage (% of requirement met) (Percent)
Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?
Selected Demand Site
All Years | ☐ Percent of Time Exceeded
Area: Water Audit-Mean-75 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5.15: Demand Coverage - Tamale

ii) *Irrigation Water Supply;*
This scenario results in water shortages for Lac Bam Irrigations.

Bagre Irrigation

From the results, the Bagre Irrigation project will be able to meet its its crop water requirements during high rainfall seasons in 2015, 2020 and 2030.

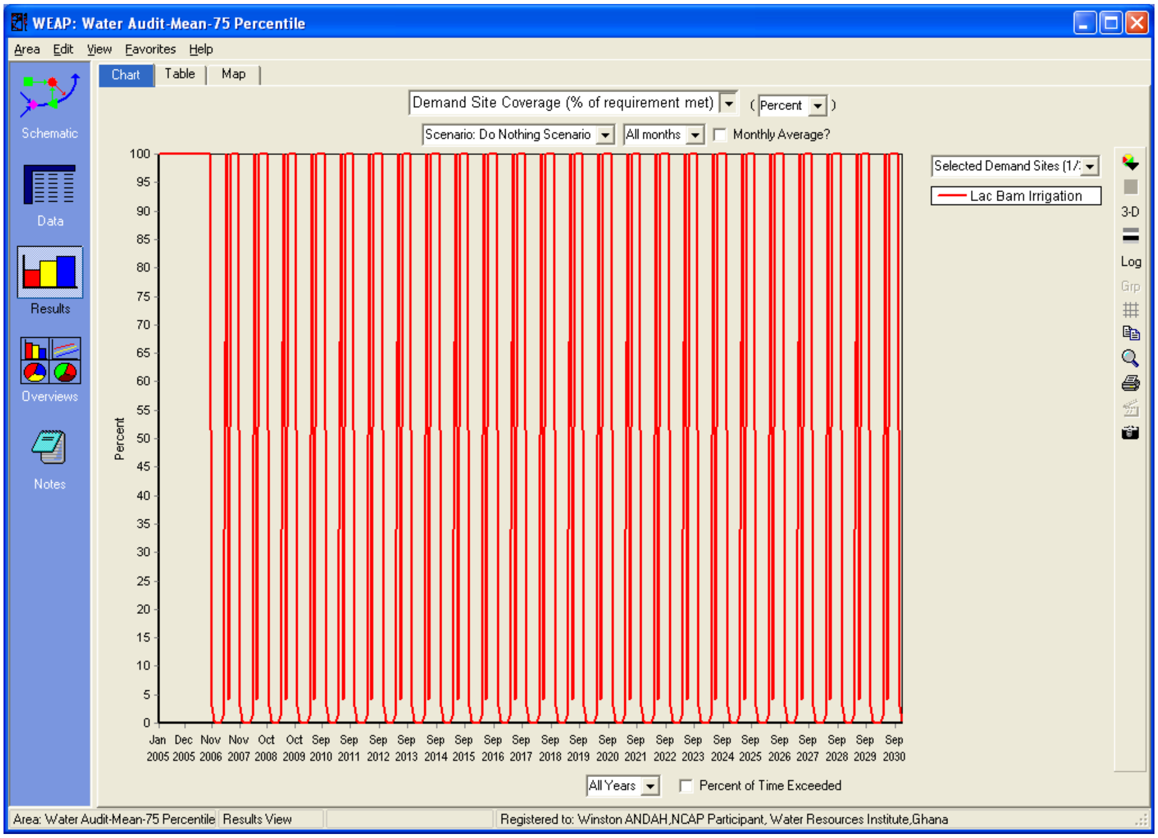


Demand Site Coverage (% of requirement met) (Percent)
Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?
Selected Demand Sites (
All Years | ☐ Percent of Time Exceeded
Area: Water Audit-Mean-75 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5:16: Demand Coverage – Bagre Irrigation

Lac Bam

Lac Bam Irrigation project will still be affected during wet seasons. The irrigation water demand coverage will be around 42.4% in 2010, 2015, and 2020 through to 2030. The results indicate that 186,093 m^3 of water will require every year supplement the irrigation water demand. In December, January, February and March, there will be barely water to irrigate the crops. The water demand coverage for Lac Bam Irrigation as depicted in the fig 5.17.



WEAP: Water Audit-Mean-75 Percentile

Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (1/ | Lac Bam Irrigation

All Years | ☐ Percent of Time Exceeded

Area: Water Audit-Mean-75 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5:17: Demand Coverage – Lac Bam Irrigation

5.5.5 The "Wet" Scenario (75 Percentile)

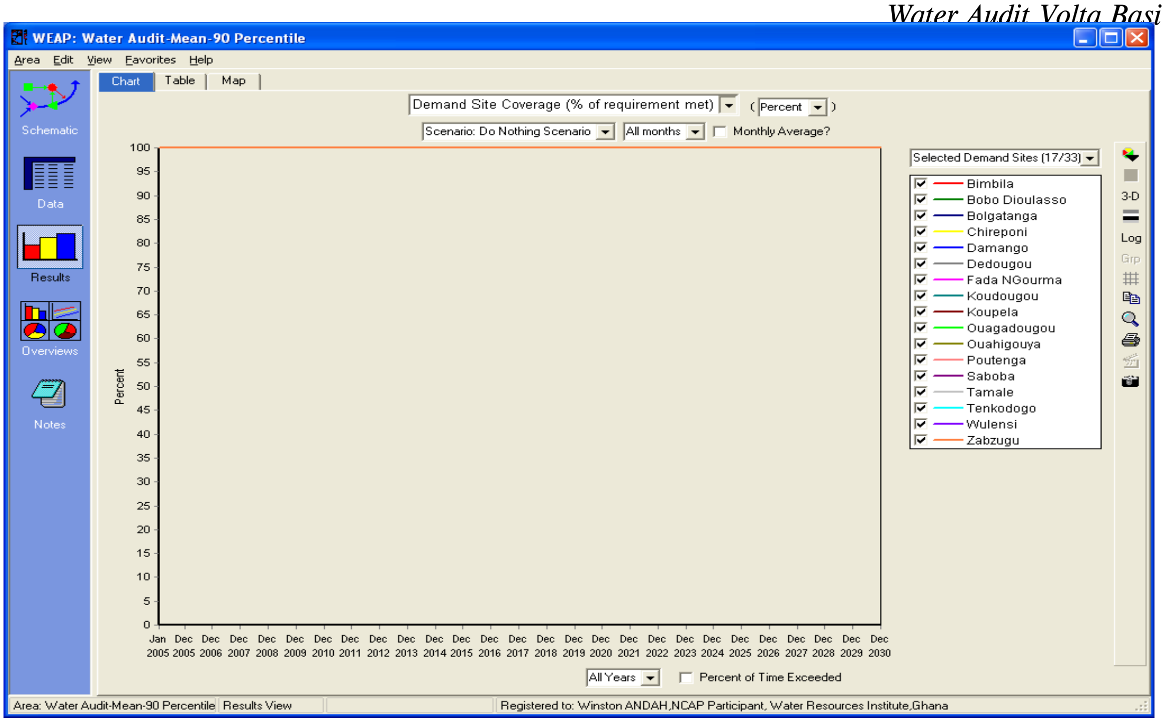
This Scenario examines the effects of very wet seasons on the water resources in meeting water demands in the basin.

The results obtained from the running of the model indicate that for:-

i) *Domestic Water Supply;*

This scenario results in:-

- Sufficiency of water resources to meet the water requirements in Ouagadougou, Tamale, Bolgatnaga, Bimbila, Wulensi, Chereponi, Saboba, Poutenga, Ouahigouya, Bobo Dioulasso and all the domestic water demands in the basin throughout the plan period. These demand sites will have 100% demand coverage as indicated in fig 5.18



Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (17/33)

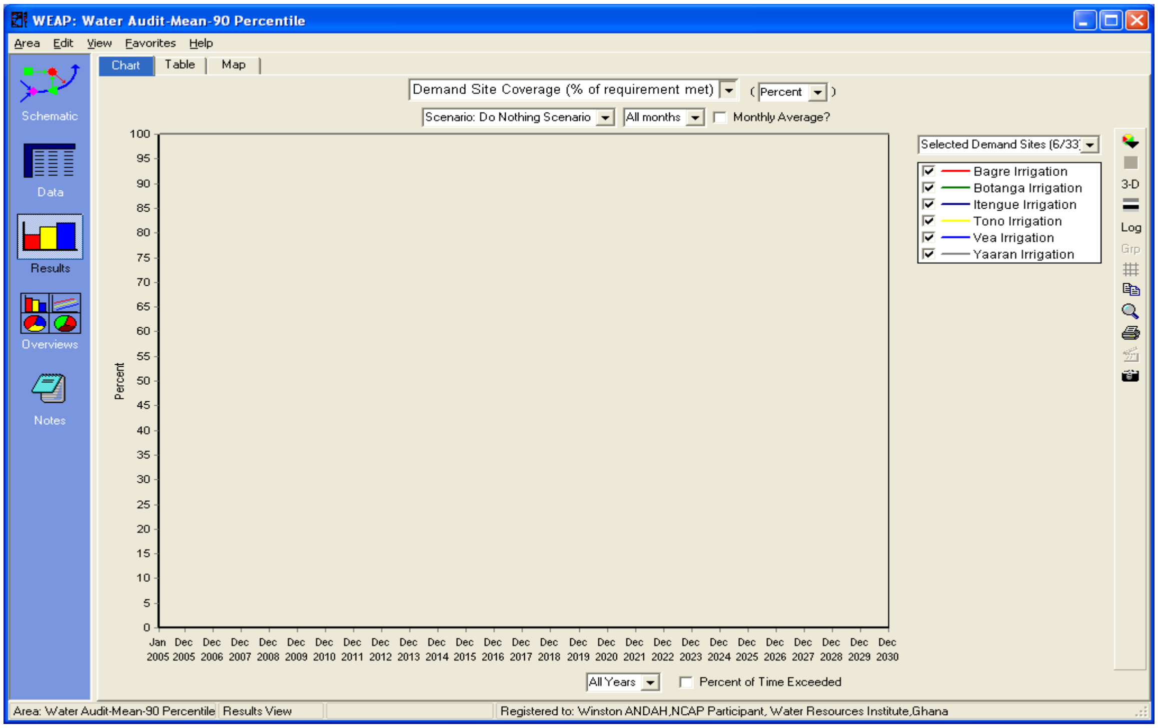
All Years | ☐ Percent of Time Exceeded

Area: Water Audit-Mean-90 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5.18: Demand Coverage – Domestic Demand Sites

ii) *Irrigation Water Supply*

This scenario results indicate that there are enough water resources to meet irrigation water requirements in all irrigation demand sites with the exception of Lac Bam Irrigation which will experience water shortages. The shortages in Lac Bam Irrigation are not due to the paucity of resources supply but can be attributed to infrastructural limitation.



Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (6/33

All Years | ☐ Percent of Time Exceeded

Area: Water Audit-Mean-90 Percentile | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

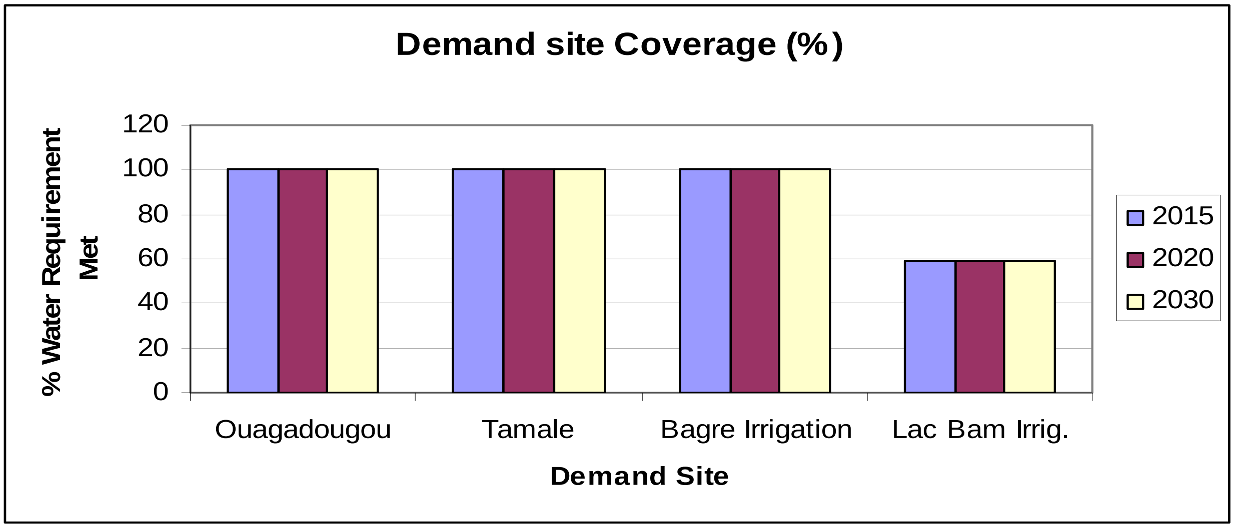
Fig 5.19: Demand Coverage – Irrigation Demand Sites

Lac Bam

Lac Bam Irrigation project will still be affected during very wet seasons. The irrigation water demand coverage will be around 59.1% in 2010, 2015, and 2020 through to 2030. The results indicate that 138,823 m^3 of water will require every year supplement the irrigation water demand. In December, January, February and March, there will be barely water to irrigate the crops.

Table 5.5: Demand Site Coverage Wet Year scenario (% of water requirement met)

Demand Site	2015	2020	2030
Ouagadougou	100	100	100
Tamale	100	100	100
Bagre Irrigation	100	100	100
Lac Bam Irrig.	59.1	59.1	59.1



5.5.6 The "Climate Change" Scenario

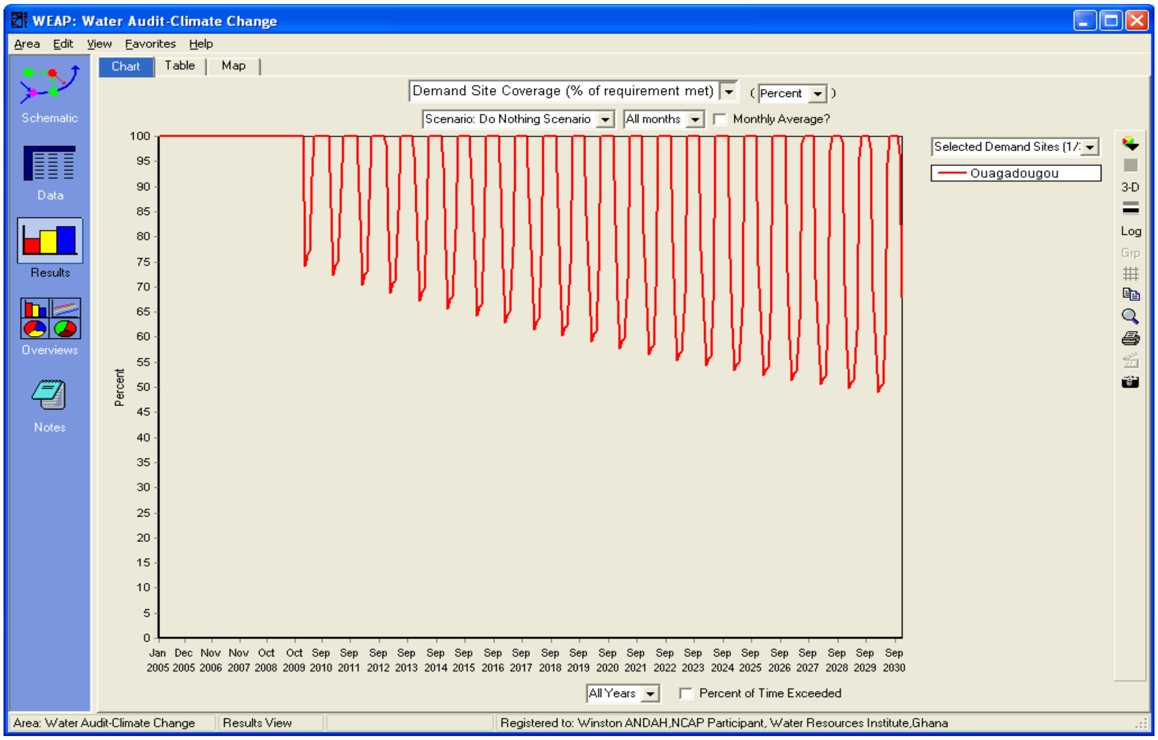
This Scenario examines the impact of climate change on water resources in the basin in meeting increasing demand. The results obtained from the running of the model indicate that discharges are sensitive to changes in climate. The magnitudes of the changes are approximately similar to "dry" scenario for the year 2015 and "very dry" scenario for the 2030. This impact of climate change on water resources could have serious consequences on the socio-economic development of the basin.

i) *Domestic Water Supply;*

This scenario results in:-

- pronounced water shortages during the dry months for these demand sites i.e. Ouagadougou, Tamale and Damango,
- sufficiency of water resources to meet the requirements in Bolgatnaga, Bimbila, Wulensi, Chereponi, Saboba, Poutenga, Ouahigouya and Bobo Dioulasso throughout the plan period. These demand sites will have 100% demand coverage.

Ouagadougou



WEAP: Water Audit-Climate Change

Demand Site Coverage (% of requirement met) (Percent)

Scenario: Do Nothing Scenario | All months | ☐ Monthly Average?

Selected Demand Sites (1/…

All Years | ☐ Percent of Time Exceeded

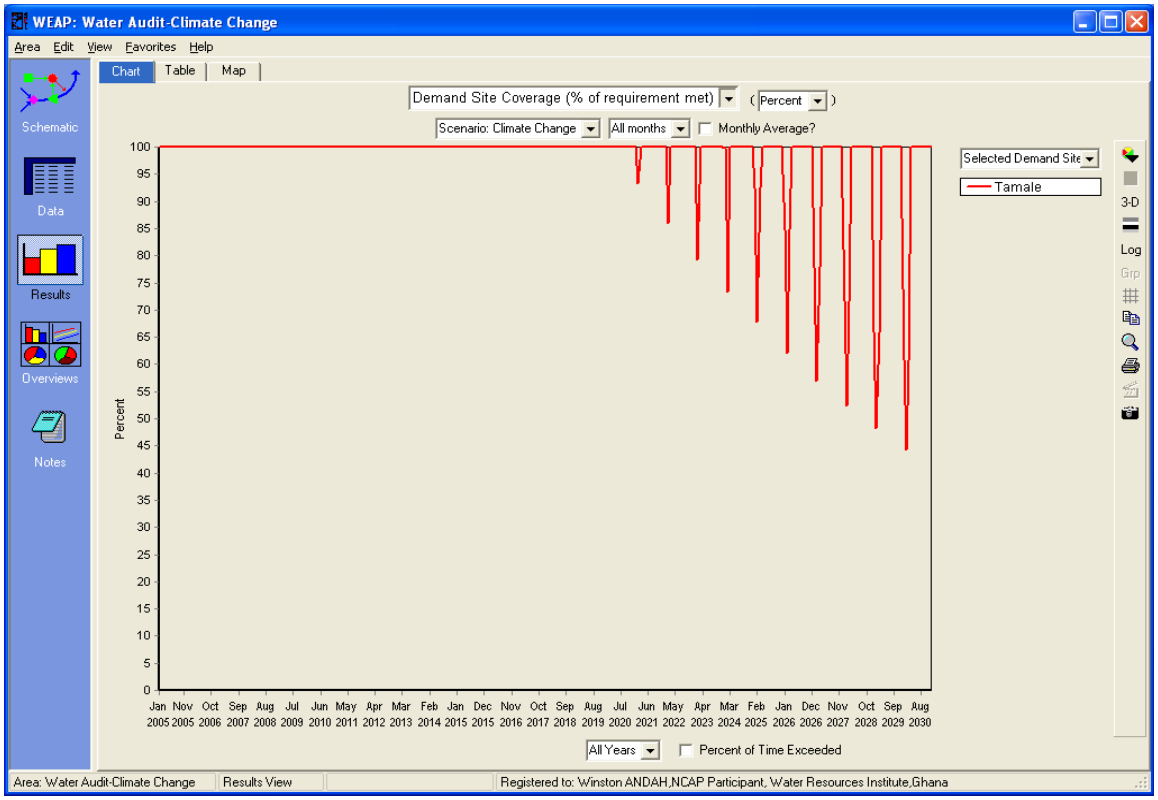
Area: Water Audit-Climate Change | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5.20: Demand Coverage - Ouagadougou

As a consequence of climate change, Ouagadougou will experienced water shortages right from 2009. The water demand coverage will be around 87.7% in 2015, 83.5% in 2020 and in 2030 only 68.9% of the water demand will be met. Thus, if composition of various sources is unchanged, i.e. groundwater contributing 10% of the total supply, Loumbila Dam 20% and the rest of 70% contributes by Ziga Dam. In 2015, Ouagadougou will need a top up of about 410,763 m^3 of water to meet the yearly demand, 636,633 m^3 of water in 2020 and 1.57 million m^3 will be needed to make up the deficit in 2030. The deficit usually occurs from December to May.

Tamale

With the impact of climate change, Tamale will experience water shortages especially during months of January, February and March. Water demand coverage in 2015, 2020, 2024, 2027, 2029 and 2030 will be 100%, 100% 99.8%, 97.9%, 95% and 93.4% respectively. Thus, 5,234 m^3, 63,177 m^3, 169,826 m^3 and 231,887 m^3 of water will be needed to supplement demand requirement in 2024, 2027, 2029 and 2030 respectively.



Demand Site Coverage (% of requirement met) (Percent)

Scenario: Climate Change

All months

☐ Monthly Average?

All Years

☐ Percent of Time Exceeded

Area: Water Audit-Climate Change | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

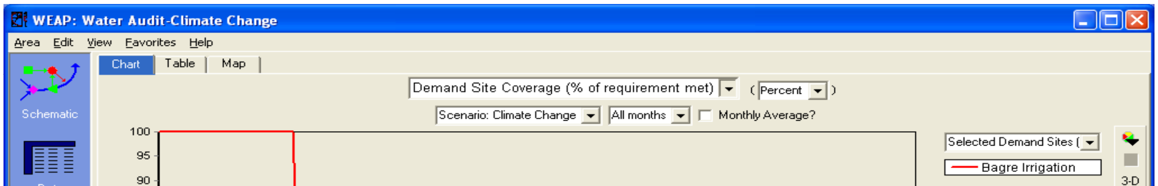
Fig 5.21: Demand Coverage - Tamale

ii) *Irrigation Water Supply;*

This scenario results in pronounced water shortages at Bagre and Lac Bam Irrigations.

Bagre Irrigation

From the results, the Bagre Irrigation project will be severely hit. The water demand coverage will be around 29.9% in 2015, 23.8% in 2020 and in 2030 only 14.5% of the water demand will be met. January to April are the months that will be severely hit as shown. In 2015, Bagre Irrigation project will need a top up of about 1.7 million m^3 of water to meet irrigation water requirement and 2 million m^3 will be needed to make up the deficit in 2030. The deficit usually occurs from December to May.



Demand Site Coverage (% of requirement met) (Percent)

Scenario: Climate Change

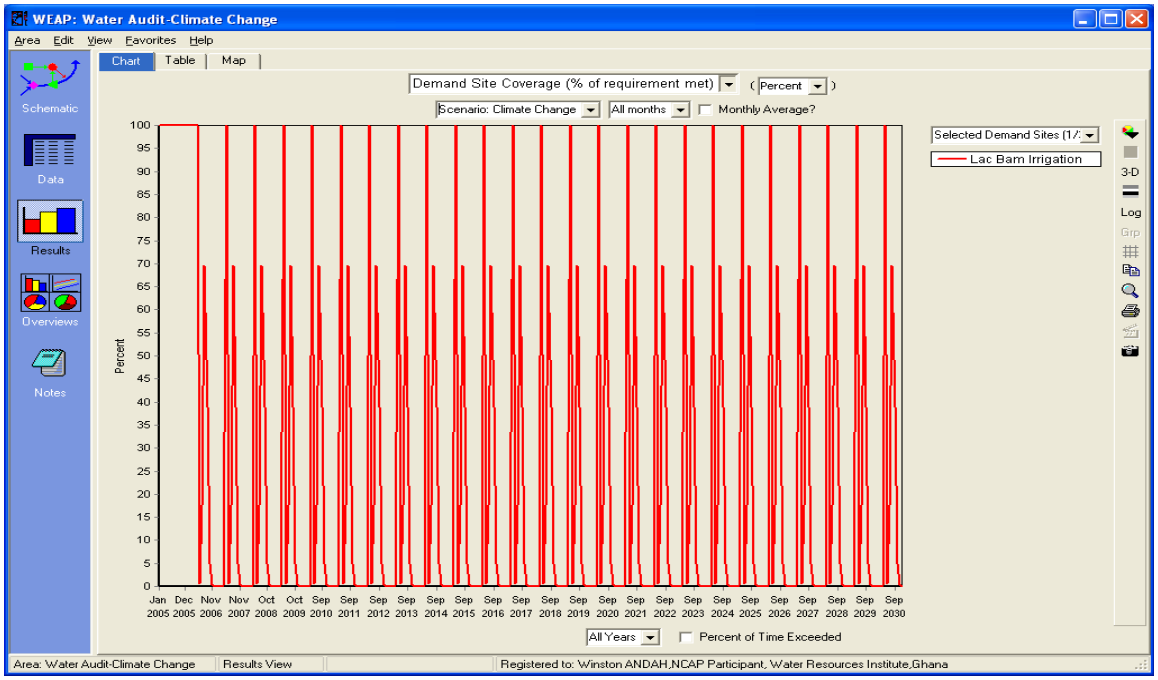
All months

☐ Monthly Average?

Fig 5:22: Demand Coverage – Bagre Irrigation

Lac Bam

Lac Bam Irrigation project will be severely affected during dry seasons. The irrigation water demand coverage will be around 17.9% in 2010, 2015, and 2020 through to 2030. The results indicate that 265,096 m3 of water will require every year supplement the irrigation water demand. In December, January, February and March, there will be barely water to irrigate the crops. The water demand coverage for Lac Bam Irrigation as depicted in the fig 5.23.



WEAP: Water Audit-Climate Change

Demand Site Coverage (% of requirement met) (Percent)

Scenario: Climate Change | All months | ☐ Monthly Average?

Selected Demand Sites (1/

All Years | ☐ Percent of Time Exceeded

Area: Water Audit-Climate Change | Results View | Registered to: Winston ANDAH,NCAP Participant, Water Resources Institute,Ghana

Fig 5.23: Demand Coverage – Lac Bam Irrigation

Table 5.6: Demand Site Coverage Climate Change scenario (% of water requirement met)

Demand Site	2015	2020	2030
Ouagadougou	87.7	83.5	68.9
Tamale	100	100	93.4
Bagre Irrigation	29.9	23.8	14.5
Lac Bam Irrig.	19.3	19.3	19.3

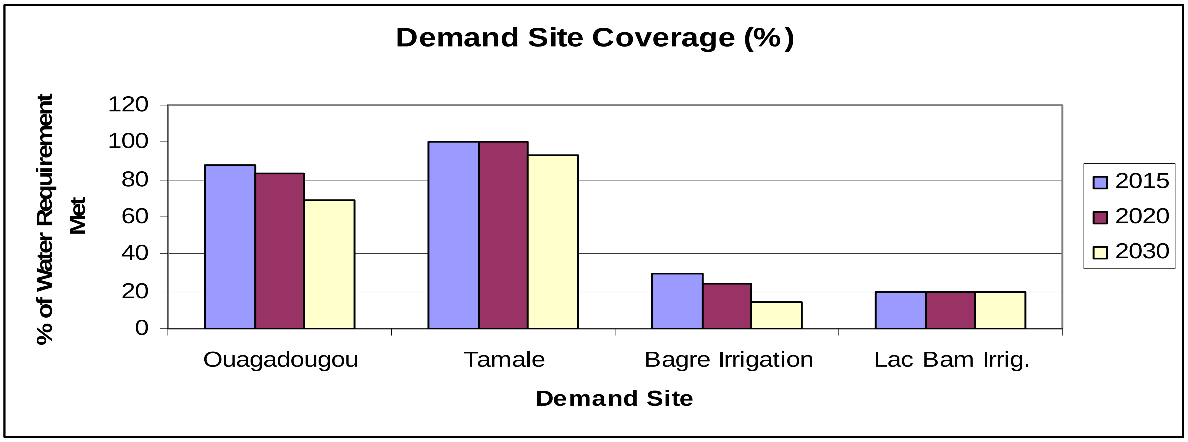
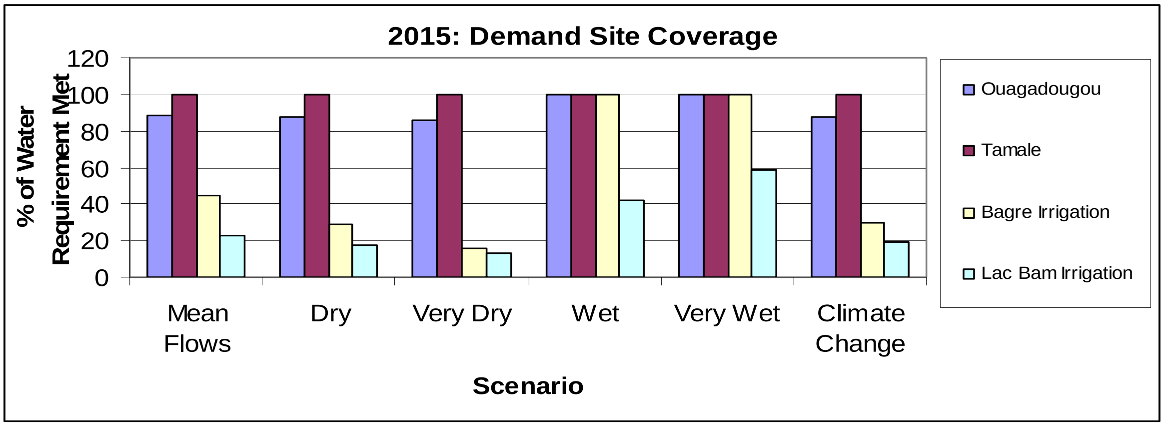


Table 5.7: Summary of Demand Coverages under various Water Availability scenarios

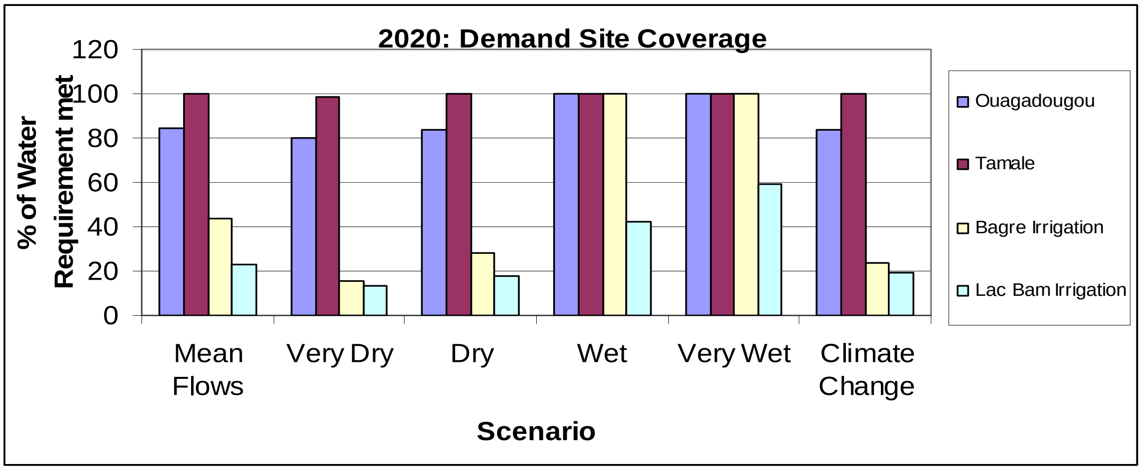
Year 2015: % of Water Requirement Met

Scenario	Demand Site			
	Ouagadougou	Tamale	Bagre Irrigation	Lac Bam Irrigation
Mean Flows	88.3	100	44.5	23.0
Very Dry	85.7	99.8	15.5	13.5
Dry	87.4	100	28.8	17.9
Wet	100	100	100	42.4
Very Wet	100	100	100	59.1
Climate Change	87.7	100	29.9	19.3



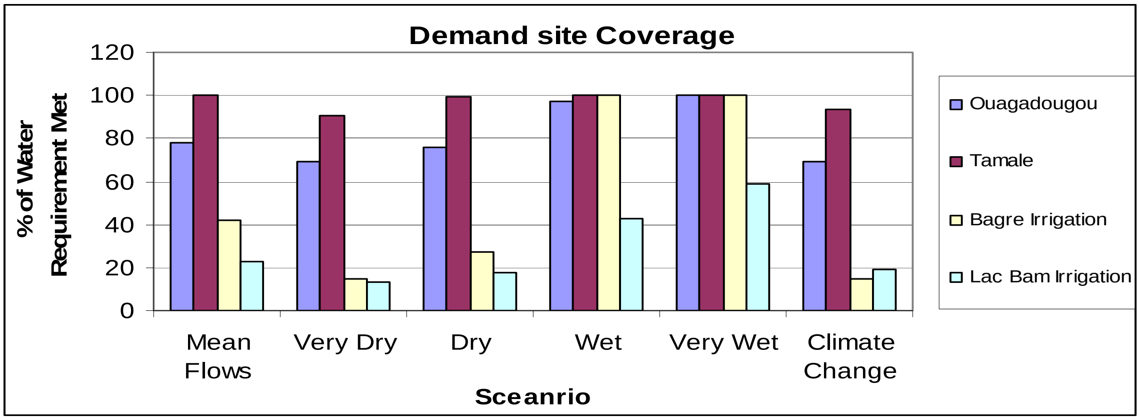
Year 2020: % of Water Requirement Met

Scenario	Demand Site			
	Ouagadougou	Tamale	Bagre Irrigation	Lac Bam Irrigation
Mean Flows	84.4	100	43.8	23.0
Very Dry	80.3	98.3	15.2	13.5
Dry	83.5	100	28.2	17.9
Wet	100	100	100	42.4
Very Wet	100	100	100	59.1
Climate Change	83.5	100	23.8	19.3



Year 2030: % of Water Requirement Met

Scenario	Demand Site			
	Ouagadougou	Tamale	Bagre Irrigation	Lac Bam Irrigation
Mean Flows	78.4	100	42.1	23.0
Very Dry	68.9	90.7	14.6	13.5
Dry	76.0	99.6	27.1	17.9
Wet	96.9	100	100	42.4
Very Wet	100	100	100	59.1
Climate Change	68.9	93.4	14.5	19.3



6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the study, it is concluded that:-

i) The audit has enabled the gaps in the flow data at the selected stations to be filled by using:-
    a) The SMAP Rainfall/Runoff Model for Burkina Faso
    b) Multiple Regression Analysis of hydrological and meteorological parameters in Ghana.

ii) The results of the different methods were preliminarily accepted for use in the assessment of water availability because a random check of results obtained by estimating the flows at Pwalugu with the SMAP Model showed good agreement with the results obtained by the Regression method.

iii) Long-term flow statistics have been computed for the stations for various water availability scenarios (viz means, extremes and climate change).

iv) A water availability/water demand (domestic, industrial, irrigation, environment) balance model has been constructed using the WEAP model to cover the period 2005 to 2030. The model has been run on the "Do Nothing" scenarios and the preliminary results show that for:-
    a) Domestic and industrial water demand;
        - Present supply will be inadequate to meet the demand in Ouagadougou from 2015 up to 2030;
        - The demand in Tamale will not be met in the dry season even for now. On an annual basis, the demand can be met except under climate change impact.
    b) Irrigation
        - The demand cannot be met by the supply from the Bagre and Lac Bam dams will not be met from 2008.

v) The Development options available to meet shortfalls include:-
    a) Increasing storage at the intake of the Tamale water supply;
    b) Create new surface storage for the Bagre Irrigation project or do away with the plan to bring additional land under irrigation or mobilize groundwater to supplement the surface supply.
    c) Using non-structural means such as Water Demand Management and Regulatory Measures.
    d) The impact of the above options are yet to be evaluated.

vi) *Decisions Support System*: That the WEAP Model was selected for use as the DSS for the Volta Basin shared between Burkina Faso and Ghana. The selection was based on the fact that it is cheaper and the data requirements are manageable.

6.2 Recommendations

The following recommendations are submitted for consideration:-

i) The data-bases of the two countries should be harmonized. The organization of the data base for IWRM is not the same in the two countries. Burkina Faso is better organized with spatial presentation of data within basin and administrative frameworks. The use of GIS data bases and GIS ArcView are well developed. Ghana on the other hand organizes its data on administrative framework.

ii) The gaps in the river flows and their extension to cover other years were done by different methods. It will be necessary that the two countries investigate and adopt a method agreeable to them. This should take into account the GLOWA Volta and the Challenge Programme on Water for Food.

iii) The present and future water demands are based on different standards (e.g. per capita water use per day). It will be important to adopt one standard wherever feasible.

iv) The model will have to be refined by disaggregating the demands for irrigation and livestock and assigned their proper locations in the sub-basins so as to avoid skewing the results.

v) The only current water quality information was gathered from the field during the Pre-Water Audit. The information is not adequate to assess trends in surface water quality. Consequently, stream flow and ground water quality monitoring should form an important part of water resource monitoring. Stream flow should be monitored at all the 19 selected stations on a regular and long-term basis. This should be harmonized with the Volta-HYCOS Project.

vi) The Groundwater Assessment Project in Ghana should provide data on the groundwater characteristics at Sub-basin and if possible at demand site levels. Similar assessment need to be carried out on the Burkina Faso using the data from the 38 monitoring stations of DGIRH. The information should be used to run the model for a more accurate assessment of the groundwater potential to meet future demand.

vii) As the data on hydropower was incomplete, the model run did not incorporate this. The data about the flow and reservoir characteristics should be completed and used to re-run the model to find the impact various flow sequences.

7. LIST OF PERSONS CONTACTED

1.	Dr. Charles Biney:	Executive Director, Water Resources Commission (WRC)
2.	Mr. Minta Aboagye:	Director, Water Directorate, Ministry of Water Resources, Works and Housing (MWRWH)
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18.	Jacob W. Tumbulto:	Cor-ordinator, Volta – HYCOS, Ouagadougou.

8. LIST OF DOCUMENT CONSULTED

1. B.A. Amisigo, N.C. van de Giesen (2005) Using a spatio-temporal dynamic state-space model with EM algorithm to patch gaps in daily river flow series.

2. Bart J.M. Goes (2005): Pre-Water Audit for the Volta River Basin.

3. Baseline Report No. 8 (2006): CCIAR Challenge Programme on Water for Food

4. GEF (2002): Volta River Basin Preliminary Transboundary Diagnostic Analysis. Final Report. Global Environment Programme. Pre-Feaseability.

5. Ghana Statistical Service – 2002: 2000 Population and Housing Census. Special Report on 20 Largest Localities. Republic.

6. Kunstman H and G Jung (2005): Impact of Regional Climate on Water Availability in the Volta Basin of Vest Africa in: Re Regional Hydrological Impacts of Climate Variability and Change – Impact Assessment and Decision Making, IAHS publication 295 p. 75-85.

7. Nii Consult – 1998: Water Resources Management Study - Information Building Block Study Part II. Volume 2: Information in the Volta Basin System (Final Report) Ministry of Works and Housing.

8. Nippon Koei Company Limited – 1967: Report on the Lower White Volta Basin Development Project Volume I – Main Report. Ministry of Lands and Mineral Resources Government of the Republic of Ghana.

9. Nippon Koei Company Limited – 1967: Report on the Lower White Volta Basin Development Project Volume II – Appendices 1. Ministry of Lands and Mineral Resources Government of the Republic of Ghana.

10. Nippon Koei Company Limited – 1967: Report on the Lower White Volta Basin Development Project Volume III Appendices 2. Ministry of Lands and Mineral Resources Government of the Republic of Ghana.

11. Nippon Koei Company Limited – 1967: Preliminary Report on Comprehensive Development Project of Water Resources in South Western Ghana Ministry of Lands and Mineral Resources Government of the Republic of Ghana.

12. Snowy Mountain Engineering Corporation – 1976: Bui Hydro-electric Project. Feasibility Report – Commissioned for the Government of Ghana. Prepared for the Government of Australia under the Special Commonwealth African Assistance Plan.

13. Tahal Consulting Engineers – 1997: Strategic Investment Program. Interim Report. Ministry of Works and Housing. Ghana Water and Sewerage Corporation. The Republic of Ghana.

14. Bulletin Agrométéorologique décadaire, 2004

15. Bulletin Agrométéorologique décadaire, 2005

16. Calcul hydrologiques, Institut Hydrologique de l'ENINGRAD-URSS 1970, K.P. KLIBACHEV et I.F. GOROCHKOV

17. Cours d'hydrologie, SAIDI Mohamed El Mehdi, Faculté des Sciences et Techniques MARRAKECH

18. État des lieux des ressources en eau du Burkina Faso et de leur cadre de gestion, ministère de l'Environnement et de l'Eau, Mai 2001

19. Méthodes de calcul pour les études hydrologiques concernant l'aménagement des eaux, UNESCO 1985 Paris, B.S. Eichert, G.A. Sokolor, Président

20. Note technique (NT- A.1.3.1) Résultat 1.3 : Demande en eau connue et pertinence du suivi analysée, Activité A1.3.5 : Estimer les demandes. Avril 2000

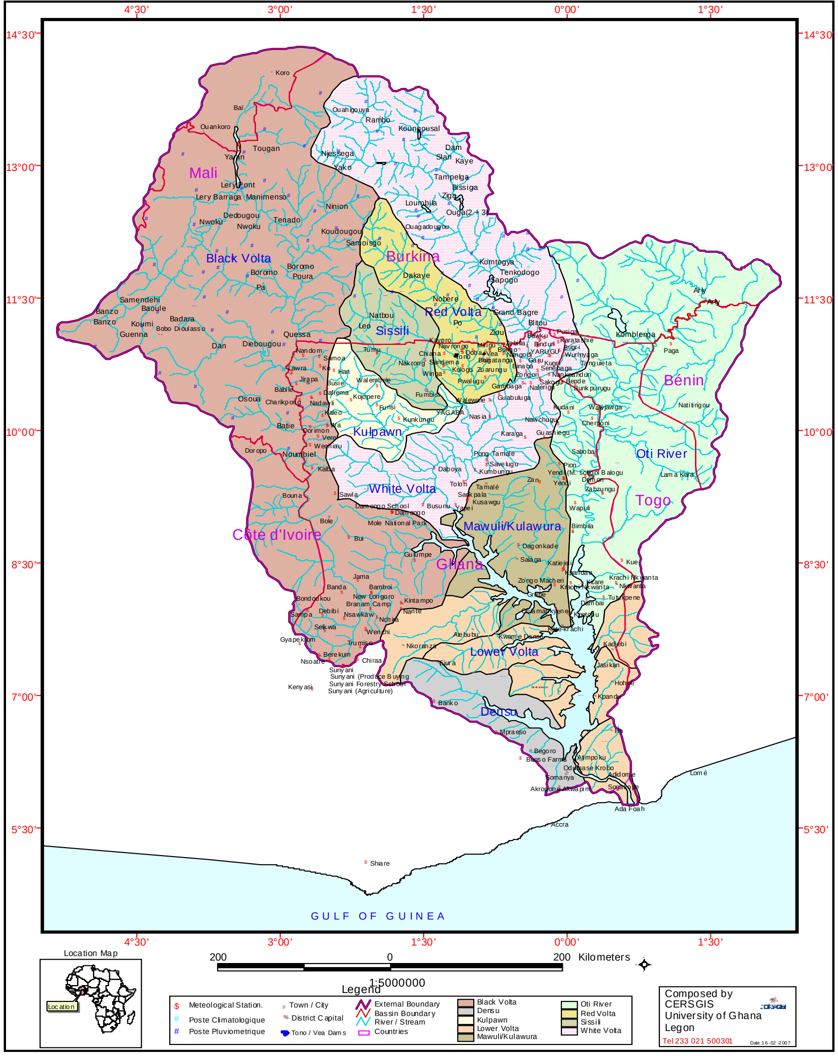
21. Politique et stratégies en matière d'eau, ministère de l'Environnement et de l'Eau, juillet 1998

22. Rapport technique n° RT-OTEG-R 1.1, Connaissance des ressources en eau sur le plan quantitatif, Pertinence du système de suivi, Avril 2001

MAPS

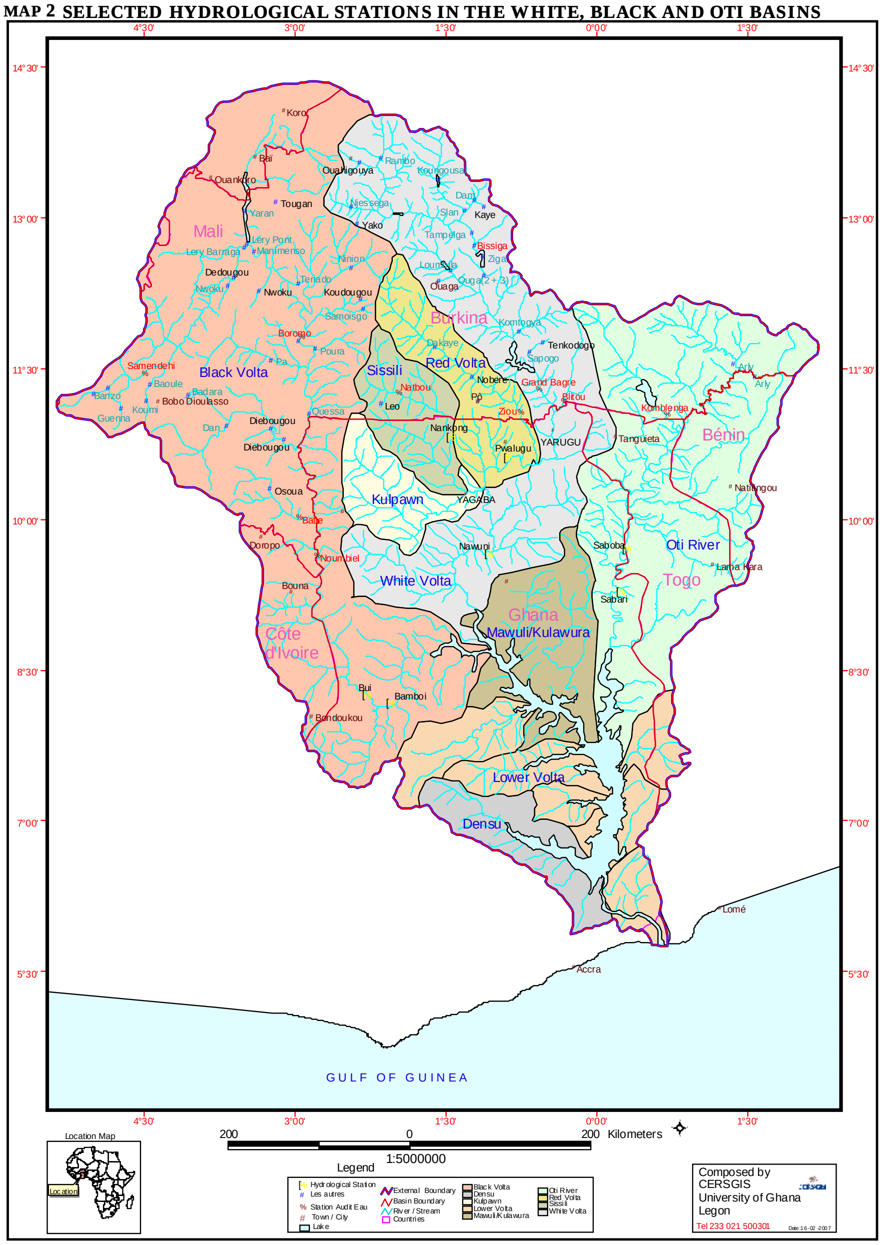
VOLTA BASIN WATER AUDIT:

MAP1 SELECTED METEOLOGICAL STATIONS IN THE WHITE, BLACK AND OTI BASINS

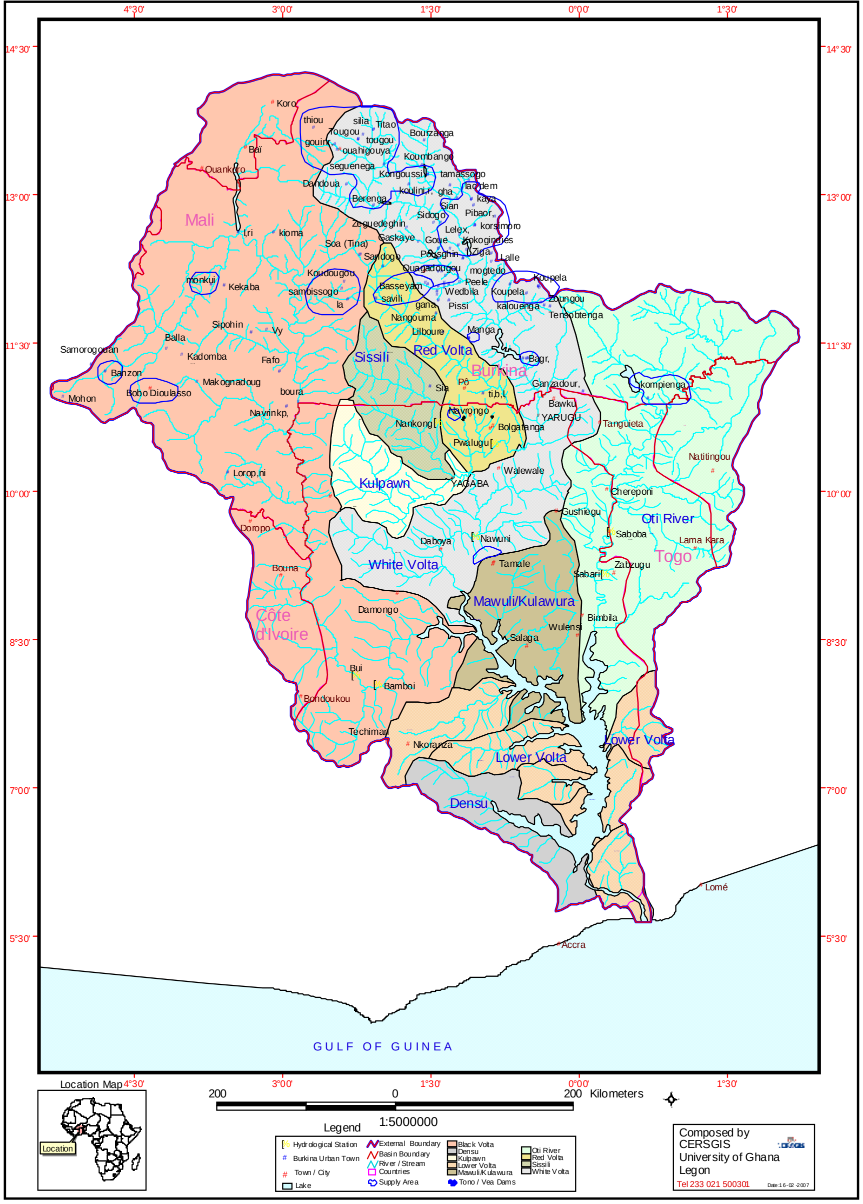


VOLTA BASIN WATER AUDIT:

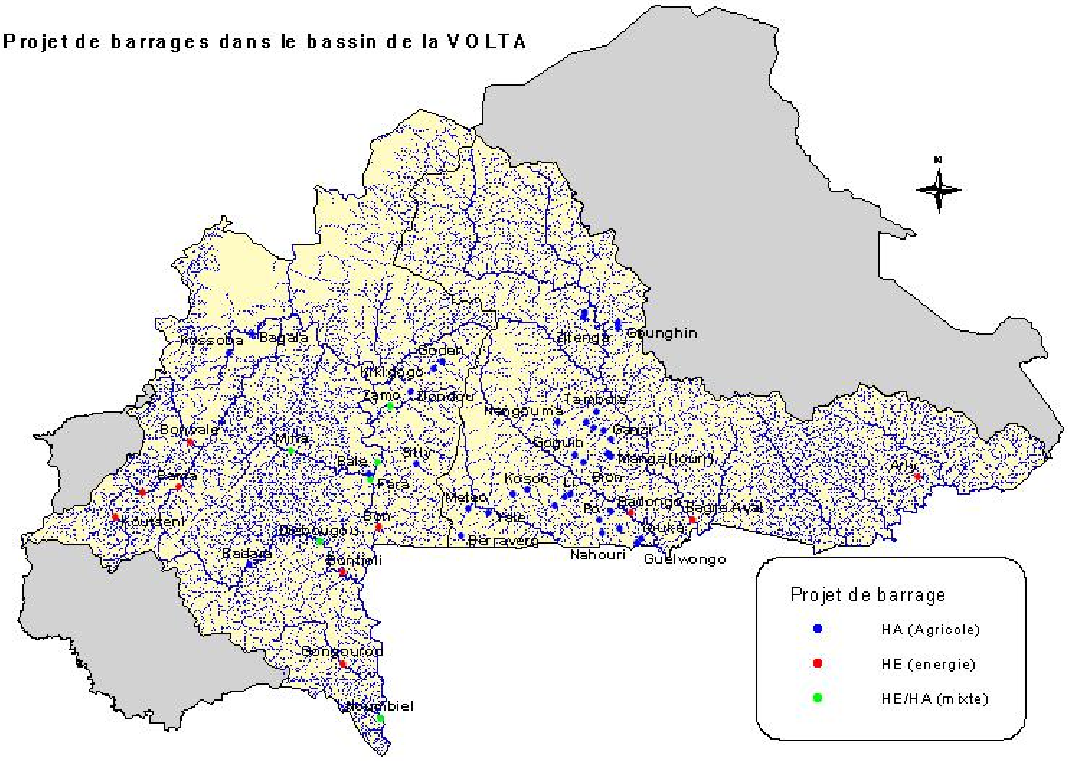
MAP 2 SELECTED HYDROLOGICAL STATIONS IN THE WHITE, BLACK AND OTI BASINS



VOLTA BASIN WATER AUDIT:
MAP 3 MAJOR TOWNS AND CITIES IN THE WHITE, BLACK AND OTI BASINS



Map 4: Proposed Dams in Burkina Faso



Map 5: Water Reservoirs in the Upper East Region (Ghana)

WATER RESERVOIRS IN THE UPPER EAST REGION (GHANA)