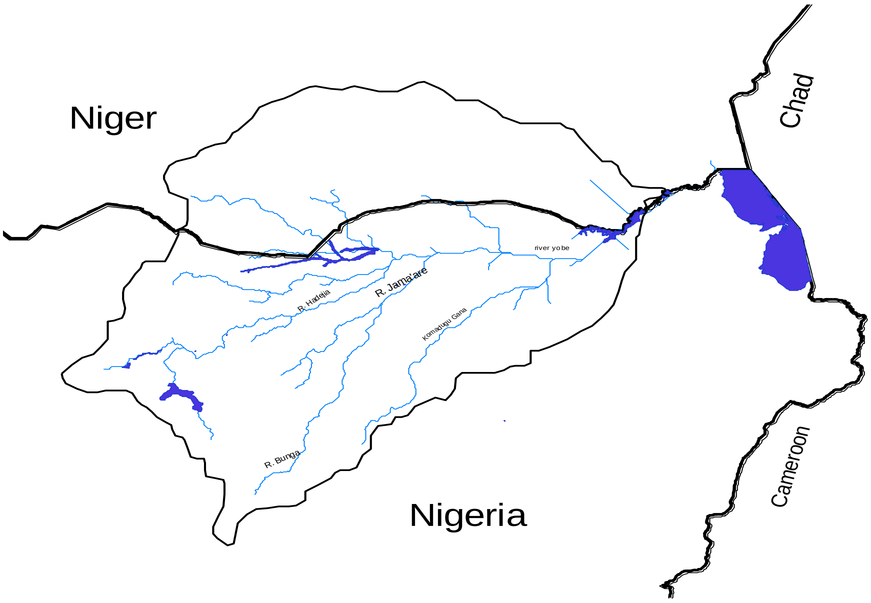
FMWR-IUCN-NCF KOMADUGU YOBE BASIN PROJECT 2006

WATER AUDIT

for

Komadugu Yobe Basin



Final Report

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May 2006

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Foreword

During the last 36 years, parts of Komadugu Yobe Basin (KYB) have been at the forefront of watershed development and other innovative programmes aimed at tackling the challenges of poverty alleviation and environmental sustainability. The period witnessed unprecedented development at the upper reaches of the basin, which led to significant socio-economic advances but this was at a cost of several environmental degradation and some socio-economic dislocations. In response to the increasing evidence of deterioration of the KYB's water situation and the river system, as well as the growing community concern over their impact on their livelihood, the Coordinating Committee of Hadejia-Jama'are-Komadugu-Yobe Basin (HJKYBCC) was formed in 1999 to coordinate and foster cooperation towards adaptive Integrated Water Resources Management (IWRM) across the basin. The logical starting point for the HJKYBCC was to direct the preparation of a water audit to assess water use in the basin, comment on the effects of the projected increases, and assess the likelihood and potential impact of further increases in the future. Handicapped by lack of funds to implement this and other water management related interventions that were considered necessary to set the stage for IWRM, the HJKYBCC through the Federal Ministry of Water Resources (FMWR) entered into a joint initiative with the West African Office of World Conservation Union (IUCN-BRAO) and the Nigerian Conservation Foundation (NCF) to implement the Project for "Improving Land and Water Resources Management in the Komadugu Yobe Basin" or simply the Komadugu Yobe Basin Project (KYBP). Among the components of KYBP are Water Audit, a Decision Support System (DSS) and a Catchment Management Plan (CMP). The project is being implemented in six Nigerian States of Plateau, Kano, Jigawa, Bauchi, Yobe and Borno and two regions, Diffa and Zinder, of the Niger Republic.

The Water Audit has highlighted the need for greater attention to data collection and collation, but most especially to the accuracy of official statistics held by different line Ministries, departments and relevant organisations. As these statistics underpin decision-making at all levels, increased effort is also required to make water-related information accessible to those who need it. Furthermore, the KYB Water Audit makes recommendations for policies and interventions, some of which take a long-term approach to developing and managing water resources in the region. These recommendations include practical strategies in which both the individual Local Governments and States in the KYB as well as collectively under the guidance of Federal Government of Nigeria and Niger Republic through River Basin Authorities (including Lake Chad Basin Commission) could introduce and pilot integrated water resource management systems. All the strategies have the aims of protecting basic water supplies, promoting equitable access to water for productive uses and enhancing the efficiency and productivity of water use at all levels. Given that demand and competition for water resources in KYB is almost certainly going to intensify in coming years, the contribution of the Water Audit to on-going debates and policy formulation would be crucial.

The KYB Water Audit, when related in partnership with relevant line projects and complementary programmes, has shown that on-going water-related policies and programmes have produced and are still producing a range of benefits. However, the Water Audit has also identified situations in which current programmes run the risk of being victims of their own successes. For example, cases of continuous releases of water from Challawa Gorge and Tiga at the request of downstream communities have led to increase in invasive weeds. These in turn have resulted in blockages of the river channels, frequent flooding and reduction in overall utility of water releases for beneficial purposes.

The FMWR-IUCN-NCF KYB Project, DFID-supported Joint Wetlands Livelihoods (DFID-JWL) Project and the LCBC-GEF Project are complementing one another in providing an excellent opportunity to the various levels of governments in KYB. It is an opportunity to develop and assess novel approaches to helping communities and households overcome the complex water constraints and impediments that impact on all aspects of their livelihoods. The projects, especially the Water Audit, are also providing an opportunity to identify and build upon the successful components of existing water programmes and policies. There is no doubt in my mind that, where relevant, they will also provide opportunities to rethink and modify those strategies that either have been less successful or have resulted in unintended adverse consequences.

Alh. Muhtar S. Shagari
Hon. Minister of Water Resources
May 2006

Executive Summary

Background and Aims of KYBP Water Audit

In response to the increasing evidence of deterioration of the drought-prone Komadugu Yobe Basin's (KYB's) precarious water resources situation and the growing concern of the basin's communities, the Coordinating Committee of Hadejia-Jama'are-Komadugu-Yobe Basin (HJKYBCC) directed that a Water Audit be prepared.

The primary aims of the Water Audit were to (1) sssess the current status of water resources in the basin; (2) evaluate water-related demand trends in the basin; (3) study patterns of water-related access and entitlements of, in particular, poorer social groups; (4) consider gender and social exclusion issues surrounding access and entitlements to water for both domestic and productive purposes; (5) assess the functionality of water-related policies and institutions at the village, district and state levels; (6) identify improved resource management practices and policies; and (7) provide a practical framework for more productive, sustainable and/or equitable use of water resources. This report summarises the main findings and recommendations of the Water Audit.

Water management problems and the study approach

The water management problems in the basin include (i) scarcity of water due to climatic variations, (ii) limited knowledge about available water and about the nature and magnitude of water demands, (iii) increasing population in the basin, (iv) macrophyte and silt blockages in the Hadejia-Nguru Wetlands preventing the Hadejia River from contributing adequately to the Yobe River, (v) competitive unilateral development and operation of the two River Basin Development Authorities (RBDAs) in the basin, and (vi) lack of sufficient robust instruments to foster effective cooperation among the riparian States in the basin.

The approach adopted in this Water Audit exercise built on experiences from a 1999 Regional Land and Water Resources Development Planning Study (RLWRDPS) funded by the defunct Petroleum (Special) Trust Fund (PTF). Similar to RLWRDPS, the KYBP Water Audit started from the premise that planning data are scanty in Nigeria. Water balance techniques were used to assess current and future patterns of water availability, demands and uses. Information on access and entitlements to water, the functionality of village-level programmes and institutions were assessed.

Innovative methodologies

The Water Audit developed and refined a number of methodologies some of which were first used during the RLWRDPS. These included: (a) Geographical Information System (GIS), using secondary data, mostly collected during the pre-water audit study and in-filled with data obtained from field visits; (b) water auditing that combines terrestrial and remotely-sensed data; (c) a simple modeling technique for assessing the impact of water retaining structures on downstream water resource availability; (d) decision trees that use social, and institutional information along with physical information for targeting project interventions and activities; and (e) a simple GIS-based participatory assessment methodology for Maintenance and Evaluation of rural water supplies.

Physical characteristics of the basin

The KYB is a sub–catchment, 35%, of the larger Chad Basin, covering an area of 148,000 km^2, 57% of which lies in north-eastern Nigeria and the rest in south-eastern Niger. The Nigerian sector of KYB accounts for 95% of the basin's total contribution to the lake. The Hadejia and Jama'are rivers meeting in the Hadejia-Nguru Wetlands form the Yobe River draining into Lake Chad. The KYB is divided into Hadejia, Jama'are, Gana and Yobe sub-basins. Two large dams on the Hadejia sub-basin, viz; Tiga and Challawa Gorge, are currently feeding two large irrigation schemes and contributing to the Kano City Water Supply. The headwaters region in Plateau State, underlain by the basement complex rock, is the main source of water to the KYB.

The Hadejia River, joined by the Watari River upstream of Wudil in Kano State, is a gaining river until the geological boundary between the Basement Complex and the Chad Formation. River Jama'are rises from Jos Plateau and flows through Fogo, Bunga and Katagum to join River Hadejia system at Gashua within the Hadejia-

Nguru Wetlands (HNWs). The flow in the Jama'are River is ephemeral (June to October) because there are no major dams in this sub-basin. A dam is proposed on River Jama'are at Kafin Zaki. In the Gana sub-basin, the river flow reductions are, compared to the Jama'are and Hadejia rivers, relatively large. On average, the river flow reduction between Kari and Dapchi is 73%. The river forms a wide floodplain downstream of Dapchi. This river, thus, provides only a small and unreliable contribution to the Yobe River.

Socio-economic and environmental characteristics

The principal economic activities of the basin are mainly water dependent: agriculture, fishery, animal husbandry, and commerce. The estimated current total population of the basin is 20.8 – 25.0 million representing almost 60% of the Lake Chad Basin's population and consisting of predominantly male farmers, fishermen and nomadic pastoralists below 60 years of age.

Before the commissioning of Tiga Dam in 1974, fishing was the main income generating economic activity among most communities in the Hadejia River sub-basin. Due to changes in river flow associated with these dams (including the Challawa Gorge Dam), coupled with the water pollution from industrial waste discharge into the river from textile mills and tanneries in Kano, fish population has declined considerably thus making fishing less attractive as an economic activity. Communities downstream especially in Yobe and Borno States have complained seriously over their increasingly poor access to water. The unsatisfactory and uncoordinated management of the reservoirs coupled with profligate operation and maintenance of the irrigation schemes as well as Kano City water intake structures have led to over-abstraction and at times destructive river-flow.

Assessment of IWRM institutional framework

Although there is a large number of land and water management agencies, administrative units, land and water users and other stakeholder groups, not all of these play a significant role in the allocation and conservation of these resources. Water Resources Act cap. W2 of 2004 was first promulgated and published in the supplement to official Gazette No. 27, Vol. 80, September 1993. It is the highest extant legislation governing water resources management in Nigeria. It confers on the Federal Government represented by the Federal Ministry of Water Resources (FMWR) the responsibility for controlling the use of both surface and groundwater resources **traversing more than one state** throughout the Federation.

In its present form, Water Resources Act cap. W2 of 2004 would be difficult to administer, because it vests all the powers on the Minister of Water Resources. Meanwhile, the River Basins that were statutorily empowered to comprehensively plan and develop the Nation's water resources are not delegated any such powers. The need for long range planning based on comprehensive and integrative environmental management, informed the water resources decree, but without any reference to Federal Environmental Protection Agency (FEPA) decree of 1988. On the other hand, in 1991, FEPA published water quality standards without reference or consultation with the Federal Department of Water Supply and Quality Control (FDWSQC) in FMWR which also had the statutory responsibility to operate National Water Quality Laboratories and to engage in water quality control. Further more, the Water Resources Act cap. W2 of 2004 gives the Minister of Water Resources the powers and responsibility of control, regulation and planning of development of water resources; prevention of pollution and formulation of national policies relating to the control and use of water resources for multipurpose as well as short- and long-term provisions of water for various sectoral purposes.

In summary, therefore, none of the existing institutions and ministries is responsible for holistic and integrated management of basic natural resources, notably soils, water and vegetation. Although the natural system makes land and water resources inseparable, their policy and legislation are being formulated and implemented in isolation and without adequate coordination and participation of all stakeholders.

Status of stakeholders at river basin level

The number of RBDAs rose to 18 and fell to 11 and then increased to 12 over the years, with their functions expanding or contracting according to prevailing political thinking and other extraneous considerations. This clearly reveals lack of awareness of the concept, philosophy and principles of integrative management of land and water resources in contiguous natural system (the river basin) by policy-makers. The RBDAs are currently both water resources managers/regulators as well as water services providers and users as they are responsible for the field operation of Federal Government of Nigeria's (FGN's) water resources and rural development programmes in their catchments.

Land and water services (operational functions) providers

The RBDAs are currently constrained by: shortage of staff and funding, lack of effective extension services on and management of their schemes, absence of effective mobilisation of farmers' resources towards operation, maintenance and management (OMM), inadequate tractors and implements, and scarcity of spare parts.

The North East Arid Zone Development Programme (NEAZDP)

The North East Arid Zone Development Programme (NEAZDP) is an integrated rural development project, for the northern fringes of the semi-arid zone of Yobe State. It started as a joint FGN-Yobe State Government-European Union (EU) project with linkages to University of Maiduguri, through its Centre for Arid Zone Studies (CAZS), and Ramat Polytechnic in Maiduguri. However, the suspension of the EU's financial support in 1996 as part of its econo-political sanction against Nigeria drastically reduced the performance of the project.

State Government Agencies

The State Irrigation Department (SID) and the Agricultural Development Projects (ADPs) belong to Ministry of Agriculture and Natural Resources (SMANR) in some States, and to Ministry of Water Resources and Rural Development (SMWRRD) in some others. The SMANR and SMWRRD have developed several dams, such as the Bagauda, Gari, Tomas and Watari, for domestic and agricultural water requirements. The responsibility for provision of municipal and rural water supply and sanitation services lies with the State Governments.

Water-related functionality of village level institutions

Evidence exists that village level institutions have been formed in the basin, especially at the two major irrigation projects. The participation of water users and other village level institutions is not only desirable but must be effective. Water scarcity, flood and *Typha* grass invasion have all forced communities to rise up and formulate ways of solving their problems.

Status of water resources

Rainfall, evaporation and stream flow

Annual rainfall varies from 700 mm to 1,200 mm, from 800 mm to 1,200 mm and from 250 mm to 600 mm in Hadejia, Jama'are and Yobe sub-basins, respectively. The declining trend in rainfall since the 1980s was more pronounced in the Yobe sub-basin than the Hadejia and Jama'are sub-basins.

Evaporation in the northern part of Nigeria is a function of location (radiation ratio), temperature and relative humidity. On the average, the computed rate of potential evapotranspiration varies between 3.7 mm/day and 8.2 mm/day with a mean annual value of 2,200 mm. The implication of this is that the rate of evaporation is higher than rainfall in the basin, especially in the Gana and Yobe sub-basins. The phenomenon also accounts for high losses from impounded water in the Hadejia and Jama'are sub-basins.

The mean annual flow at Wudil reduced by 34% from 1,906 Mm^3 during pre-Tiga Dam to 1,264 Mm^3 during post-Tiga Dam. During the same period, the annual flow in Bunga reduced by 17% from 1,837 Mm^3 to 1,520 Mm^3. If the reduction in flow at Bunga, which has no dam on its river, is mainly due to climatic variation, then the extra 17% reduction in Wudil can most probably be attributed to the operation of the dams upstream of Wudil.

Available surface water ranged between 2,609 Mm^3 and 5,845 Mm^3 depending on the climatic patterns. The available surface water, during (a) a prolonged dry season and (b) a wet season, could be, respectively, as low as 51% of and as high as 40% above the long-term mean of available surface water. This result highlights the importance of appropriate water management plan for the basin. The analysis showed that Hadejia sub-basin contributes 60% (30% from Tiga area, 20% from Challawa Gorge area and 10% from unregulated area) of the surface water resources, while Jama'are sub-basin contributes 40% to the KYB at Gashua. While these proportions remain essentially constant, the amount of water contributed by each sub-basin varies with climatic scenario.

Groundwater resources, water quality and water resources infrastructure

Recharge to the shallow aquifer underlying the floodplains in these sub-basins could be by river channel seepage, floodwater infiltration or direct rainwater infiltration, or combination of all three. Floodplain recharge is the major mechanism of recharge to the shallow floodplain aquifer. In the Hadejia and Hadejia-Nguru Wetlands, 1,250 km^2 in area, recharge ranges between 73 mm and 197 mm, with an average of 132 mm, while in the 1,150 km^2 Yobe sub-basin, the estimated recharge is 50 mm, although from Gashua to Yau channel seepage predominates at about 1 mm/annum. The 500 km^2 Jama'are sub-basin has an estimated recharge rate of 100 mm. These figures give the estimated total recharge to the shallow aquifers in the floodplains of all the sub-basins as 250 Mm^3.

The potential sources of surface water pollution in the KYB are mainly in the Hadejia sub-basin, which has the largest irrigation projects, most industries and the most densely populated areas. Drainage water from large- and small-scale irrigation projects may contain insecticides and nutrients from fertilisers. Chemicals in drainage waters from the processing industries are obvious sources of water pollution in the basin.

Most of the water resources infrastructures in the basin suffer from a massive backlog of neglected maintenance. For example, the distribution system in Kano City is in extremely poor condition. Unaccounted water is estimated to be in excess of 60% of total production. Water mains are blocked and other problems include lack of flow proportioning structures at critical positions in the river system, inadequate maintenance of irrigation canals and structures resulting in high losses.

Decision Support System

The Decision Support System (DSS) is a predictive model with capability for predicting the flow pattern along the river system on weekly time step for one year or a multiple of years for a maximum of 10 years. The user is expected to either assume the climatic scenario or the monthly rainfall depth for each sub-basin. Six climate scenarios were: (i) Prolonged dry year, (ii) Very dry year, (iii) Dry year, (iv) Normal year, (v) Wet year, and (vi) Very wet year, considered in the study. Various water management options can be considered in the DSS using the current water requirements of Kano City Water Supply (KCWS), Kano River Irrigation Project (KRIP), Hadejia Valley Irrigation Project (HVIP) and downstream section summarized in the following table, as a basis, for example:

Table: Summary of Current Annual Demand for KYB

Sub-basin	User	Annual demand Mm^3	Proportion %
Hadejia	KCWS	215.36	43.8
	KRIP	123.50	25.2
	HVIP	24.16	4.9
	Others	24.25	4.9
	HNWs*	87.73	17.9
Jama’are	Kawali Irrigation	0	0
Yobe	Others	16.17	3.3
	Total	**491.26**	**100**

*Hadejia-Nguru Wetlands

The analysis showed that while the current water requirement of Hadejia sub-basin, excluding the requirement of Hadejia-Nguru Wetlands (HNWs), accounts for 80% of the annual demand of KYB; the sub-basin contributes 60% of water resources in KYB. The DSS can facilitate decision-making on equitable allocation of the available water resources. For example, it can be shown that in a normal year, neither the water requirement of the HNWs nor the irrigation requirement of HVIP can be satisfied during the first quarter of the year under the existing situation. This implies that the available surface water resources in the KYB, under the existing condition, are not sufficient to sustain the proposed Sugar Project in

Jigawa State. The situation in a dry year is even worse. In addition, the water requirement of communities along the river system after Gashua could not be satisfied from week 1 to week 20 (January to April). The Manual for the DSS model is provided as an Annex 1 to this report.

In summary, there should be a much greater emphasis on water resource management and a shift of emphasis from supply to demand management of water resources in the basin.

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Abbreviations and Acronyms

ADPs	Agricultural Development Projects
BaSADP	Bauchi State Agricultural Development Project
BaSMWR	Bauchi State Ministry of Water Resources
BaSWB	Bauchi State Water Board
BBC	British Broadcasting Corporation
BoSADP	Borno State Agricultural Development Project
BPE	Bureau of Public Enterprises
BRAO	West Africa Regional Office of IUCN
CAZS	Centre for Arid-Zone Studies (University of Maiduguri)
CBDA	Chad Basin Development Authority
CBOs	Community-Based Organisations
CCA	Causal Chain Analysis
CMP	Catchment Management Plan
CTA	Technical Centre for Agricultural and Rural Cooperation
DFFRI	Directorate of Food, Road and Rural Infrastructure
DFID	Department for International Development (UK)
DPSIR	Driving Forces, Pressures, States, Impact, Responses
DSE	Department for Sustainability and Environment
DSS	Decision Support System
DW	Deutsche Welle
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EU	European Union
FAO	Food and Agriculture Organisation (of the United Nations)
FDID	Federal Department of Irrigation and Drainage
FDWSQC	Federal Department of Water Supply and Quality Control
FEPA	Federal Environmental Protection Agency
FGN	Federal Government of Nigeria
FMA	Federal Ministry of Agriculture
FMA&NR	Federal Ministry of Agriculture and Natural Resources
FMARD	Federal Ministry of Agriculture and Rural Development
FME	Federal Ministry of Environment
FMWR	Federal Ministry of Water Resources
FMWR&RD	Federal Ministry of Water Resources and Rural Development
FORMECU	Forestry Monitoring, Evaluation and Coordinating Unit
GEF	Global Environment Facility
GIS	Geographical Information System
GIWA	Global International Water Assessment
GKWS	Greater Kano Water Supply
GPS	Global Position System
GWP	Global Water Partnership
HIA	Health Impact Assessment
HJKYBCC	Hajejia-Jama'are-Komadugu-Yobe Basin Coordinating Committee
HJRBDA	Hadejia Jama'are River Basin Development Authority
HJKYB	Hadejia-Jama'are-Komadugu-Yobe Basin
HNWs	Hadejia-Nguru Wetlands
HNWCP	Hadejia-Nguru Wetlands Conservation Project
HVIP	Hadejia Valley Irrigation project
IAR	International Agricultural Research
IMF	International Monitoring Fund
INRM	Integrative Natural Resources Management
IRIN	Integrated Regional Information Networks
ITAD	Information Technology Assistance for Development
ITCZ	Inter-Tropical Convergence Zone
IUC	International Education Centre
IUCN	International Union for the Conservation of Nature (The World Conservation Union)
IWACO	International Workshop on Aliasing, Confinement and Ownership
IWMI	International Water Management Institute

Abbreviations and Acronyms cont.

IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
JSMWR	Jigawa State Ministry of Water Resources
JWL	Joint Wetlands Livelihood
KCWS	Kano City Water Supply
KRIP	Kano River Irrigation Project
KSMWR	Kano State Ministry of Water Resources
KSWB	Kano State Water Basin
KYB	Komadugu Yobe Basin
KYBP	Komadugu Yobe Basin Project
LCBC	Lake Chad Basin Commission
LGA	Local Government Authority
MA	Ministry of Agriculture
MDG	Millinnieum Development Goal
NAFDAC	National Agency for Food and Drug Administration Commission
NCF	Nigerian Conservation Foundation
NEAZDP	North East Arid Zone Development Programme
NEEDS	National Economic Empowerment and Development Strategy
NEMA	National Emergency Management Agency
NEPA	National Electric Power Authority
NEPAD	New Partnership for Africa Development
NFDP	National Fadama Development Project
NGOs	Non-Governmental Organisations
NIPSS	National Institute for Policy and Strategic Studies
NNJC	Nigeria-Niger Joint Commission
NPC	National Population Commission
NRIS	Natural Resource Information System
NWRMP	National Water Resources Management Plan
NWSRP	National Water Supply Rehabilitation Programme
O&M	Operation and Maintenance
ODA	Overseas Development Assistance
OMM	Operation, Maintenance and Management
PSC	Project Steering Committee
PTF	Petroleum (Special) Trust Fund
RBDAs	River Basin Development Authorities
RBRDAs	River Basin and Rural Development Authorities
RIMS	Risks and Insurance Management Society
RLWRDPS	Regional Land and Water Resources Development Planning Study
RUWASA	Rural Water and Sanitation Agency
SCIP	South Chad Irrigation Project
SEEDS	State Economic Empowerment and Development Strategy
SEPA	State Environmental Protection Agency
SID	State Irrigation Department
SMANR	State Ministry of Agricuture and Natural Resources
SMWRRD	State Ministry of Water Resources and Rural Development
SON	Standard Organisation of Nigeria
SRRBDA	Sokoto-Rima River Basin Development Authroity
SST	Sea Surface Temperature
SWBs	State Water Boards
TAC	Technical Advisory Committee (of the HJKYB)
TC	Tropical Continental
TM	Tropical Meritime
ToR	Terms of Reference
UBRBDA	Upper Benue River Basin Development Authroity
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development

Abbreviations and Acronyms cont.

UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCC	United Nations Framework Convention on Climate Change
UNPD	United Nations Population Division
UNSO	United Nations Students Organisation
USACE	United States Army Corps of Engineers
VoA	Voice of America
WBs	Water Boards
WHO	World Health Organisation
WRECA	Water Resources and Engineering Construction Agency
WSSD	World Summit on Sustainable Development
YSADP	Yobe State Agricultural Development Project
YSWC	Yobe State Water Corporation

Introduction 1

1.1 Background to the KYB Water Audit

In response to the increasing evidence of deterioration of the Komadugu Yobe Basin's (KYB's) water situation and the river system, as well as the growing community concern, the Coordinating Committee of Hadejia-Jama'are-Komadugu-Yobe Basin (HJKYBCC) (essentially the same as KYB) directed that a water audit be prepared to assess water use in the basin, comment on the effects of the projected increase, and assess the likelihood and potential impact of further increases in the future. To implement this and other water management related issues, the HJKYBCC represented by the Federal Ministry of Water Resources (FMWR) entered into a joint initiative with the West African Regional Office of the World Conservation Union (IUCN-BRAO) and the Nigerian Conservation Foundation (NCF) to implement the Project for "Improving Land and Water Resources Management in the Komadugu Yobe Basin" or simply the Komadugu Yobe Basin Project (KYBP). The project covers six Nigerian States of Plateau, Kano, Jigawa, Bauchi, Yobe and Borno, and two regions, Diffa and Zinder, in the Republic of Niger.

Taking watershed development as an entry point, the KYBP has the prime objective of developing effective and sustainable approaches to socio-economic development of the drought-prone KYB. Livelihoods in this drought-prone basin are intimately linked with the availability of water resources and, in particular, access and entitlements to water for domestic and productive purposes. In recent years, there have been dramatic changes in the surface and sub-surface hydrology of the basin primarily as a result of inappropriate resource management upstream and increased groundwater abstraction basin-wide for domestic water supply and irrigation. In general, the ability of livelihood systems in the basin to withstand the shock of drought and floods is deteriorating. Hence, it is in a context of **demand** for water outstripping **supply** that the KYBP is operating. To facilitate Integrated Water Resources Management (IWRM) in the basin, it was considered most appropriate to commission a Water Audit with the goal of improving database, information and basin-wide assessments of land, water and biological resources to support sustainable development. The water audit is expected to serve as the foundation for comprehensive assessment of surface water and groundwater availability, as well as the nature and magnitude of the water demands.

In the letter reference No. IUCN-KYBP/Afre003/2111/2005 dated 21/11/2005, the FMWR-IUCN-NCF KYB Project of 15A Race Course Road, Kano commissioned **Messrs Afremedev Consultancy Services Ltd of Abuja (ACS)** to carry out a Water Audit of the Komadugu Yobe Basin, build a Decision Support System (DSS) and develop a Catchment Management Plan (CMP), all to be completed by Friday 31st March 2006.

1.2 Objectives of the KYB Water Audit

The KYB Water Audit is aimed primarily at articulating an Integrated Water Resources Management (IWRM) Plan that would provide participatory and proactive approach to the planning, development, operation, maintenance, monitoring and evaluation of water resource utilisation in the basin. The KYB Water Audit study commenced in December 2005 with a series of inception meetings that provided the consultants, the KYB Project officials and main stakeholders with an opportunity to discuss the Audit's specific objectives, methodology and institutional arrangements. The agreed wider objectives of activities in the study areas were:

i. To assess the status of water and other natural resources at scales ranging from the micro-watershed to the macro-watershed, thereby, to *inform decision-making and policy formulation at all levels in the KYBP and the basin's integrated water resources development programme.*

ii. *To assess pressures on groundwater and surface water resources and current trends in use and demand (e.g. water demands for domestic purposes, irrigation, non-land-based activities etc.).*

iii. *To assess the relative value of different water uses in terms of productivity, equity and basic human and environmental needs with a view to creating overall water balance.*

iv. *Based on the above, to identify resource management practices and policies that are economically viable and that have the potential to bring about more equitable, sustainable and productive use of water in the long-term.*

v. *To provide baseline data against which some resource-related indicators can be monitored.*

vi. *To build a computerized decision-support system (DSS) to aid policy-makers in project valuation what-if water resources management scenarios.*

vii *To prepare an integrated catchment water management plan (CMP).*

The detailed ToR for the Water Audit Study is as contained in Appendix 1.

1.3 Description of the KYB and Strategic Importance of Study Area

The KYB is a sub-catchment of the larger Lake Chad Basin. It is situated in the Sudan-Sahel zone of north eastern Nigeria and south eastern Niger covering an area of 148,000 km^2, out of which 84,138 km^2 is in Nigeria (57% of basin area). The basin is drained by two main river sub-systems. The first sub-system, the Yobe River, is formed by the Hadejia and Jama'are tributaries, which create the Hadejia-Nguru floodplain at their juncture. The second sub-system is the Komadugu Gana (or Missau River). Historically, it is a tributary of the Yobe River (Figure 1.1).

About 80% of the flow in the Hadejia River sub-system, which is a tributary of the Yobe River, is controlled by the upstream Tiga and Challawa Gorge dams (completed in 1974 and in 1992 respectively), both in Kano State. The Jama'are River is presently uncontrolled, although, there are plans for a dam on it at Kafin Zaki in Bauchi State. The Komadugu Gana, another tributary of the Yobe River, forms a wide floodplain downstream of Dapchi in Yobe State. The confluence of the Komadugu Gana and Komadugu Yobe is largely silted up, thereby, providing only a small and unreliable contribution to the Yobe River. All three tributaries of the Yobe River are effluent until they reach the geological boundary between the largely impermeable rocks of the Basement Complex and the permeable sands, gravels and clays of the fluviatile and lacustrine Chad Formation.

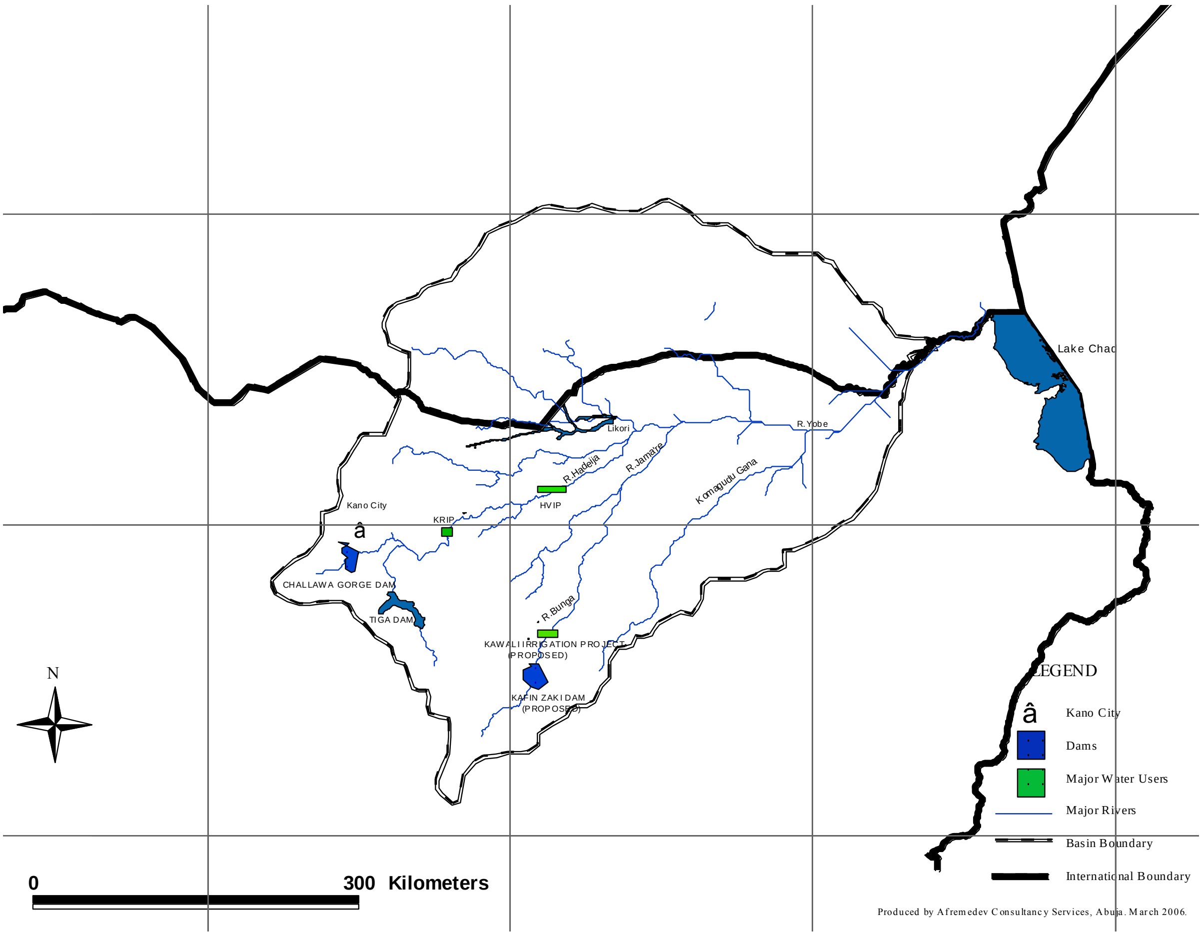


Figure 1.1: Location of Komadugu Yobe Basin

The Hadejia River splits into three channels in the Hadejia-Nguru Wetlands (HNWs): the northern channel (Marma Channel) flows into the non-returning

Nguru Lake, the southern channel (Old Hadejia River) joins up with the Jama'are River to become the Yobe River and the relatively small channel in-between is called the Burum Gana River. In the eastern part of the basin, the Yobe River forms the border between Nigeria and Niger. There are no major tributaries to the Yobe River in Niger. The Yobe River empties into the northern pool of Lake Chad and it is the only river flowing into the northern pool. The present contribution into the Lake Chad area is estimated at less than 2% of the total input. The river gradients in the upper part of the basin are up to 5 m km^{-1} with the average gradient of the Hadejia River in the middle part of the basin being only 0.13 m km^{-1}. In the flat middle and lower parts of the basin, the river therefore spills onto the floodplains during the wet season (June to October); the most extensive floodplain areas in the basin being the HNWs between Hadejia and Gashua.

The mean annual rainfall ranges from between 1,000 mm in the upstream Basement Complex area to approximately 400 mm in the middle part of the basin and less than 300 mm near Lake Chad. However, climatic variability has resulted in these mean annual rainfall values being unrepresentative for different periods. Since the mid-1990s, the decreasing trend in annual rainfall seems to have been reversed.

The dams at Tiga and Challawa Gorge are supplying water to two on-going large formal irrigation schemes, namely: the Kano River Irrigation Project (KRIP) and Hadejia Valley Irrigation Project (HVIP) near Kano and Hadejia, respectively. The dams also contribute to Kano City Water Supply (KCWS).

Much of the catchment is relatively flat with only significant hills rising in the south-west from the Jos Plateau where the headwaters of the Jama'are River and to a lesser extent Kano River begin. The majority of the basin falls within the Sudan-Savannah Ecological Zone which has a natural vegetation cover that is dominated by shrubs and occasional dense grassland with scattered tree components. However, much of the natural vegetation cover has been affected by human activities and artificial constraints upon the river systems have increased the complexity of the hydrology of the basin.

The network of river systems and wetlands that constitute the KYB support a wide range of ecological processes and economic activities, including recession agriculture, pastoralism, forest regeneration, fish breeding and production, trading, drought-fall-back security, and tourism potential. Based on these activities, several centres of development, trading and administration have emerged along river courses and on floodplains in the basin, constituting very high population concentrations in a characteristically sparsely populated dryland region. Currently, the livelihood of the over 10 million people in the basin, both in Nigeria and Niger, depend almost exclusively on these activities. The Hadejia-Jama'are-Komadugu-Yobe River system is the life-wire of these communities.

The wetlands of the KYB host biodiversity of global significance. In addition to providing fire-wood and grazing in the dry season, there are also about 100 species of fish, about five of which are endemic. There are also some endemic plant species of agronomic importance, which are threatened with extinction. An important example is a variety of rice that is found in the Gashua to Geidam stretch. In addition, over 370 species of birds have been inventoried in the basin, with 33% of them being migratory. IUCN and partners estimated at USD 170 per ha the annual economic benefits from the overall land-use systems of the Hadejia-Nguru wetlands (Barbier *et al*., 1991).

The KYB is considered to be of strategic national and international importance. The basin is an area of relatively dense population concentration in a dryland region, with the population critically and increasingly dependent on scarce water resources. It is the source of internationally shared water whose management in Nigeria has an important bearing on diplomatic relationships between Nigeria and four countries (Niger, Chad, Cameroon and Central African Republic). These countries share the Lake Chad Basin in which the KYB is located. The KYB contains very important wetlands, in particular, the Hadejia-Nguru Wetlands

(HNWs), Nigeria's premier Ramsar site and which are of immense local, national and international economic and ecological importance.

1.4 Water Management Problems of the KYB

The major hydrological and institutional issues of concern in the KYB are summarised below:

i) **Scarcity of water** with substantial portion of available water sources that can possibly be economically exploited having already been developed. The potential surface water requirements in the Hadejia sub-basin by estimation of the late nineties are 2.6 and 1.8 times larger than the mean available surface water resources, for the Hadejia and Jama'are Rivers, respectively.

ii) **Fragmented, inequitable and uncoordinated management** of surface water uses, with ill-defined and often conflicting responsibilities between agencies. For example, two River Basin Development Authorities (HJRBDA and CBDA) are responsible for water management in the catchment with little, if any, coordination. ***The limited knowledge about available water and about the nature and magnitude of the water demands*** remain a major constraint to improved water management in the basin.

iii) **Increasing population and vulnerable groups:** Rapid population growth in the basin is a major problem. By the year 2025 the population of the basin is projected to rise to over 25 million from the figure of 15 million in 1991. This and migration in pursuit of livelihood by the pastoralists, fishermen and environmental refugees as a result of increased desertification, have intensified the competitions for scarce land and qualitative water resources in the basin, resulting in frequent conflicts. Similarly, the growing human and animal populations are in part responsible for the cultivation of marginal land, increased deforestation, depletion of grazing land and reduction of fallow period, which have seriously degraded the land in the basin. The majority of this population is comprised of women and children under the age of 15, who are vulnerable and deprived of their means of livelihood through degraded environments and inadequate water resources development. With declining per capita incomes, poverty has reached critical levels in most States in the basin, especially those in the lower reaches. Immediate actions that will facilitate proper targeting of the poor and design of effective measures for poverty reduction are necessary to make progress towards improved living conditions.

iv) **The invasion of aquatic weeds, notably *Typha domingenis***, in the Hadejia sub-basin (see Plate 1), the consequences of which include:

- Macrophyte and silt blockages in the HNW preventing the Hadejia River from contributing to the Yobe River
- Hindrances in the use of surface water bodies from fishing and navigation
- The creation of a favourable environment for the multiplication of vectors of waterborne diseases
- A reduction in biodiversity

Plate 1: *Typha* infested area in Nguru Wetland

iv) **Degraded environment:** Poor land and water management practices coupled with water variability basin-wide are contributing to severe ecosystem degradation in an already poverty-stricken environment. The increased needs for energy and limited access to electricity, compels the basin population to use wood and charcoal for domestic purposes, resulting in deforestation and biodiversity loss from over-exploitation. Cumulatively, these factors are perpetuating a vicious cycle of environmental degradation which is in turn directly threatening rural communities whose livelihood is dependent upon the very ecosystem. Over the years, the combination of recurrent drought and flood periods, high population growth rate and inadequate water resources development for meeting the needs of a growing population, have further increased poverty and put severe pressure on land and water resources in the basin. Reversing the basin's environmental degradation would call for concrete actions that will offset the poor land and water resources practices, which negatively affect natural resources use and promotion of those practices that facilitate effective natural resources management.

v) **Unutilized development potential:** The basin is endowed with considerable natural resources. However, inadequate management and development of water resources have resulted in sub-optimal benefits. Given this situation, improvements in both agriculture and livestock production – the primary sectors of the basin – can be achieved by optimizing benefits from existing water infrastructure. Furthermore, adequate water resources development and management can facilitate incremental benefits associated with increased productivity and incomes. Current development opportunities in the basin include: (i) over 1 million ha of irrigable land of which less than 40 percent are developed and less than fifty percent of which is actually irrigated, (ii) substantial hydropower potential but none is developed, (iii) navigable waterways but little is currently exploited. Additional opportunities include the development of fisheries, watershed management and ecotourism, all of which could provide incremental benefits associated with existing large infrastructure. Immediate actions are required to assist the River Basin Authority and the riparian state governments to develop a clear framework that will, in an integrated and optimized manner, tap these opportunities.

vi) **Inadequate operation and maintenance of existing water infrastructure**: Inadequate operation and maintenance are heavily impeding the effective management of existing hydraulic assets. Such situation overtaxes existing infrastructure, defers maintenance and resulted into sub-optimal utilization of water infrastructure which might otherwise have generated multiple benefits to the basin's population. While it is apparent that additional infrastructure is required to effectively mitigate the seasonal and annual variability of the water resources, improved operation and maintenance of the existing ones will ensure greater efficiency and long-term sustainability. Adequate operation and maintenance of existing large water infrastructure such as Challawa Gorge, Tiga and Bagauda are constrained by varied issues ranging from inappropriate maintenance and conflicting planning to poor funding. The situation is similar for small water infrastructure. Investments are required to rehabilitate and upgrade existing infrastructure and to establish a clear framework of interventions that will promote sustainable management of valuable assets, as well as optimization and development of the existing water resources potential.

vii) **Competitive unilateral development and operation of RBDAs:** The lack of sufficient robust instruments to foster effective cooperation among the riparian States in the basin is contributing towards persistent unilateral development of the river's resources. It is evident that lack of such instruments will likely result in weak mechanisms for clearly assigning benefits to each riparian country and state. Over the last decades, this unilateral development has limited RBDA's and indeed LCBC ability to assert themselves, as strong champion using appropriate coordination mechanism to effectively promote regional development. To optimize the basin's opportunities, it is imperative for the basin's riparian countries to empower the LCBC and ensure that it is fully committed to the preparation of key legal instruments and institutional mechanisms for joint investments and development within the basin.

viii) **Extremely large and small floods** were recorded in 1992, 1993, 1998 and 2001 in particular. The extremely large floods combined with unco-ordinated reservoir operations resulted in the displacement of tens of thousands of people in 1998. The floods in 2001 took the lives of over 200 people and displaced over 35,000. Furthermore, contrary to what was expected after the completion of the dams, the timing of the floods in the HNW became less predictable and even resulted in dry-season floods. Along the Marma Channel in the HNW, the flooding has become more or less permanent since 2001. Some villages like Dabar Magini had to be moved to the west of Nguru Lake while the Hadejia-Nguru road is almost completely inaccessible during the wet season (see Plate 2).

ix) **The irregular and low flows in the Yobe River** have affected the small and large irrigation schemes along this river, and many of them have now been abandoned. With the exception of year 2001, the flooding of the floodplains along the Yobe River has been very limited in the past five years. Fadama exploitation has been stimulated in the basin through World Bank assisted subsidies, which has raised concern over possible over-abstraction of groundwater in the basin.

Plate 2: Main road taken over by flood in Nguru Wetland

x) **The shrinking and splitting of Lake Chad** at the downstream part of the Yobe River. Although the historical contribution from the Yobe River to

Lake Chad had been small, under the present circumstances any little increase in inflow into the lake would be significant.

xi) **A suspected degradation in water quality** due to industrial activities as well as large and small irrigation activities.

1.5 Institutional Arrangements for the KYBP

The KYBP began 2005 with the establishment of a Project Office in Kano. Because of the fact that the proposed project has various complex components, efforts was made to bring together partners with complementary expertise and strengths. Given the KYB Project's emphasis on capacity building, it was decided that the Pre-Water Audit would be implemented by International consultant while the Audit would be executed by an indigenous specialist consultancy firm with counterpart staff team from FMWR and in tandem with other complementary projects and studies. The logic was that active involvement in the Water Audit of, in particular, HJKYBCC secretariat staff from FMWR would build their capacity so that they would be able to scale up the water auditing in future.

The Project Management Unit consisting of a Project Director (part-time), a Project Coordinator, a Project Financial Administrator and three technical officers (a Legal/Social Science Specialist, a Water Resources Expert and a Database Manager) contributed in enriching the study. The Project Steering Committee (PSC) also monitored the implementation of the study. The membership of the PSC is composed of, among others, representatives of the following institutions:

- Federal Ministry of Water Resources (FMWR) (appointed by the Federal Minister) is the chairperson
- Nigerian Conservation Foundation (NCF)
- Federal Ministry of Environment (FME)
- Federal Ministry of Agriculture and Rural Development (FMARD)
- The World Conservation Union (IUCN)
- Lake Chad Basin Commission (LCBC)
- Stakeholders Consultative Forum
- Project Director

- Project Coordinator (playing the role of Secretary of the steering committee)
- Representative of major donor(s)

The PSC[1] reports to the HJKYBCC. The project also serves as the Secretariat of the TAC of HJKYBCC.

[1] PSC and TAC of HJKYBCC are comprise of essentially the same members and therefore are one and the same thing

Methodology 2

2.1 Background

Water audits, under various names, are being promoted increasingly as a key step towards effective, sustainable and adaptive integrated water resource management. For example, the International Water Management Institute (IWMI) has taken a lead in advancing the case for water accounting and in developing relevant definitions and procedures (Molden, 1997; Molden *et al.*, 2001; IWMI, 2002). Similarly, the Global Water Partnership (GWP) and the United States Army Corps of Engineers (USACE) have stressed the importance of water resource assessments as part of adaptive integrated water resource management (GWP, 2000). Although there are some subtle differences between the methodologies that are being promoted by these organisations, the overall objectives of the different approaches are similar (see Box 1).

Effective water audit should seek to gain a holistic view of the water resources situation and its interaction with societal activities. This includes: (1) addressing the occurrence of surface and ground water, in space and time, and, in particular, assessing levels of sustainable use and the frequency of extreme events such as droughts and floods; (2) providing a tentative assessment of the demand trends for different uses; (3) identifying the main driving forces influencing demand and use (e.g. government policy and societal behaviour); (4) assessing the functionality and effectiveness of institutions charged with developing and managing water resources; (5) understanding the environmental and ecological problems affecting water use and management; and (6) understanding factors that affect access and entitlements to water for both domestic and productive uses. These are the objectives that were carried forward to all the stakeholders in the process of interacting and seeking information from them.

Box 1. Why carry out a water audit?

Because a water audit can:

· Identify the current status of water resources at different scales and trends in demand and use;
· Provide information on access and entitlements to water and the trade-offs that have resulted or will result from different patterns of water use;
· Provide information on social and institutional factors affecting access to water and reliability of water supplies;
· Help identify externalities which only become apparent when the patterns of water use are considered at the macro temporal and spatial scales;
· Provide information that is required for assessing efficacy of existing water-related policies;
· Identify opportunities for saving or making more productive and/or equitable use of water;
· Identify the effectiveness of current drought and flood coping strategies;
· Identify potential problems resulting from competing or multiple uses of water;
· Assess the accuracy of available water-related statistics;
. Identify the environmental/ecological problems associated with water resources; and
· Identify the extent to which decision making is based on hydrological myths or misconceptions.

The fundamental concept of water auditing should be based on the argument that knowledge of the current status of water resources and trends in demand and use is a pre-condition for successful adaptive water management into the future. Equally important, should be the understanding of factors affecting patterns of access and entitlement to water resources. This is fundamental in any interventions that may seek to improve and protect the livelihoods of poorer social groups.

2.2 Sources of Information

Although the Water Auditing used primarily quality controlled secondary information supplied by the KYBP, additional controlled secondary information were collected wherever possible, from partner institutions and projects (FMWR, HJRBDA, CBDA, DFID-JWL, LCBC-GEF and a host of others). These were further supplemented with some primary data collection that was done over a limited period that was available to fill-in gaps and to collect additional data. The combination of time constraint and limited financial budget for the water audit constraints the extent of collection of primary data. Agreement on the methods of collecting the additional data was reached with KYBP Project Management Team before the commencement of the field verification and data gap filling visits.

Compared to many countries, relatively little quantities of hydrological, geological, agricultural, social and other information are collected routinely in Nigeria at the national, state and community levels by government and non-government organisations. This fact clearly emerged from the pre-water audit study. Unfortunately, even the little data that were available, they were found often not always easily accessible or utilisable for reasons that include:

- Data are fragmented in that they are held by different organisations and, in some cases, by different departments or individuals within these organisations;
- Spatial and non-spatial data are stored in a wide range of formats (e.g. maps, remotely-sensed images, tables of figures, text, graphs, etc.) and media (e.g. in year books, on computer disks, etc.);
- Spatial and temporal scales at which data have been collected are not at all consistent; and
- Data qualities were extremely variable.

Furthermore, the available secondary data gathered during the pre-water audit study and subsequently by KYBP were mostly monthly rather than daily rainfall and river flow data.

Consequently, in fashioning out the philosophy of our methodology we were guided by the fact that the study has to be concluded within a time limit of three (3) months and has a spatial scale that covers the entire basin (at least 5 States). Secondly, that the study is primarily aimed at helping policy-makers in the basin to take more informed decisions on water management decisions. To do this required that in considering the natural systems, the human component should not be underestimated. We therefore had to source for socio-economic and institutional information from knowledge studies commissioned by KYBP and partner project. However, considering also the urgent need for advice on daily management of the dams and the need for the inclusion of flood extents in the water audit, the DSS model was built on at least a weekly time-scale. It was made flexible such that it could be made more detailed in future to allow the inclusion of daily records of river flows, whenever higher quality data became more readily available.

In consideration of all of the foregoing, the study avoided "reinventing the wheel", and took advantage, wherever practicable, of several related document prepared on water resources management and socio-economic studies in the basin, either by KYBP or partner projects (DFID-JWL and LCBC-GEF) thereby releasing the limited time to be channelled into filling the physical information gaps. The study enjoyed close cooperation of the partner projects. Certain aspects were mutually deferred to be executed by suitable partner project in due course without sacrificing the primary goal of the study. For instance, LCBC was to launch a groundwater study for the entire Chad Basin in 2006, thus groundwater in the deeper (2nd and 3rd) aquifers were not studied in detail during the auditing, and this was deferred to this project. Furthermore, pre-water audit analysis suggested that these deeper aquifers most likely only receive negligible recharge (if they are recharged at all) from within the KYB.

Close collaboration with the relevant governmental organisations, notably the riparian State Governments' organisations, FMWR and FME that are essential for acceptance of the outcome of the work were established early in the study, through appointment of the counterpart staffers and circulating the reports of the study in spite of the time limitation.

Although water quality is important in determining if the available water would be good enough for all the uses, the water audit was focused on water quantity. The decision arose from the facts that:

i. doing a water quality study requires a different discipline than a water quantity study,
ii. the most relevant water quality studies was earlier done during the pre-audit study and is reproduced in this report as section 6.4,
iii. the environmental laws are not being enforced on the polluters,
iv. no functional water quality monitoring network was identified for the basin, and
v. water quality study is more location specific (mainly downstream of potentially polluting activities) than the quantitative water audit (basin-wide).

The highly specialised nature and time constraints limited the work that was done on the impact of climate change on the water resources management of the KYB. Accordingly, the water auditing only took into account extreme events for the water availability in the basin (dry and wet scenarios) since almost all regional climate scenarios predict a high variability in rainfall and river flow.

The inter-basin transfers were also excluded from the water auditing at least for now, because the environmental impact of the inter-basin transfers on the donor river basin would be required, which was not available. Furthermore, studying an additional basin meant a lot of unforeseen extra work. The study, however, recognised the suggested 'Dindima' transfer that is to carry water from the Gongola River to the Komadugu Yobe (Diyam, 1986), and the Oubangui River water transfer which intends to transfer a fraction of water from Oubangui river (biggest tributary of Congo River) into Lake Chad through the Chari River. Although, the former transfer may not happen since there are already two dams on the Gongola River, and the latter is still on the drawing board.

Box 2. KYBP Water Audit Methodology Philosophy

1. The KYBP Water Audit is a policy relevant study – must therefore factor in economic, sociological and the institutional consideration and issues as well as focus on changes to the state of nature and human systems that could or has affected ecological quality and sustainable community development.
2. Make maximum use of secondary baseline information (e.g. soil maps, hydrological data, remotely-sensed data, etc.) and resource monitoring information (e.g. rainfall records, statistics etc.) that has been or is being collected by KYBP and other government line departments and organizations. A quality controlled secondary data was sent as attachment to series of e-mail containing the following information by the KYBP:
    - All readily available hydrological and meteorological data, (including daily river flow, river gauging, groundwater levels etc) and reports including surface water model, collected and developed respectively from IUCN-HNWCP;
    - Other monthly rainfall data including that from Nguru (1942-1998 from Department of Meteorological Services);
    - Substantial monthly river flow data for the basin (based on IUCN-HNWCP, WRECA, and Sanyu and Sumiko, 1995; UNESCO, 1995);
    - Some scientific papers on the basin in pdf format and hard copies.
3. Analyse the contemporary literature relating to the region and to adaptive integrated water resources management and identify suitable secondary information based on the assessment of their relevance to the study objective.
4. Adopt an approach that builds on experience gained during the PTF funded Regional Land and Water Resources Development Studies and, in particular, include the data collected for social and institutional studies by collaborative Joint Wetlands Livelihood Project (DFID-JWL);
5. Use GIS software to consolidates spatial information and, where necessary reconcile differences between administrative and physical boundaries;
6. Ensure maximum involvement of specialists that are either based in the KYBP districts or have long experience of working in this area; and
7. Encourage active involvement, where possible of the FMWR, HJRBDA, CBDA, NEAZP, LCBC and/or staffers from other line departments.

The small rivers that do not contribute flows to the Hadejia or Jama'are rivers were excluded from the DSS Model built for the water audit. These rivers are mainly located north of Kano near Kazaure and are small with only local importance as they do not directly affect the runoff in the Komadugu Yobe system. Nevertheless, the hydrological connection through groundwater flow and these small rivers which form a part of the total water balance for the basin was recognised in the study. As such these rivers, their dams and their uses are mentioned in this water audit report although they were not studied in detail. In addition, not much recent data were available for these rivers at the time of the study.

2.3 Collection and Quality Control of Physical Data

A major feature of the KYBP Water Audit was the consolidation of spatial and non-spatial data from a wide range of sources onto Geographical Information System (GIS) databases (see Figure 2.1). Some verification and gap filling became necessary during the collection processes even on the database collected from KYBP. A major part of the quality control process took the form of double-mass analysis for rainfall data, development of rating curves and comparison with previous rating curves, inter-comparison of data and statistics from different sources, analysis and discussions aimed at understanding the reasons for disparities and concluding on which to discard. This was arguably the key step in the water audit as it also involved assessing whether data support accepted wisdom relating to the development and management of water resources in the basin.

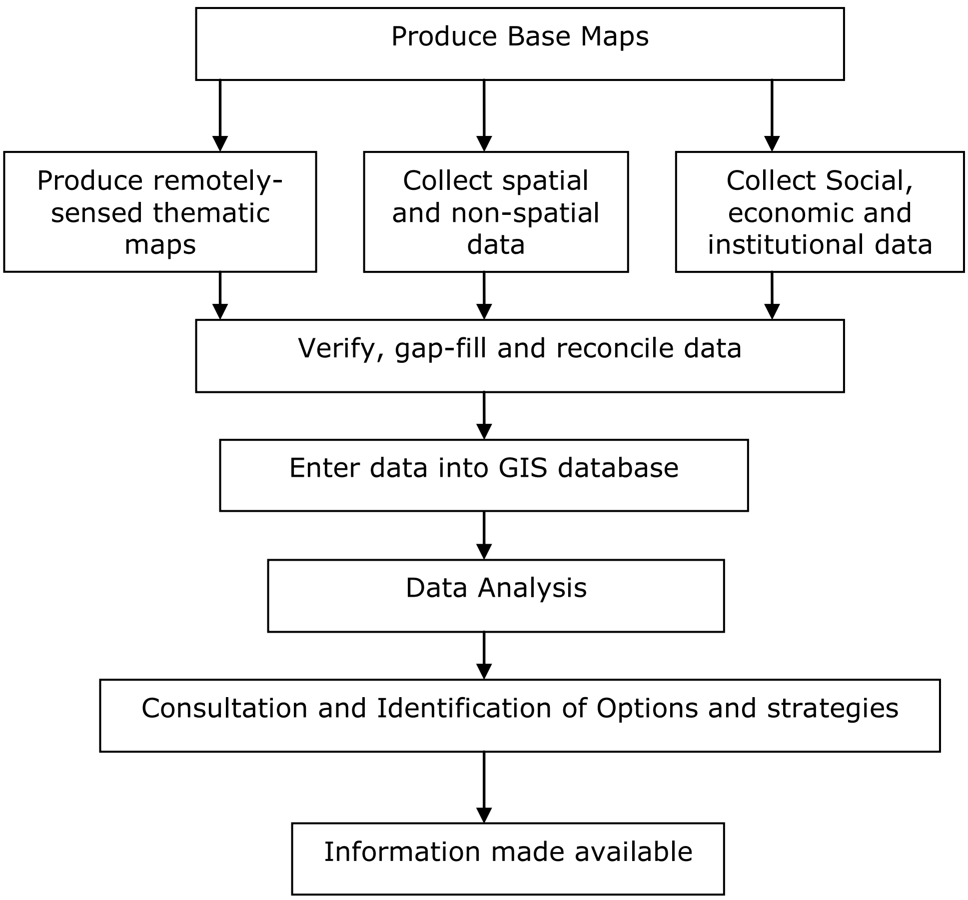


Figure 2.1: General procedure for collecting, quality controlling and processing data

The supplementary field data collection was carried out primarily by consultant staff and staffers of KYBP as well as counterpart staff from line Federal Ministries. In addition, the ACS staff undertook some specialist tasks. This arrangement, although potentially good for capacity building, led to some avoidable delays as the counterpart staff were only appointed late in January 2006, after most of the field visits were concluded. Some satellite imagery of the basin (in digital format) of the land use had to be procured from Federal Department of Land Resources. These maps were used as base maps for marking the location of point features such as prominent dams and schemes. At the same time, GPS handsets (Garmin 12XL, USA) were used to record the latitude and longitude of some of these features.

The field survey team visited every major water development infrastructure to collect data relating to their dimensions, the latitude and longitude, their condition and status as well as relevant but peculiar information needs were also recorded. For instance, for irrigation schemes, information relating to whether they are under cultivation, levelled or flat were also recorded. All the water impoundment structures such as dams, weirs, earthen bunded or rock-filled dams were surveyed and their effectiveness and condition noted. Regarding the dams, the conditions of bund, sluice, weir and feeder channel were recorded during the survey along with the year it was constructed, cost, potential command area, area irrigated between the years 1999-2005 and water spread area. Some of the information were collected from the FMWR, HJRBDA, CBDA, KSMWR, JSMWR and other organizations and departments and were only verified during the field visit.

For the well surveys, the ADPs in the riparian States, FMWR, and FMARD were relied upon to provide the primary data and only representative sample of the well were visited and any additional data collected that included: type of well, use of well, dimensions of well, year of construction, area irrigated (where applicable), pump capacity and discharge of well, reliability of well, latitude and longitude and survey number. Water samples were collected from such well for analysis at the FMWR regional laboratory in Kano, and the results provided for input into the study.

In the main, cropping statistics were collected by KYBP who in turn had received them from the relevant organization and line Ministries at both Federal and State levels. Indication of land holdings were not, however, included in the collected data from these irrigation agencies.

2.4 Analysis of Remotely-sensed Data

Data sourced from Federal Department of Land Resources were used as the main source of remotely-sensed data. Once analysed, these data were reconciled with other relevant terrestrial spatial data. Final mapping was done to appropriate scale. Any cadastral maps were digitised and its mosaics created to extract the basic map of the basin. Well locations, drainage patterns, dams, gullies and embankments were also digitised from cadastral maps which have been annotated by the field teams. Watersheds, sub-watersheds, mini-watersheds and micro-watersheds to the extent possible were delineated and digitised using suitable topographical maps (where available) otherwise the delineated watersheds in National Water Resources Master Plan were adopted. The delineation of different boundaries was done by considering factors such as river morphology, drainage and slope/elevation. Alphanumeric symbolic codes were allocated for all polygons by adopting the Natural Resource Information System (NRIS) guidelines.

The land use and land cover themes were prepared by Federal Department of Land Resources of FME using the following data analysis procedures. Onscreen interpretation (based on tone/colour, texture, pattern, shape, size, location, shadow, association) of satellite image and its digitization performed using an Imagine Software. Before further interpretation and analysis of the satellite imagery, the satellite images were rectified and re-sampled using a first order polynomial transformation model and/or a bilinear interpolation algorithm. To perform the same, the ground control points were taken from topographical maps and used with relevant GPS data sets to achieve accuracy. These images were used for interpretation/analysis.

The field data and GPS collected data were also linked to the respective spatial database and relevant field data. To link non-spatial data to the spatial database, the primary database key (linking code) for wells, dams, gullies and embankments were defined with respect to known locations in the States. After defining the primary key, the non-spatial databases were linked using GIS database relational utility.

2.5 Collection and Analysis of Socio-Economic and Institutional Information

Secondary data and literature from past and on-going socio-economic studies commissioned by KYBP and partner projects were used as the main method of collecting qualitative water-related socio-economic information.

Reasons for choosing this form of assessment include:

- Large sample size: At the minimum **all the five main riparian States and Plateau State would need to be covered in a short space of time (i.e. 3 months) at an acceptable cost. A minimum low cost qualitative method would require the use of conventional rapid-rural appraisal tools (involving transect walks and focus group discussions) in at least 30 villages/communities per State, each lasting a day. Clearly, this was considered impossible to achieve within the time limit of the study.**
- Only qualitative secondary sources could provide both qualitative and quantitative information that are required within the time frame.
- GIS-compatible information are needed**: The best opportunity for qualitative and quantitative physical (natural) system information that could be collected to be combined in the GIS database was through the use of the more "detailed" socio-economic information that have been collected by other studies and groups.**

Following the fieldwork to gather available secondary data, numerical socio-economic information were entered either into Excel spreadsheets or into an Access database, while any supporting qualitative information gathered are recorded in this study report. Considerable thought and discussion went into developing different formats for presenting the data that are available as part of GIS layouts and incorporating it in the development of decision-support model and tools.

Attention was paid to collecting supplementary data on the profitability of both rainfed and irrigated crops and a sample of farmers were interviewed (where necessary). The resulting data was used to undertake both financial and economic analysis of different crops and cropping systems. Additional supporting information was collected on the relative profitability of non-landbased activities, the role of livestock, fisheries, proximity to markets and drought-coping strategies.

Simple economic analysis were also done on the ability of farmers to service loans on tube-wells and wash-borehole investments and the levels of risk that, in particular, small and marginal farmers have been taking when developing new wells.

2.6 Fundamental Strategic Principles

All the stakeholders in the basin were unanimous in accepting that adopting a more integrated approach to water resources development and management through an integrated Water Resources Management (IWRM) and water efficiency management strategy would be helpful in addressing the problems of the basin. *IWRM is essentially, a philosophy* that offers a guiding conceptual framework rather than a concrete blue print. It, however, require a change in the working practices to look at the bigger picture that surround actions and to realize that these do not occur independently of the actions of other sectors, other users, and other communities. In other words it seeks to introduce an element of decentralized democracy into water management with emphasis on stakeholder participation and decision making at the lowest appropriate level. *It* *also requires negotiation of differences between the stakeholders.* IWRM requires that platforms be developed to allow very different stakeholders, often with apparently irreconcilable differences to somehow nonetheless work together.

IWRM requires reform. Because of the existing institutional and legislative frameworks, implementing IWRM is likely to require reform at all stages in the water planning and management cycle involving: Step-by-step process. In the first instance *the* **ENABLING ENVIRONMENT** need to be created *setting out the appropriate rules, and the* **INSTITUTIONAL ROLES** *and functions to define the players who make use of the* **MANAGEMENT INSTRUMENTS** to achieve comprehensive assessment of water resource and supporting ecosystems based on ***appropriate scales of analysis of the drivers, pressures, states, impacts and resources (DPSIR) auditing and scoping to achieve equitable water allocation, modified by consideration for ecological sustainability principles together with 'coping' strategies for greater stakeholder inclusion in the decision-making process***. Consequently, the KYBP water auditing and scoping study was based on step-by-step IWRM process (see Box 3 for Global Water Partnership (GWP) recommended key actions), with some recommended changes to take place immediately and others requiring several years of planning and capacity building.

The International Conference on Water and Environment, held in Dublin, Ireland, in the month of January 1992 gave rise to four principles of IWRM that have been the basis for much of the subsequent water sector management reform.

a) ***Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment***. Since water sustains life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems. Effective management links land and water uses across the whole of a catchment area or groundwater aquifer.

Box 3. GWP Recommended Key Actions to Implementing IWRM and Water Efficiency Strategy

The use of the word “strategy” rather than “plan” is to underscore the dynamic and change-oriented nature of the IWRM process, because water is not only the most basic needs but also at the centre of sustainable development and is essential for poverty eradication. Water is intimately linked to health, agriculture, energy, education, and biodiversity. Without progress on water, reaching the other Millennium Development Goals will be difficult, consequently the following are the key recommendations for developing and implementing IWRM and water efficiency strategy:

- Use national development goals or water-related challenges as a starting point.
- Secure commitment at the highest level, but ensure a broad base of support which reaches down to the grass-roots.
- Involve high-level officials in water-related sectors from the outset, and assign the task of developing the strategy to a multi-sectoral steering group.
- Ensure that stakeholders are meaningfully involved in the process, taking particular care to give women and poor people a voice.
- View the strategy as an opportunity to establish more integrated decision–making processes, rather than as a one-off checklist of actions.
- Ensure a realistic plan of implementation that includes a clear definition of roles and responsibilities, a sound financing strategy, provision for capacity-building, and systems to monitor progress and make adjustments as needed.
- Link to and build on other national plans and strategies-including country poverty reduction strategy papers, national strategies to meet the Millennium Development Goals, and strategies called for by key environmental conventions, such as the National Biodiversity Strategy and Action Plans and the National Plans to Combat Desertification.

b) ***Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.*** The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects.

c) ***Women play a central part in the provision, management and safeguarding of water:*** This pivotal role of women as providers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. Acceptance and implementation of this principle requires positive policies to address women’s specific needs and to equip and empower women to participate at all levels in water resources programmes, including decision-making and implementation, in ways defined by them.

d) ***Water has an economic value in all its competing uses and should be recognised as an economic good.*** Within this principle, it is vital to recognise first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Water has a value as an economic good as well as a social good. Many past failures in water resources management are attributable to the fact that the full value of water has not been recognised and has led to wasteful and environmentally damaging uses of the resource. Treating water as an economic good is an important means for decision making on the allocation of water. This is particularly important when increasing supply is no longer a feasible option.

2.7 Review of Water-Related and Environmental Policies

The process of developing an IWRM and water efficiency strategy within the process of KYBP Water Audit provided an opportunity to take a coherent approach to improve the development, management and uses of water resources to further sustainable development goals and meet development challenges of the basin. It built on existing IWRM and water plans by more purposeful incorporating water into National Economic Empowerment and Development Strategy (NEEDS) and State Economic Empowerment and Development Strategy (SEEDS). This is supported by reforms in many water-related and environmental sectors and at many levels (states, local governments, and communities). A well thought out reform – the kind that is embodied in the strategy- would hopefully catalyse the process and produce more sustainable results than attempts to completely overhaul the whole system or the current *ad-hoc* approach to change.

Core stakeholders that were consulted in formulating the strategy and whose policies and programmes were reviewed and analysed included government ministries and related institutions and policies involved in such activities as domestic and industrial water supply, sanitation, irrigation, agriculture, energy, health, finance, transport, fisheries, environment and tourism; and water utilities, agencies and related bodies. Other stakeholders were involved during the stakeholder consultation workshop. These included the communities and civil society and private sector organizations. The report of the study commissioned by DFID-JWL project to review the policies and institutions in environment and water-related activities served as foundation.

2.8 Water Balance Calculations

Water balance calculations was used to assess the status of water resource availability, with particular attention being given to evaluating the impacts of land use change, groundwater extraction and water harvesting structures on temporal and spatial patterns of water resource availability and use. The KYBP water auditing was done within the context of coordinated development and management of water, land and related resources, integrating the needs of various human uses including vital needs of terrestrial and aquatic eco-systems. Agricultural, industrial, rural, power generation and other infrastructural development policies and programmes particularly as they impinge on land and water use were considered.

Conservation of mass requires that, for the basin over one year, inflow shall equal to outflows, plus any change of storage within the basin. Although many components of the water balance were difficult to estimate, establishing water balances was possible using data that are readily available. Impact of internal changes in land use as well as policies and programmes with regard to soil and water conservation were tested after overall water balance for the entire land phase of the hydrologic cycle was studied. The contribution of shallow aquifers to the dry season flow was considered. In the basin, shallow aquifer water use for agriculture is slowly turning out to be a major component in the basin, and this would affect the base flow in rivers besides lowering of the water table. Results were crosschecked with the qualitative observations and experiences of specialists and local people working and living in the basin.

Separate water balance calculation was done for irrigation, domestic and livestock uses; actual evaporation from irrigated, rainfed arable and groundwater recharge. As a caveat, it must be stated that there were uncertainties in the absolute values that are being presented and we anticipate that these uncertainties will be reduced as more reliable data become available.

Box 4. Estimation of annual average recharge
Recharge estimates would be made using the simple water balance equation:
R = Qp + Qa + Rd + Et + Bf - s
Where:
R = annual groundwater recharge,
Qp = groundwater pumped from wells,
Qa = aquifer through-flow,
Rd = recharge to deep aquifers,
Et = groundwater abstraction by deep-rooting vegetation,
Bf = the base-flow contribution to streams, and
s = change in aquifer storage.

For the areas over which recharge estimates would be made, Qa would be assumed to be very small. This assumption is based on the knowledge of aquifer characteristics and levels of groundwater depletion in the region. Rd is also assumed to be negligible because of the impermeable layer underlying the shallow aquifers in the basin. Et is assumed to be negligible because of aridity of the basin and sparse deep rooted trees that would extract water from deeper groundwater levels. and s was also assumed to be small because of the growing tendency during recent years for farmers to want to pump wells until they are almost failing. Hence, recharge would approximate the groundwater extraction for irrigation and base flow contribution to streams which, in turn, would be estimated using areas under different crops and information to be gathered locally on actual irrigation application rates for these different crops as well as the hydrograph separation analysis.

2.9 Runoff Analysis

River flow data collected from KYBP and other official government sources for four sub-basins that drain the KYB of northern Nigeria and southern Niger Republic were consolidated into continuous monthly and annual river flow records of at least 5 to 20 years duration. Continuous monthly rainfall data were also collated for rainfall stations within the study catchments. Stations with long periods of missing data were excluded from the analysis. Records with only a few months of missing data were patched using data from the nearest adjacent station. Areal rainfall values were determined from the individual rainfall records using the Thiessen method.

The impact of impoundment along drainage lines on reservoir inflows were estimated using a simple "bucket-type" water balance model. The main aim of this model is to assess the affects of the additional storage created by new reservoir structures, and the relationship between runoff attenuation and different patterns of rainfall. For the KYBP Water Audit, runoff analysis was carried out using data from Challawa and Tiga representative reservoir catchment areas. Runoff estimates were computed from these. The main findings of this analysis were crosschecked against the perceptions and knowledge of villagers and staff living and working near these reservoirs. Subsequent to the Water Audit, the model may be refined by the KYBP and further developed based on a daily time step. This model could be used to analyse the effects of impoundment/water harvesting on patterns and availability of runoff in the catchment areas of an additional reservoirs in future.

Physical Characteristics of the KYB 3

3.1 General Information

As noted in the preamble, the KYB is a sub–catchment of the larger Chad Basin, covering an area of 148,000 km^2, 57% of which lies in north eastern Nigeria and the rest in south eastern Niger. It represents approximately 35 percent of the conventional basin of Lake Chad. The Nigerian sector of KYB accounts for 95% of the basin's total contribution to the lake. The geological formation of the upstream part of the catchment consists of mainly impermeable basement complex rocks which dip away to the east where it is covered with the permeable sands, gravels and clays of the Chad Formation. Alluvial sediments are present overlying the Chad Formation close to the rivers. Much of the catchment is relatively flat with the only significant hills (the Jos Plateau) rising in the south-west from where the headwaters of the Jama'are River and to a lesser extent the Kano River begin. Soils tend to be sandy and relatively deep with the exception of shallower soils dominating the headwaters of the Jama'are. The majority of the basin falls within Sudan Savannah Ecological Zone which has a natural vegetation cover dominated by shrubs and dense grasses with a minor tree component. However much of the natural cover has been affected and is continuing to be affected by man, and large areas are used for various forms of rainfed agriculture or pasture. Natural woodland only dominates in the south-western parts of the basin.

The main rivers of the basin are the Hadejia and Jama'are Rivers that meet in the Hadejia-Nguru Wetlands to become the Yobe River that drains to Lake Chad.

Historically, the Yobe River has been estimated to contribute only about 1-2% of the total flow into Lake Chad. The hydrology of the basin is complex: both the Hadejia and Jama'are river systems are "gaining" rivers until they cross the geological divide between the Basement Complex and the Chad Formation after which their flows decrease (Goes and Zabudum, 1998). The hydrology of the internationally significant Hadejia-Nguru Wetlands where the two river systems meet is consequently very complex and has been the subject of numerous studies (Goes and Zabudum, 1998; IUCN, 1998). Seasonal flooding plays an essential role in maintaining the ecological system of the wetlands and enables both flood and recession farming to be conducted in the wetland region and along the lower reaches of the rivers.

Artificial constraints upon the river systems have further increased the complexity of the hydrology. The Hadejia River system is thought to be more than 80% controlled by both the Tiga Dam (closed in 1974) on the Kano River and the Challawa Gorge Dam (closed 1992) on the Challawa River (IUCN, 1998). These dams feed two large, partly finished, formal irrigation schemes (Kano River Irrigation Project – KRIP, and the Hadejia Valley Irrigation Project – HVIP) near Kano and Hadejia respectively. Both also contribute to the Kano City Water Supply. The Jama'are River system is presently uncontrolled but plans do exist to build a dam at Kafin Zaki. Plans are already being considered for building a structure at the upstream end of the Nguru Wetlands to control the destination of the wetland's flow. This is known as the Likori split flow proportioning structure.

Supply of water to the basin's river system is dominated by the contribution from the headwater regions underlain by the basement complex rock. Network of river gauging stations were installed in the 1960s and 1970s to monitor the flows (Afremedev, 1999). Meteorological stations observed within the basin that are used to assess water availability are as shown in Figure 3.1. The information from these stations were used, together with discharge gauging stations data, to develop the modelling methodology for the project and hence the water availability within the Hadejia-Jama'are sub-systems.

The river systems also support the Hadejia-Nguru Wetlands (HNWs), which is Nigeria's premier Ramsar site that is of immense local, national and international economic and ecological importance. The HNWs harbour over 370 species of birds, 33% of which are migratory as well as about 100 species of fish. There are also some endemic plant species of agronomic importance which are threatened with extinction and which have attracted strong conservation interest. These include a local variety of rice cultivated between Gashua and Geidam stretch (IUCN, 1997).

3.1.1 Hadejia Sub-basin

River Hadejia is formed by the confluence of the Challawa and Kano Rivers at Tamburawa (Figure 3.2). For the first 50 km of its course the Hadejia River never maintains a gradient of 2.5 m per km. As it enters the Lake Chad Formation below Wudil (coinciding roughly with the Kano-Kari highway), this gradient reduces abruptly resulting in the channel becomes poorly defined and characterized by numerous oxbow lakes. The hydraulic capacity of the river channel is insufficient to contain flood flows. Portions of the flood flows leave the main river channel and spread out through distributaries to inundate vast areas to varying depths and to raise the water levels in perennial oxbow lakes.

The third main river in the upstream part of the Hadejia sub-basin is the Watari River. This river joins River Hadejia upstream of Wudil. The Hadejia River is a gaining river until the geological boundary between the Basement Complex and the Chad Formation. The upstream Basement Complex region is hilly (with peaks of up to 1,200 m). In the upstream area, from 1980 onwards, there has been a tendency for the tree-dominated savannah to be replaced by land-use for rainfed agriculture and grazing (Afremedev, 1999). The middle and downstream parts are, except for some ancient sand dunes, relatively flat.

The Challawa River forms the most northerly sub-catchment of the headwaters. Compared to the southern headwater catchments, the area is relatively flat. Deep sandy soils dominate with a tendency for the soils to form crusts (Geomatics International, 1998). The catchment area at Challawa Gorge is 3,860 km^2 and the average annual rainfall (1928 to 2001) is 931 mm. Most of the natural grass dominated scrub has been altered by man with various forms of rainfed agriculture and grazing dominating. Since the 1970s, there appears to have been a significant increase in denuded and gullied areas.

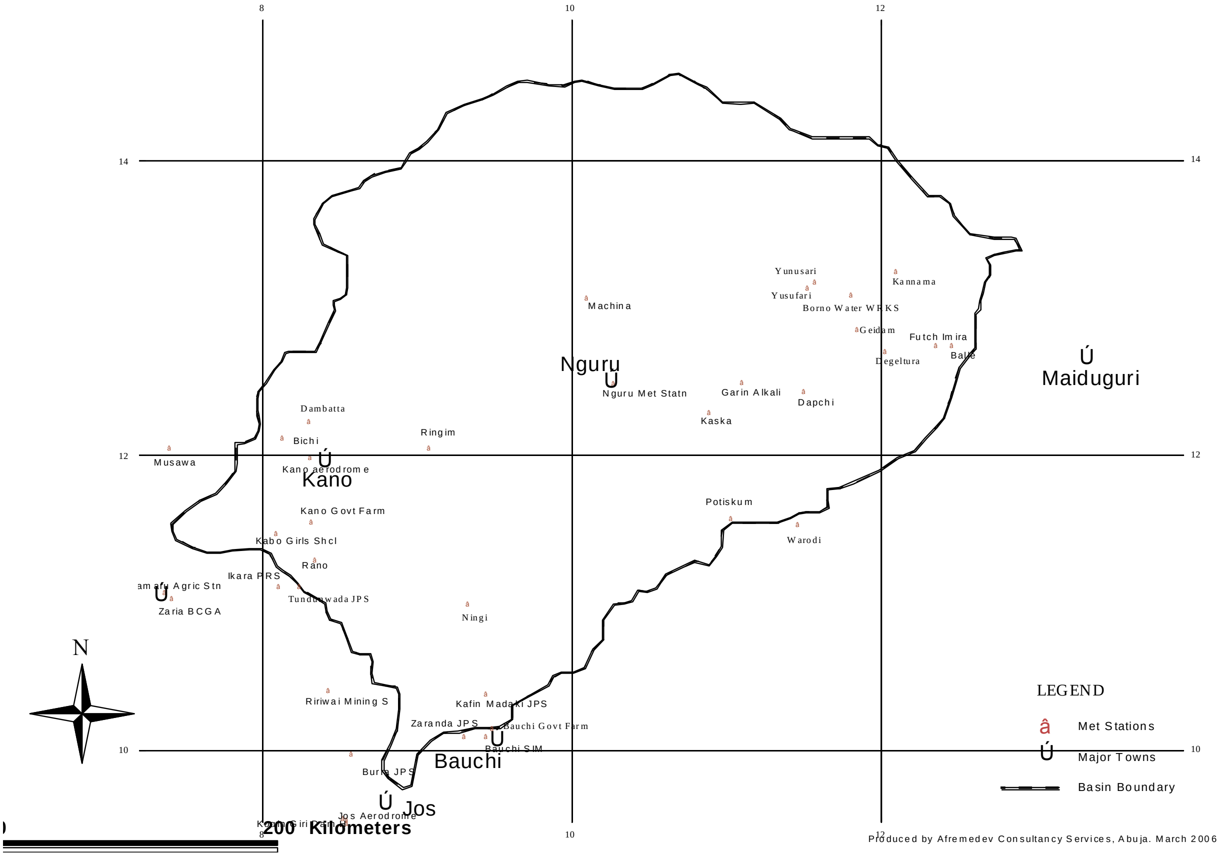


Figure 3.1: Meteorological Stations in KYB

The Kano River catchment lies in the south of Kano City. The watershed lies in the foothills of the Jos Plateau. The land use is dominated by a mixture of intensive and extensive agriculture practice, with remnants of natural vegetation occurring in the south. However over the last 20 years there has been a tendency for the tree dominated savannah to be replaced by forms of rainfed agriculture and grazing. The catchment area at Tiga Rapid is 6,975 km^2 and the average annual catchment rainfall from 1928 to 1994 is 1,063 mm.

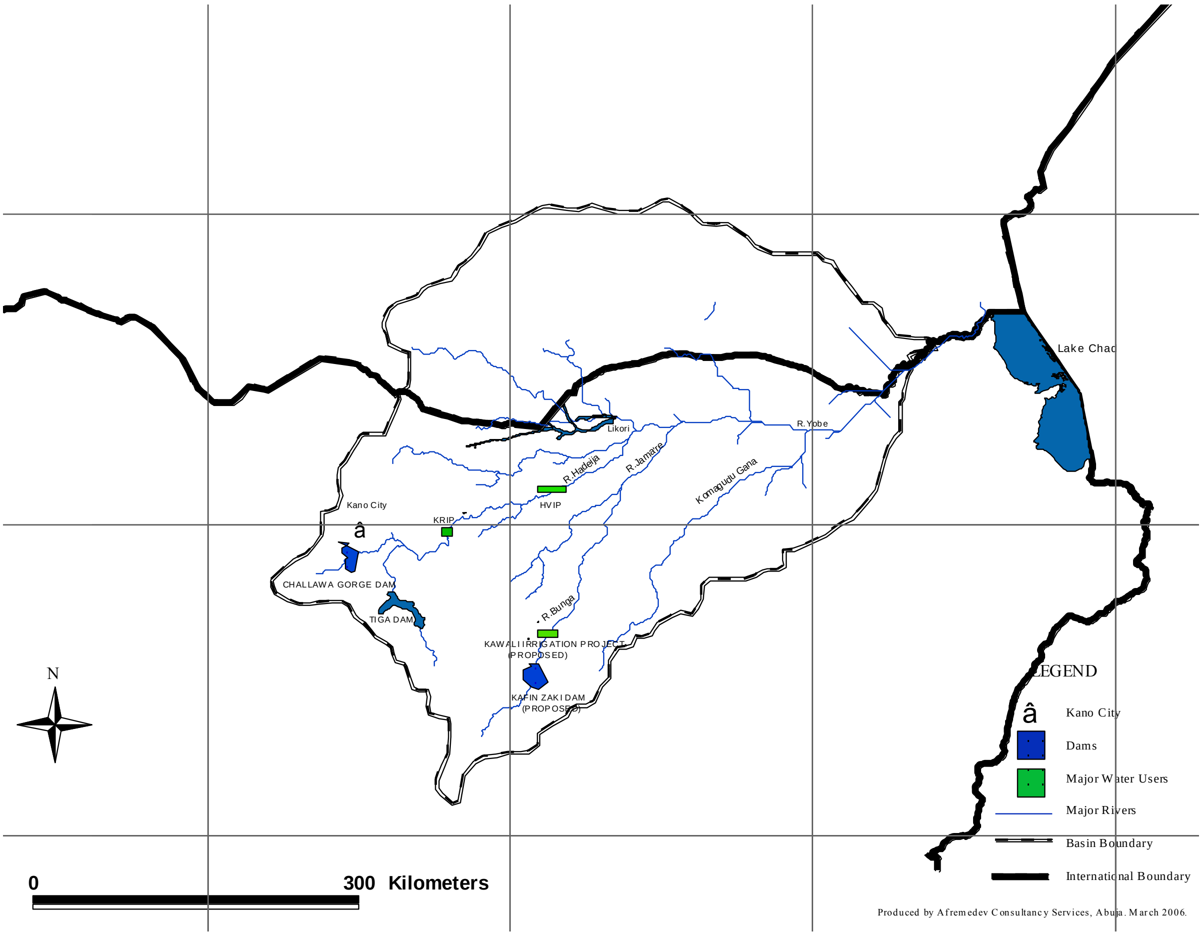


Figure 3.2: Major rivers in the KYB

3.1.2 Jama'are Sub-basin

River Jama'are rises from Jos Plateau and flows through Fogo, Bunga and Katagum to join River Hadejia system at Gashua within the HNWs. The cathment area of the Jama'are River system is 7,980 km^2 at Bunga and 15,000 km^2 at Katagum. The soils tend to be sandy though shallower than those in the rest of the sub-catchments (Geomatics International, 1998). Hilly areas with significant areas of bare rock are common. The catchment area within Bunga retained more of its natural vegetation cover than the headwater sub-catchments of Hadejia. However over the last 20 years there has been a tendency for the tree dominated savannah to be replaced by forms of rainfed agriculture and grazing. The mean annual rainfall from 1922 to 1992 is 1,239 mm.

The flow in the Jama'are River is ephemeral (June to October) because there are no major dams in this sub-basin. The river is a gaining river until the geological boundary between the Basement Complex and the Chad Formation. In the Basement Complex area the soils tend to be sandy though shallower than those in the Hadejia sub-basin. The upstream Basement Complex region is hilly (up to 1,700 m) with significant areas of bare rock. This implies that the river flow in the upstream part of the basin responds relatively fast to rainfall. Furthermore, the Basement Complex area has retained more of its natural vegetation than in the Hadejia sub-basin (Afremedev, 1999). Downstream of Katagum in the flat HNWs, the Jama'are River splits into a number of smaller channels. *Typha domingenis* and other weeds did not invade the channels of the uncontrolled ephemeral Jama'are River. The weeds cannot survive in this river because of a lack of water during the dry season and the high wet season peak flows that flush the main channels clean.

3.1.3 Komadugu Gana Sub-basin

The period of predominant flow in the Komadugu Gana is June to October at Kari and August to December further downstream at Dapchi. The river is a gaining river until the geological boundary between the Basement Complex and the Chad Formation. The river flow reductions are, compared to the Jama'are and Hadejia rivers, relatively large. On average (1970-1977) the river flow reduction between Kari and Dapchi is 73%. The river forms a wide floodplain downstream of Dapchi. The confluence of the Komadugu Gana and Komadugu Yobe is largely silted up. This river, thus, provides only a small and unreliable contribution to the Yobe River. In almost all the studies on the KYB, this river is neglected.

3.1.4 Yobe Sub-basin

The Yobe River is situated in a very flat ancient alluvial plain overlying the lake sediments of the Lake Chad formation. Approximately 43% of the water that flows into the HNWs flows into the Yobe River at Gashua. Due to the weed and silt blockages the contribution from the Hadejia to the Yobe River has been practically nil since at least the early 1990s. NEAZDP and YSADP reported a slight increase in the contribution from the Hadejia to the Yobe River due to the clearing of weeds and silts in a part of the Burum Gana River. The clearing was initiated by JWL Project in the 2004/2005 dry season. If the Gashua annual discharge is taken as 100% then roughly 70% arrives at Geidam, 45% at Damasak and 28% at Yau (IUCN, 1999). The period of predominant flow is June to October at Gashua and August to January at the downstream end (Yau). The Yobe River ends in the northern pool of Lake Chad and is the only river flowing into the northern pool. The present contribution into the Lake Chad area is estimated at less than 2% of the total input.

3.2 Agro-Climate

The basin lies largely within the Sudan Savannah agro-ecological region of West Africa. Its uplands are in the Northern Guinea zone while its floodplains in the north, mark the beginning of the Sahel. The Climate of the region is governed primarily by the interaction of two major air masses, the Tropical Maritime (TM) and the Tropical Continental (TC), which meet along the Inter-Tropical Convergence Zone (ITCZ). Warm and moist TM air moves inland in a general southwest to northeast direction from the Gulf of Guinea. Warm and dry TC air moves southwest from the desert and rises over the TM air, which assumes a wedge shape increasing in thickness towards the southwest.

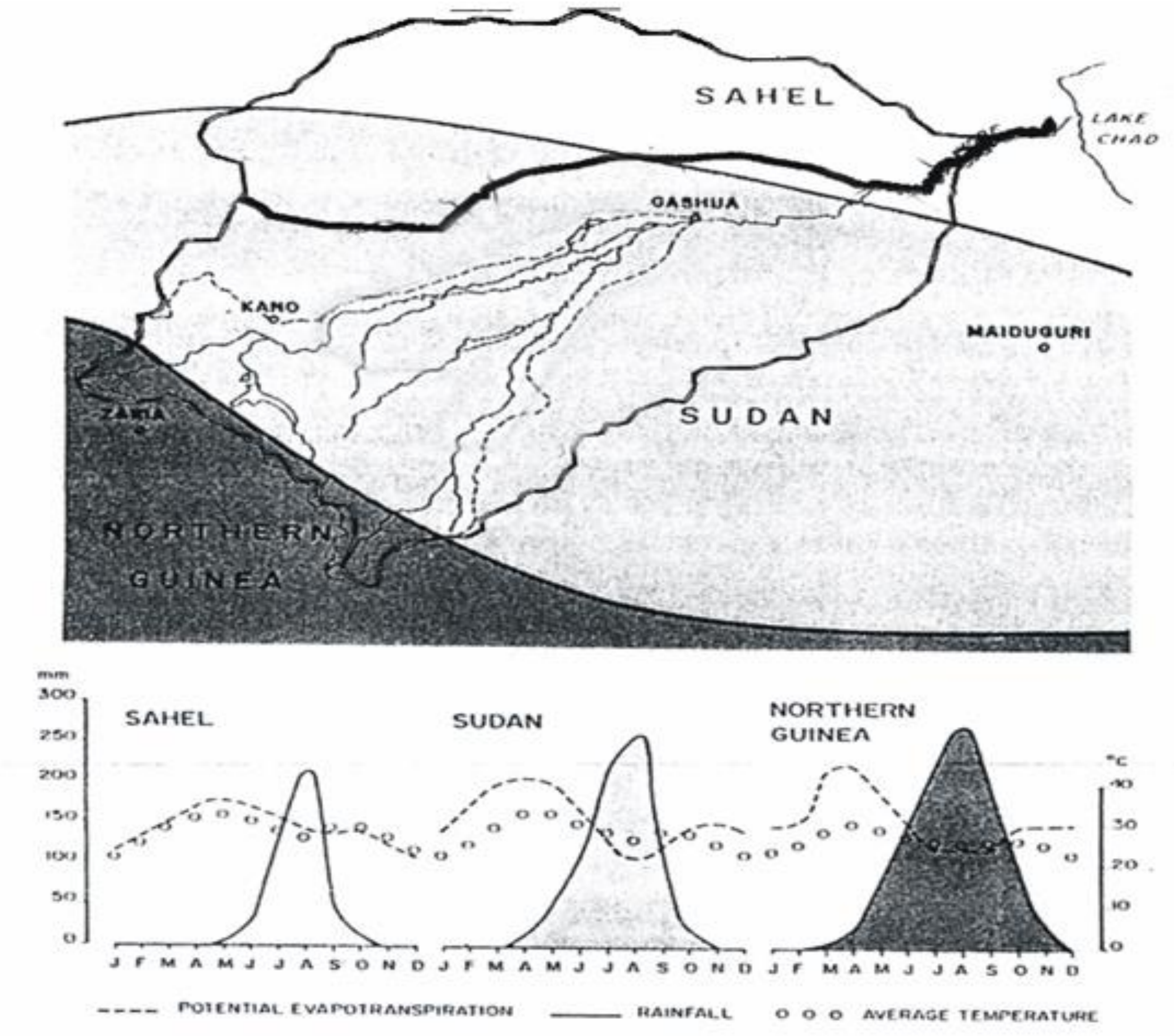
The rainfall at any location in West Africa depends on the relative movement of the ITCZ. In general, the thicker the mass of the TM air, the greater the rainfall. The seasonal migration of the ITCZ results in a decrease in mean annual rainfall from the southwest to the northeast and gives rise to two distinct seasons. The length of time that the TM air remains at any location determines the length of the rainy season of that location. The TC air mass is associated with the dry season, during which rainfall is extremely scarce.

Specifically in Komadugu Yobe Basin, the ITCZ contact with the ground arrives from the southwest in April or May and passes back over the basin in September or October. During these transitional months the wedge of humid air is too thin for convective rain but line squalls are common providing intense, localized rainfall of short duration. For agricultural requirements, this type of rainfall is unreliable, because the ITCZ may either become stationary or oscillate before moving on.

From June through September, the humid air mass is usually thick enough for convective rain, with the highest concentration generally occurring in August. The months of November to March are almost totally dry throughout the basin and river flows are essentially zero by the end of March. During this period, the TC air mass overlies the basin and winds, locally known as "Harmattan", laden with fine dust, are frequent. Figure 3.3 shows the variations in climatic parameters from the southern relatively moist Guinea Savannah zone through Sudan Savannah to the arid Sahel savannah. Variations in rainfall and evaporation also exist from the upland to the lowland areas of the basin which generally trends southwest – northeast. Figure 3.4 illustrates this trend.

The mean annual rainfall, occurring between May and October, varies from over 1,000 mm in the south-western plateau region to about 500 mm in and around the Nguru wetlands and to a minimum of less than 300 mm near Lake Chad in the far north-east of the catchment. The highly seasonal nature of the rainfall is a result of the annual migration of the Inter-Tropical Convergence Zone. Notable trends within the annual rainfall series have been a feature over the last 50 years, with periods of significantly below average rainfall occurring in both the early 1970s and particularly the 1980s. The corresponding pan evaporation rates are 3,400-3,600 mm per year near the Kano-Kari highway and about 3,800 mm in the Nguru-Gashua area. Annual potential evaporation tends to vary between 1,800 mm and 2,400 mm across the basin, though lower rates are recorded at Jos on the raised plateau.

Obviously in moving from the upland to the lowland areas that is from the upstream to the downstream portions of the rivers, Figure 3.4 suggests a notable south-north decrease in rainfall and marked increases in both evaporation and evapotranspiration rates. That simply translates to saying that water demands by agriculture are considerably higher in the northern part of the KYB than in the south. Put differently, crops with low water requirement would do better in the northern part of the basin than crops with high water requirement.



	RAINFALL (mm.)	RAINY SEASON LENGTH (DAYS)	POTENTIAL EVAPOTRANSPIRATION (mm.)	HOURS OF BRIGHT SUNSHINE
SAHEL	500	60 - 90 JUNE - MID SEPT.	1800 - 2000	3000-3300
SUDAN	500-1000	90-150 MAY - SEPT.	1800-2000	3000 -3300
NORTHERN GUINEA	1000	150-170 END APRIL - MID OCT.	1600-1800	2700-3000

Figure 3.3: Climatic Parameters of the KYB (After Schultz, 1976)

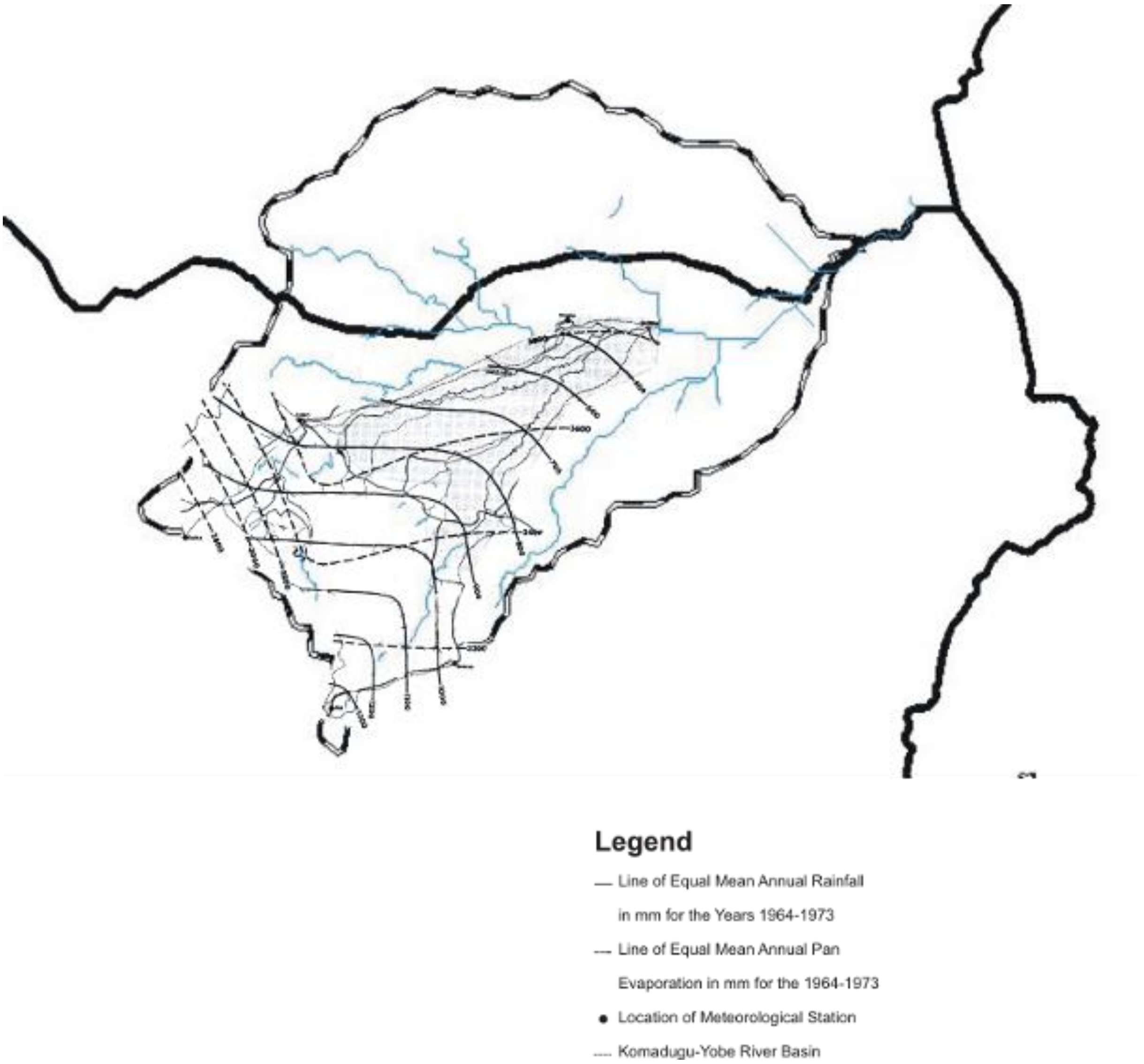


Figure 3.4: Isohyets and Pan Evaporation in the Core KYB (After Schultz, 1976)

3.3 Geology

The Chad Basin has been referred to as an interior sag basin (Kingston *et al*., 1983), due to a sagging episode that has affected it before the onset of continental separation during which a rift system junction was formed providing appropriate site for sedimentation. It therefore lies at the junction of basins (comprising the West African rift), which becomes active in the Jurassic/early Cretaceous when Gondwana started to split up into component plates (Lees, 1952; Carter *et al*., 1963). The separation of South America and Africa started down near the Cape progressing up towards the Bight of Benin. At this stage trellis configuration of rifts developed, and the Chad Basin formed at the intersection of two tectonic features known as the Tibesti-Cameroun and Teidet troughs, which trend northeast-southwest and northwest-southeast, respectively (Schultz, 1976). This led to the development of major graben and sedimentation started.

When the Chad Basin formed, shallow marine sediments were laid down over localized fanglomerates and possibly fluviatile deposits, which lay, unconformably on the basement. This sediment is hereby designated pre-Bima sediments (Avbovbo *et al*., 1986). The succeeding regression gives way to the deposition of a thick sequence of the continental Bima sandstone during Albian–Cenomanian times. The diverse lithology of the Bima sandstone indicates accumulation under widely varying conditions.

The Bima sandstone is overlain conformably by the transitional Gongila Formation. The Gongila Formation consists of basal limestone overlaid by a sandstone/shale sequence. The limestone is rich in mainly Ammonites and Mollusc (Reyment, 1965) the assemblage of which indicates an early Turonian age. The Formation has a maximum thickness of about 500 m.

The Fika shales consist of blue–black shale which are occasionally gypsiferous (Baba, 1995) and which contain thin persistent limestone. They vary in thickness from 100 m in Potiskum to about 500 m near Maiduguri, which indicates increase in thickness northeast ward. The fossils of the Fika shales indicate a Senonian-Maestischtian age. The Fika shales appear to have been deposited under a submerged (transgression) environment.

The Fika shale is overlain by the Maastrichtian Gombe sandstone which is a continental sequence of estuarine and deltaic sediments deposited over the marine shales. Gombe sandstone does not show east-west trend, which is imposed, on the earlier Formations. Lenses of siltstones and mudstone occur with ironstone at the lower beds. The middle part is characterized by well-bedded sandstone and siltstone (Kogbe, 1976). The upper part of the Formation contains poor quality coals and is cross-bedded sandstone.

The Kerri-Kerri Formation overlies the Gombe with an angular unconformity between them. It has massive claystone and siltstone with bands of ironstone and conglomerate occurring locally. The sandstones are often cross bedded, and lignite (low grade coal) occurs near the base of the Formation. The thickness of the Formation increases towards the basin centre and is overlain by Chad Formation. The Kerri-Kerri Formation is Paleocene in age and environment of deposition is lacustrine or fluvio-lacustrine.

Chad Formation is the Quaternary sediments which consist of fine to coarse grained sand, blue-grey with intercalation of sandy clay, clay and diatomite. Borehole data show that the Formation gently dips towards the centre of the basin. Maximum thickness of about 840 m has been recorded in the western shore of the Lake Chad. This Formation was thought to be Pleistocene in age. A minor unconformity indicated by a plinth of laterite is identified in a borehole as separating the Kerri-Kerri Formation from the Chad Formation.

The dunes and alluvial deposits are superficial deposits lying on the Chad Formation. The longitudinal dunes or seif occur as parallel ridges trending northeast-southwest up to 10 m to 15 m in height and extending for tens of kilometres without interruption. The river alluvium deposits consist of sands, silts and clays. Coarse sands and gravel occur along the present-day river channel. Less extensive alluvial deposits, mainly clay and silt, occur locally in interdunal depressions and semi-permanent ponds. Clays and silts also occur in oxbow lakes, abandoned channels and river floodplains. A summary of the stratigraphic succession is presented in Table 3.1.

3.4 Soils

Figure 3.5 shows the distribution of soil parent materials in a selected 23,000 km^2 out of the 84,138 km^2 area of KYB in the Nigerian sector. It is not a random sample of the KYB. On the contrary, it was selected by the Government and handed over to Schultz (1972–1976) to study and identify its development potentials.

Table 3.1: Summary of the stratigraphy of the Nigerian sector of the Chad Basin

Era	Period	Formation	Lithology
QUATERNARY	Recent	Alluvium	Younger and older alluvium, with interbedded aeolian sands up to 30 m
	Pleistocene		Predominantly clays with interbedded sands
TERTIARY	Pliocene	Chad Formation	
	Palaeocene	Kerri Kerri	Sandstone with interbedded gritstone and clays
MESOZOIC	Cretaceous	Various from Bima to Gombe	Mainly sandstones and shales
PRECAMBRIAN		Basement Complex	

The basement complex is the parent soil material for all the area south of the geological boundary. North of the boundary are the dune fields and the alluvia; constituting the parent materials for the soils covering the remaining areas. Dune fields are aeolian deposits (from which "Jigawa" State derived its name) while the alluvia, either ancient or recent, are of fluvial, lacustrine or fluvio-lacustrine. The ancient alluvia (most probably fluvio-lacustrine) are very widespread over the area. The recent alluvia, on the other hand, are restricted to contemporary river courses and floodplains.

Based on soil profile studied in the field, as well as physical, chemical and mineralogical analysis and interpretations in laboratories, Schultz (1976) produced a soil map covering a substantial portion of the core KYB. Table 3.2 summarizes the percentage distribution of the basins soils according to FAO classification, groups and suitability. Figure 3.6 also shows the spatial distribution of the different soil groups.

The salient characteristics of the major soil types constituting the groups in Table 3.2 are outlined hereunder. It would not serve any useful purpose in this exercise to extend the outline to soil sub-types; on the contrary it may even create avoidable confusion. The soil types are outlined in alphabetical orders, with some of the sub-types simply mentioned.

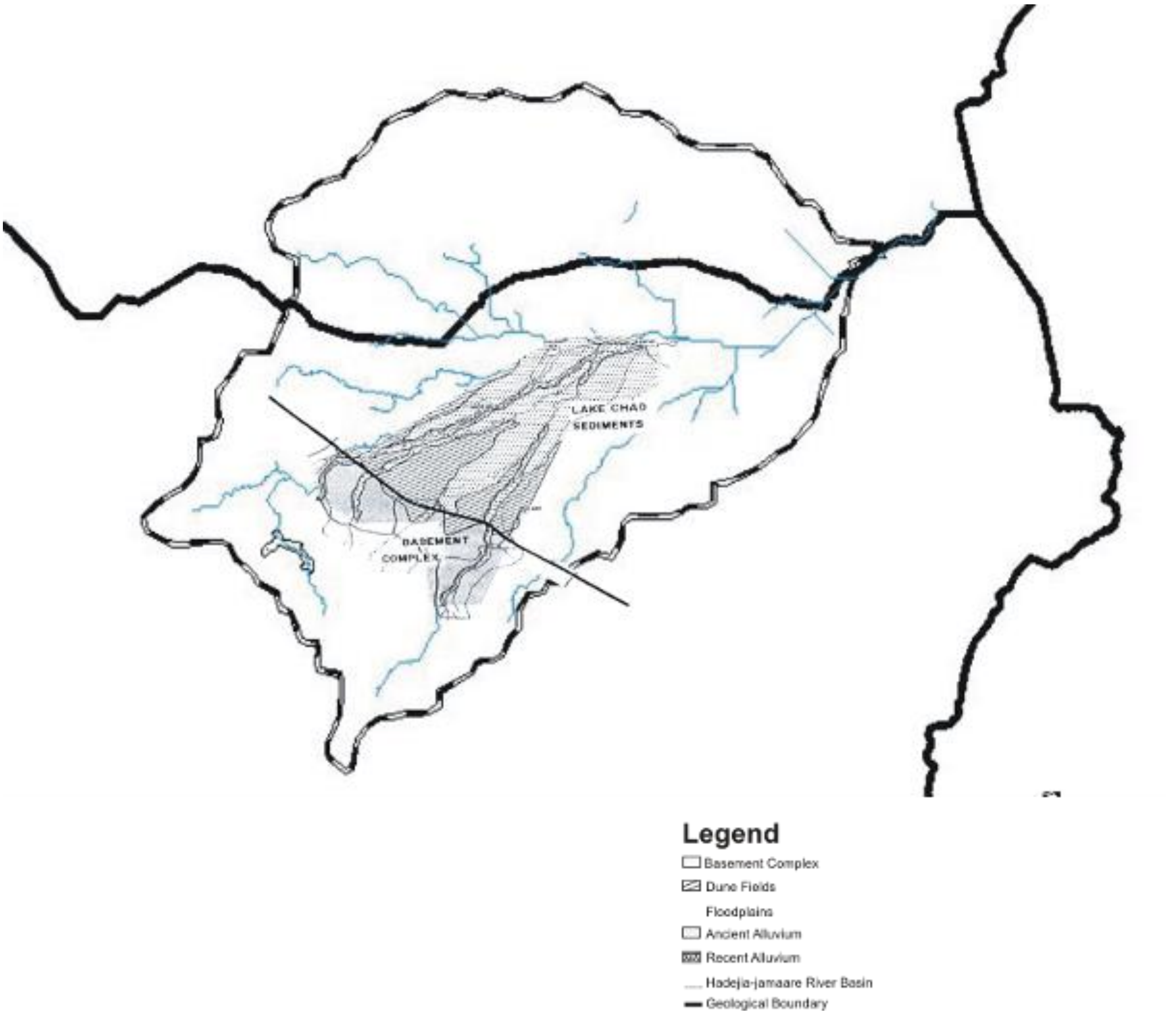


Figure 3.5: Soil parent Materials of Core KYB (After Schultz, 1976)

(i) **Arenosols:** are sandy textured, well and sometimes excessively drained soils occupying shedding sites. The sub-types include Luvic, Cambic and Lithic Arenosols.

(ii) **Cambisols**: are generally well drained sandy loams overlying sandy clay loams or clays; may occupy any site but more frequently shedding and receiving than ponded sites. Sub-types include Dystric, Chromic, Eutric and Gleyic Cambisols.

(iii) **Fluvisols**: are deep, moderately well drained to somewhat poorly drained, stratified sands, silts and clays; occupying upland shedding sites and may be flooded by the river during the rainy season. Eutric Fluvisols are the common sub-types in the KYB.

(iv) **Gleysols:** are poorly to very poorly drained clays, occupying ponded sites (such as lakes) for most of the year. Eutric gleysol is the common subtype in the KYB.

(v) **Lithosols:** are well drained, very shallow (about 10 cm) loams overlying ironstone.

(vi) **Luvisols:** are sandy loams overlying sandy clay loam; they occupy either shedding or receiving sites except the sub-type Gleyic Luvisols that may be in ponded sites. Other subtypes are Orthic and Chromic Luvisols.

Table 3.2: Core KYB Soil Groups, Classification, Suitability and Percentage Distribution

Land Class	Suitability	Constituent FAO Soil Types	Percentage Coverage
I	Highly suitable for both irrigation and dryland agriculture	Cambisols: *Chromic, Dystric, Eutric, Gleyic*; Luvisols: *Chromic, Orthic, Gleyic*; Solonetz: *Orthic*; Arenosols: *Luvic*	5
II	Moderately suitable for irrigation provided that flooding is controlled. Presently unsuitable for dryland farming because of flooding hazard	Cambisols: *Eutric, Gleyic;* Gleysols*: Eutric*; Luvisols: *Orthic, Gleyic*; Vertisols: *Chromic, Pellic*; Fluvisols: *Eutric*	22
III	Moderately suitable for dryland farming. Coarse textured and only marginally suitable for irrigation	Cambisols: *Chromic, Dystric, Eutric, Gleyic*; Luvisols: *Chromic, Orthic, Gleyic*; Arenosols: *Cambic, Luvic*; Fluvisols: *Eutric*; Vertisols: *Chromic, Pellic*; Solonetz: *Orthic*; Planosols: *Solodic*	9
IV	Marginally suitable for dryland farming. Coarse textures make these soils unsuitable for irrigation Widespread flooding occurs in depressions.	Cambisols: *Chromic, Dystric, Eutric, Gleyic*; Arenosols: *Cambic, Luvic*; Lithosols; Luvisols: *Orthic;* Solonetz: *Orthic*; Vertisols: *Chromic, Pellic;* Planosols: *Solodic*; Gleysols: *Eutric*; Fluvisols: *Eutric.*	58
V	Unsuitable for either irrigation or dryland agriculture	Cambisols: *Chromic, Dystric, Lithic, Eutric*; Arenosols: *Cambic, Luvic;* Lithosols; Fluvisols: *Euthric*; Planosols: *Solodic*.	6

Source: Schultz (1976)

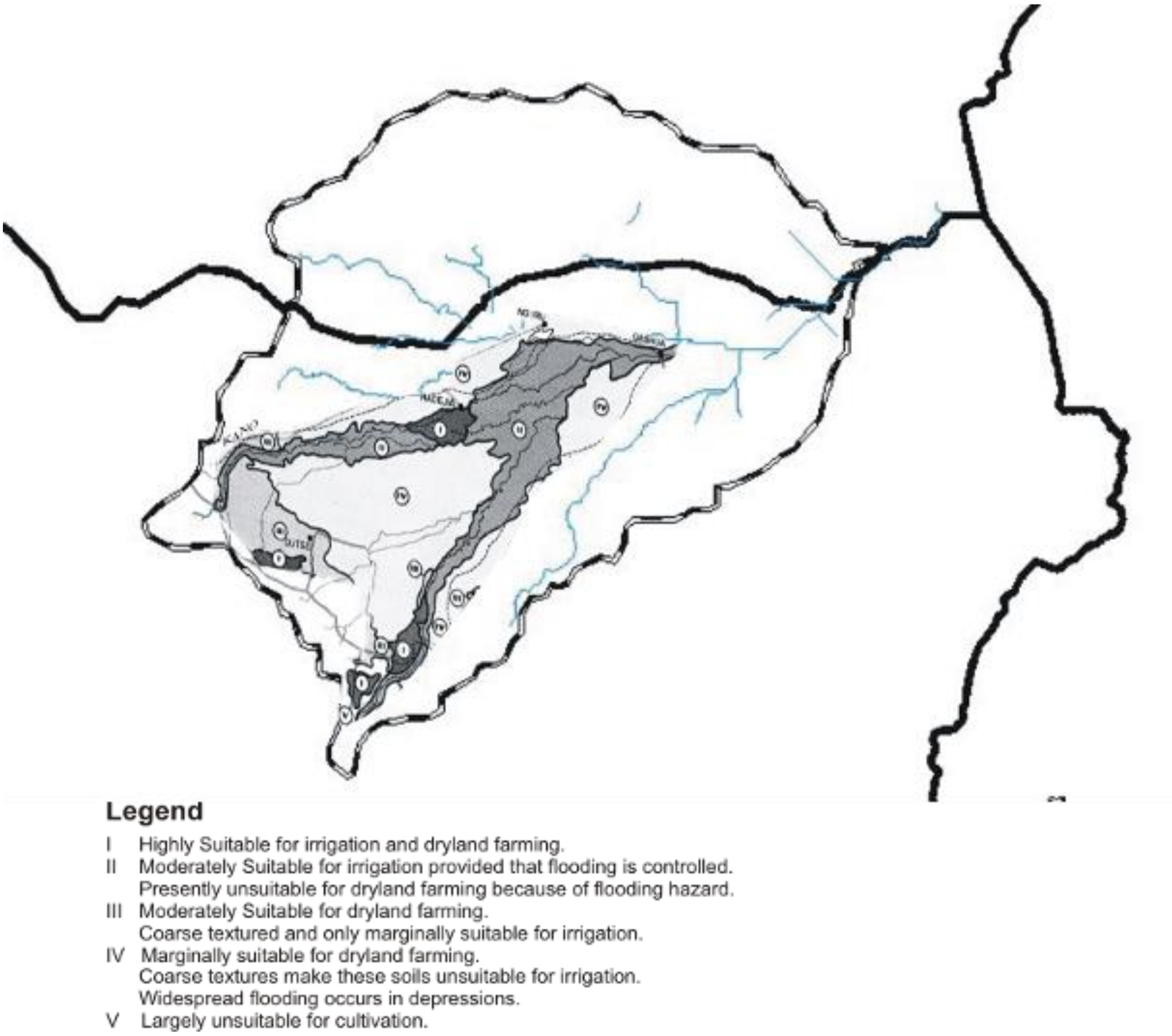


Figure 3.6: Distribution of Core KYB Soils and their Agricultural Suitability (Read with Table 3.2) (After Schultz, 1976)

3.5 Dams and Reservoirs

The river systems in the Sudan Savannah areas, that constitute about 60% of the basin, are mostly shallow and flow only during the rainy season with several non-returning channels that carry away the water flow from the main streams. Along the Hadejia River from Ringim to Nguru and along the lower reaches of the Jama'are River there are extensive low lying fadamas that get flooded annually. The complexity of the hydrology is further compounded by the man-made controls imposed upon the river systems, as illustrated in the Hadejia River system being more than 80% controlled by the combination of Tiga Dam (closed 1974) on Kano River and Challawa Gorge Dam (closed in 1992) on the Challawa River. The statistics of the storage and yield are summarised in Table 3.3. The Tiga and Challawa Gorge dams contribute raw water to Kano City Water Supply and feed two large, partly finished, formal irrigation schemes, namely the Kano River Irrigation Project (KRIP) and the Hadejia Valley Irrigation Project (HVIP). The KRIP was designed in two phases. Phase I (KRIP–I) has a total irrigated are of 27,000 ha while Phase II (KRIP–II) would add a further 40,000 ha. As at now only 13,700 ha of Phase I have been completed.

The outlet works at Tiga Dam are also deficient at present in that the valve release capacity is limited to a maximum of 47 m^3/s at full retention level. In response to seepage on the dam it has also been necessary to draw the spillway level down by 2.5 m to avoid excessive surcharging during floods. This change was made in 1992 and effectively reduced the live storage capacity to 1,283 million m^3, that is, about 70% of its former value. In an emergency situation, the limited capacity of the outlet works prevents the reservoir level being reduced rapidly, hence the need to keep the level down. Since its storage volume far exceeds the average annual inflow (Table 3.3), the reduction in storage capacity does not significantly affect its average annual yield (Tahal, 1992).

Table 3.3: Tiga and Challawa Gorge Reservoirs – Storage and Yields

Reservoir	Total Storage Volume Mm^3	Annual Average Inflow Mm^3	Ratio Volume/Inflow	Average Annual Yield Mm^{3*}
Challawa Gorge	930	380	2.5	267
Tiga	1,400	900	1.6	768
Combined	2,330	1,280	1.8	1,035

* Losses from seepage and evaporation are put at 141 Mm^3 and 113 Mm^3 for Tiga and Challawa Gorge, respectively
Source of data: Parkman 2000

Challawa Gorge Dam, which commenced operations in 1992, has a live storage capacity of 900 million m^3 with a designed maximum valve release capacity of 86 m^3/s. There are operational problems with this level of release such that the effective limit of release[2] is said to be in the order of 46 m^3/s, nor does it affect the intakes at Kano. But it may well be a matter for major concern to the HJRBDA in terms of the flood attenuation capacity of the reservoir as well as the intrinsic safety of the dam structure itself. This may not be too dissimilar to the situation prevailing with respect to the limited release capacity of Tiga Dam outlet works where the reservoir water level cannot be drawn down rapidly in an emergency and where the situation warranted a reduction in spillway level to compensate for this[3]. It is assumed that a reservoir safety inspection at Challawa Gorge would consider this limitation and make the appropriate recommendations for increasing the release capacity or whatever other measures as are considered to be appropriate.

A barrage on Hadejia River at downstream of Wudil creates a pond that has capacity to regulate the fluctuations in the releases from Tiga and Challawa Gorge reservoirs 250 km upstream. The release to Hadejia Valley Irrigation Project (HVIP) is controlled at the barrage. The barrage has a maximum spillway capacity of 38.15 m^3/s while the storage capacity 1.4 million m^3. It cannot therefore, significantly change the water release rates or non-release by the two dams Tiga and Challawa Gorge, which have a combined storage capacity of 2187 million m^3 and combined maximum spillway [release] capacity of 111 m^3/s. The permissible water levels range from 37 m above mean sea level (amsl) [minimum] to full level of 38.75 m amsl with an average operational level of 38.25 m amsl. In the case of the HVIP, out of a design of 7,000 ha for Phase 1, an award of contract has been made for 4,000 ha, but only a gross area of 3,000 ha or a net area of 2,200 ha is currently under irrigation. Water is released downstream through 5 radial gates each with capacity of 30 m^3/s.

[2] The records show that in the lead up to the 2001 flood the dam authorities tried to release as much as possible from the valves to reduce the load on the spillway. The daily discharge records for the period 31st August to 4th October 2001 show the valve release at 45 m^3/s which was indicated to be the maximum safe release

[3] It is understood that the situation at Tiga is compounded by high seepages through the dam structure which give rise to concern, whereas at Challawa Gorge there is apparently no indication of unduly high seepage losses through the dam structure

Withdrawals of the water requirements for KRIP and HVIP follow rigid design prescriptions: fixed irrigation is done six days in a week with one day off. Releases from dams and diversions to cultivated areas are planned weekly. Local reservoirs control irrigation of fields. The estimated irrigation water demand per hectare for HVIP is much higher than that of KRIP Phase I. A high percent of rice cultivation in the cropping pattern, reduced rainfall and higher evaporation are held responsible for the situation. Gravity or surface irrigation method (a great water waster) is practiced both in the KRIP and HVIP. No sprinkler system is yet adopted. High cost of sprinkler equipment and their maintenance is accorded greater priority consideration in the choice of irrigation method than the low availability and high value of water in the basin.

There is no system in place for the application of operational release rules from the dams that would match the integrated needs of the downstream users, either in terms of time or flows, nor is there currently adequate flow measurement at critical points in the basin, including the dam outlet points. A large amount of improvements would need to be made to the present defective and inadequate infrastructure in order to permit a reasonable degree of knowledge of flows, let alone their control in various parts of the basin.

There are also well over eighteen small to medium reservoirs mostly in Kano and Jigawa States (Sanyu and Sumiko, 1995). Several other irrigation projects abound in all the states, as shown on Table 3.4.

A dam is proposed on River Jama'are at Kafin Zaki. The purpose of the dam is to provide water for an area totaling 84,000 ha. Work on Kafin Zaki Dam has been started and then stopped a number of times, most recently in 1994.

3.6 Water Rights

Article 25 of the Universal Declaration of Human Rights provides that "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family…". This recognises the fact that nobody can survive for more than a few days without water, while he/she also requires it for basic needs of growing food and for sanitation. Similarly, the right to certain standard of living dictates that some right be vested in individuals to live in an uncontaminated environment, with clean air and access to clean water. The National Governments are also charged by article 24 of the 1989 Convention on the Rights of the Child to "strive to ensure" that no child is deprived access to clean water.

Table 3.4: Summary of irrigation activities in KYB

River System	Revised Potential (ha)	Developed (ha)	Cropped (ha)
Abir	1,000	130	130
Baga (Kirenowa)	1,000	500	500
Gashua	1,000	250	500
Gari	4,200	950	1,900
Galala	1,500	0	0
Jakarade	2,000	160	160
Tomas	2,300	400	800
Jakara	2,000	50	50
Jere Bowl	1,300	0	0
Yobe	1,600	700	1,400
South Chad	22,000	22,000	7,000
Kano River I	22,000	13,285	24,000
Kano River II	40,000	150	0
Watari	1,350	600	700
Kafin Ciri	660	0	0
Magaga	600	100	0
Hadejia Valley	12,500	2,075	1,500
Small Scale Yobe	1,000	120	30
Small Scale Borno	4,490	2,770	2,720
Small Scale Bauchi	500	50	90
Small Scale Jigawa	3,180	1,000	1,200
Small Scale Kano	1,000	500	800
ADP Fadama	140,000	12,500	12,500
Shadoof	10,000	10,000	10,000
Total	**277,180**	**68,290**	**65,980**

Source: Modified NWRMP (1995)

Such a responsibility must entail that at least the Federal government and indeed the upstream State Governments do not deny the States downstream the ability to discharge the foregoing rights and obligation to its citizens, by denying them adequate resources from interstate rivers. This is, however, predicated on the condition that this would be possible under the natural flow of the watercourse. Federal Government, therefore, needs to create an institution where aggrieved parties suffering from such denials could have neutral and perhaps regional platform to report and seek redress.

The Water Resources Decree 101 of 1993 is based on the principles of riparian right. The water rights will, therefore, depend on existing land rights. Consequently, establishing equitable security of tenure of land would guarantee equity of water rights which is critical in ensuring access to and active participation in conservation and protection of water resources for all groups in the society. This is particularly important for the poor and women who are generally excluded from access to land in traditional tenure and who are critical to effective land and water resources conservation and protection.

The Water Resources Decree 101 postulates that the right to use flowing water arises from ownership of adjoining land. It is, however, ambiguous on certain issues. For instance, section 2 of the Decree which guarantees water right reads as follows:

a) any person:

i) may take water without charge for his domestic purpose or for watering his livestock from any water course to which the public has free access;

ii) may use water for the purpose of fishing or for navigation to the extent that such use is not inconsistent with any other law for the time being in force; or

iii) who, has statutory or customary right of occupancy to any land, may take and use from the underground water source or if abutting on the bank of any water course, from that water course, without charge for domestic purposes, for watering livestock and for personal irrigation scheme.

Some of the controversial aspects of these clauses are with respect to what constitutes "water courses to which the public has free access". Could this include lakes, rivers and even public irrigation canals? Another controversy is with defining what constitutes personal irrigation schemes.

The water resources decree, however, requires as obligation for all to register all new water rights in terms of quantity and quality of water flow required. The Water Regulations (that is yet to be enforced) - which seeks to provide interpretation of the Decree 101 demands that water rights permits be issued seasonally for direct abstraction purposes or annually for impoundment. It, therefore, follows that those that have no land and hence no water rights cannot partake in its conservation or protection.

It is important to note that section 6 of the Decree clearly recognises the principles of integrated land and water resources management and enjoins the Minister to produce a Master Plan, current and detailed, for the development, use, control, protection, management and administration of all water resources. The Master Plan is to be reviewed periodically in the light of prevailing socio-economic and technological situation to affect activities, plans and proposals of public authorities relating to water resources development. It is thus in this section, that the relationship between the national water resources master plan and the comprehensive river basin plans to be developed by RBDAs would have to be contextualised given the background of the need for integrative management of land and water resources for sustainable development. This would be revisited in the evaluation of RBDAs in Chapter 6.

Meanwhile, it is worthwhile to observe that the importance of the master plan to integrative management for sustainable development is underscored by the provision of section 7 of the Decree, which grant powers to the President to stop the release of funds for any water project not included in the Master Plan. The provision would however appear to conflict with the constitution especially as it relates to the rights of the federating units over their statutory releases. Even without this lacuna, the expectation is that the Minister of Water Resources would submit memorandum inviting the President to exercise such powers with regard to projects that are not included or that are at variance with the Master Plan. In reality, however, nothing like that has been done. The Master Plan is rarely consulted and certainly it has not been updated since it was first produced in 1995.

The Decree in section 19, stipulates the powers to formulate and implement legal measures for Nigeria's interstate water resources in all its facets including watershed management, resources protection and preservation. Although the Minister has comprehensive authority to develop water resources policy, he has not been able to fulfil this legislated mandate for three reasons. First, the Act did not include the mechanism for implementation and the rules and regulation are yet to be approved for implementation by Federal Ministry of Justice, Federal Executive Council, National Council of State and the National Assembly. Secondly, the National Inland Waterways Act and indeed FEPA Decree contradict some of these mandates. Thirdly, the reality is that water resources policy formulation is currently exercised more by the National Water Resources Council in contravention of the Decree. Overall, the Decree is yet to be enforced thirteen years after it was promulgated.

Nevertheless, the regular review, updating and enforcement of a National Water Resources Master Plan envisaged in section 6 of the decree remains the most strategic in the conception and execution of integrated management of land and water resources for sustainable development. The significance of this becomes all the more compelling against the background of the realisation that sustainable development which presupposes preservation of natural resources should necessarily be achieved by deliberate public policies.

3.7 Land Use

Climate and physiography are two of the major variables influencing the pattern of land occupance in any given location. In the first place, they constitute two of the five soil formation factors and secondly, they determine the magnitude and character of water resources available to that location. And of course, it is the combination of available soil and water resources endowments of the location that dictates the uses to which its land can be put.

Figure 3.6 shows the distribution of land classes and their suitabilities. Nearly all the upland areas of the Sudan Savannah zone have been cultivated for many centuries. Naturally, cutting, fire, cultivation and grazing have modified the native vegetation profoundly. The flooding problems along the river floodplains of Hadejia and Jama'are rivers, especially on the flat lowlands at the downstream end of the basin to the northeast, have made over one-fifth of the basin land area unsuitable for dryland farming (Class II). This includes the Hadejia-Nguru Wetlands. Instead they are extensively used as grazing land and limited dry season recession farming. Figure 3.7 shows the major forest and grazing reserves.

Moderately and marginally suitable lands for dryland farming, Classes III and IV constitute more than 65% of the basin area. On these, sorghum, millet, cowpea, groundnuts and such other crops as vegetables are extensively cultivated. Figure 3.8 shows a southwest-northeast trend and distribution of the various crops. Millet hectarages increase from 24% in the southernmost (wettest) to 62% in the northernmost (driest) end of the basin. This is because of its greater drought tolerance than the other crops commonly grown there. In contrast, sorghum accounts for less than 10% of the crops grown in the low rainfall (less than 500 mm/yr.) area to the north whereas it accounts for up to 35% in the wetter area to the south.

Prior to the development of large-scale irrigation projects on Kano River and in Hadejia Valley, small-scale irrigation activities were taking place at several locations within the basin. The one at Yau in Borno State at the lowest reaches of the basin is one of them. Another one was at the Burum Gana floodplain. Others were along the Jama'are River floodplain.

Apart from agriculture, other occupations engaged in by the basin's inhabitants have been fisheries, livestock rearing, and potash harvesting and doumpalm collection. Table 3.5 shows the land use development changes in the five KYB constituent States in Nigeria: Kano, Jigawa, Bauchi, Yobe and Borno States from 1976/78 to 1993/95. Agriculture increased by 20,000 km^2 from 120,000 km^2 in 1976/78 to 140,000 km^2 in 1993/95. On the other hand, woodland, grassland and shrubs decreased by about 24,000 km^2 from about 94,000 km^2 in 1976/78 to about 70,000 km^2 in 1993/95. Degraded land has increased by 578% of the

1976/78 area, reaching 6,565 km^2 by 1993/95. Forestland has declined from 2,600 km^2 to 1450 km^2 during the same period. Forest water swamp area had also declined from 12,000 km^2 to 7,000 km^2 during that period.

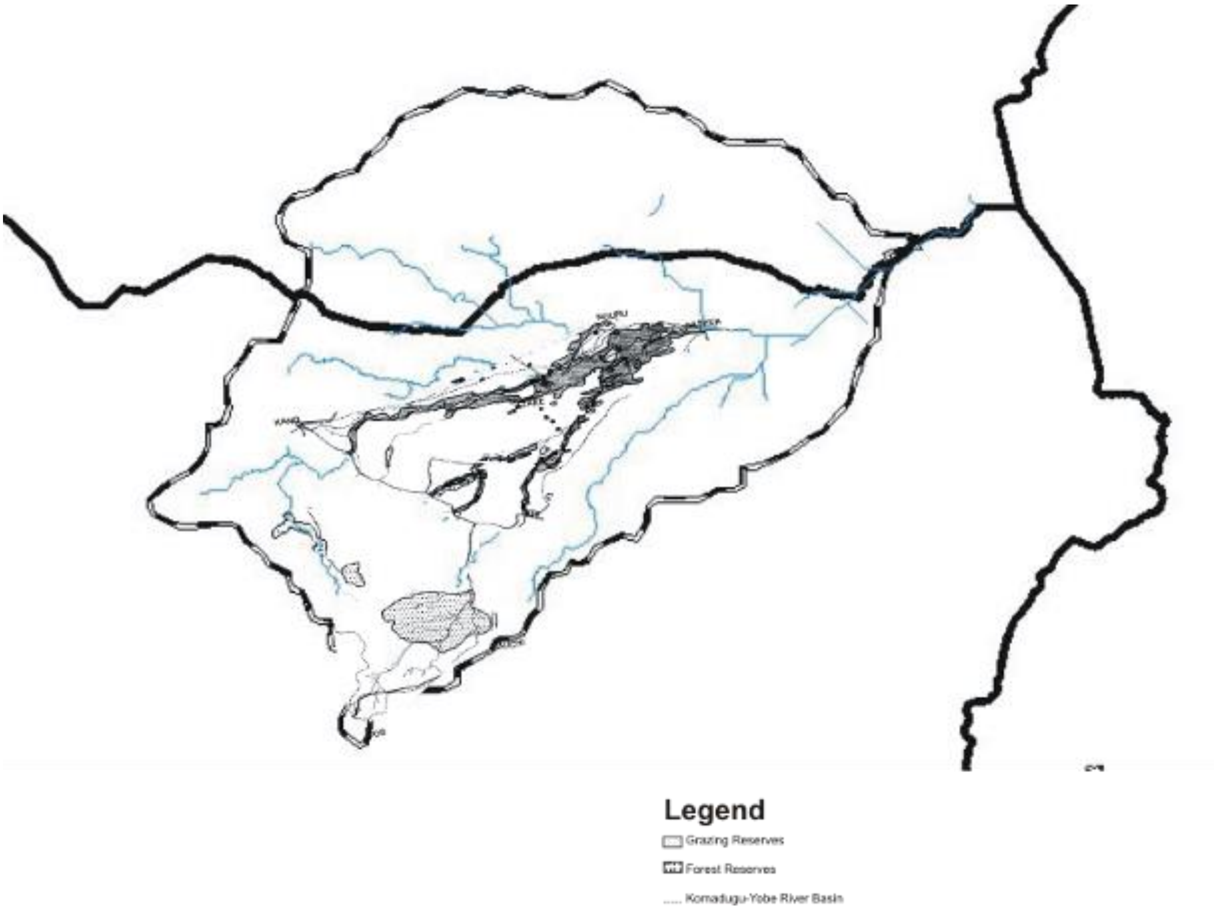


Figure 3.7: Major Forest and Grazing Reserves in Core KYB (After Schultz, 1976)

In recent past with the advent of large-scale irrigation schemes, dryland agriculture and these other occupations have been facing increasing threat of failure even total extinction. Problems arising from the projects, both of which are upstream of Hadejia-Nguru Wetlands, are: (a) releases of water where and when it is not wanted downstream of the projects, and (b) withholding of water where and when it is needed.

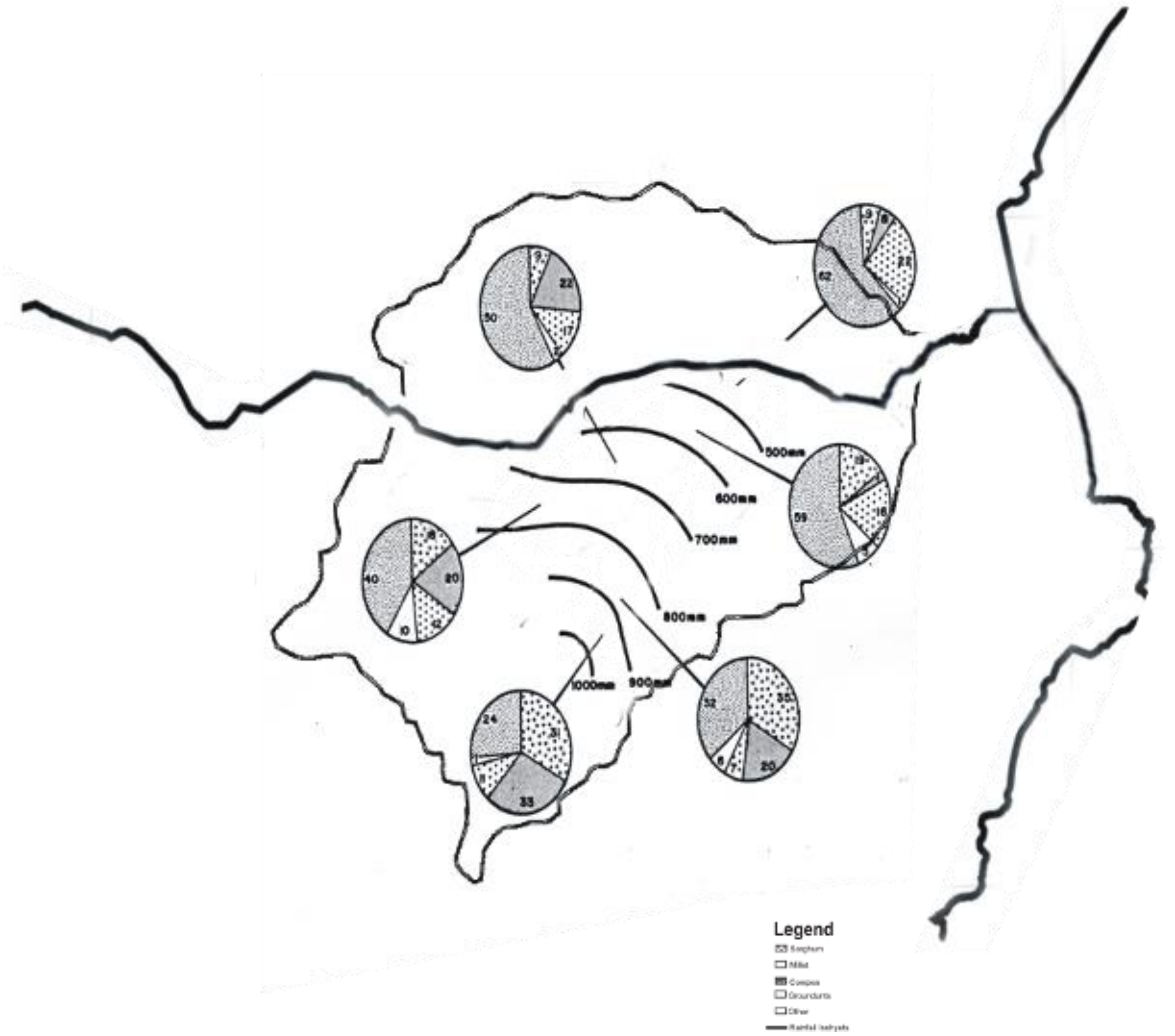


Figure 3.8: Rainfall Influence on Crop Distribution in KYB (After Schultz, 1976)

Table 3.5: Land Use Development Changes in the Basin

Land Use Category (km²)	Bauchi*		Borno		Jigawa		Kano		Yobe		Total		
	1976/78	1993/95	1976/78	1993/95	1976/78	1993/95	1976/78	1993/95	1976/78	1993/95	1976/78	1993/95	Change
1.Intensive(crop) agriculture	20,026	27,338	9,606	10,681	8,496	15,940	17,470	15,691	7,826	7,879	63,424	77,529	14,105
2. Extensive (grazing) agriculture	11,049	12,050	19,392	25,885	7,746	561	574	538	10,334	10,583	49,095	49,617	522
3.Floodplain Agriculture	882	1,163	-	-	1,795	2,341	274	258	1,272	1,824	4,223	5,586	1,363
4. Extensive Agriculture with Denuded	26	137	242	871	1,265	832	-	772	1,433	4,379	2,966	6,991	4,025
Sub-total Agriculture	31,983	40,688	29,240	37,437	19,302	19,674	18,318	17,259	20,865	24,665	119,708	139,723	20,015
5. Shrubs/Grasses	14,833	15,593	27,981	17,477	1,201	473	460	909	14,240	8,674	58,715	43,126	-15,589
6. Trees/Woodlands/Shrubs	14,754	3,571	-	-	-	-	817	171	-	-	15,571	3,742	-11,829
7. Discontinuous Grassland	683	956	1,830	3,641	692	1,122	-	-	3,024	2,841	6,229	8,560	2,331
8. Grassland	-	470	127	2,082	-	-	-	-	744	415	871	2,967	2,096
9. Grasses	-	-	8,742	6,466	48	556	-	-	3,735	4,578	12,525	11,610	-915
Sub-total Woodland/Grassland/Shrubs	30,270	20,590	38,680	29,666	1,941	2,151	1,277	1,080	21,743	17,508	93,911	70,005	-23,906
10. Shrub/Sedge/Graminoid Freshwater mash/Swamp	770	622	4,200	4,029	1,075	701	176	347	1,344	782	7,565	6,481	-1,084
11. Graminoid/sedge/ Freshwater Mash	-	-	4,200	482	251	45	-	-	-	-	4,451	527	-3,924
Sub-total Freshwater Swamp/Mashland	770	622	8,400	4,511	1,326	746	176	347	1,344	782	12,016	7,008	-5,008
12. Gullies	-	1,403	-	1,023	-	-	-	803	123	609	123	3,838	3,715
13. Sand Dunes	-	-	429	892	-	-	-	-	416	1,835	845	2,727	1,882
Sub-total Degraded land	-	1,403	429	1,915	-	-	-	803	539	2,444	968	6,565	5,597
14.Disturbed Forest	-	1,322	-	-	-	-	-	-	-	-	-	1,322	1,322
15. Undisturbed Forest	2,367	125	-	-	260	3	-	-	-	-	2,367	128	-2,239
Sub-total Forest	2,367	1,447	-	-	260	3	-	-	-	-	2,627	1,450	-917
16. Urban	-	-	57	140	-	-	-	-	-	-	57	140	83
17. Reservoir	-	175	-	-	-	45	250	335	-	-	250	555	305
18. Irrigation Project	-	-	27	411	-	-	46	109	-	-	73	520	447
Sub-total Miscellaneous	-	175	84	551	-	45	296	444	-	-	380	1,215	835
Total Land Area (km²)	66,034		74,363		23,089		20,430		44,716		228,632		
Population (1991)	4,291,000		2,595,000		2,832,000		5,638,000		1,411,000		16,767,000		
Population Density (persons/km²)	65		35		123		276		32		73		

*Only part of Bauchi State is in the basin

3.8 Land Capability

Schultz (1976) identified (see Figure 3.9) about 8,000 km^2 of the basin land as being suitable, to varying degrees, for irrigated agriculture (Classes I, II and III). About 62% of these is marginally suitable. The same reported that about twice that size (16000 km^2) was highly, moderately and marginally suitable for dryland farming (Classes I, III and IV). That means that about 3,000 km^2 of Classes I and III are suitable to some extent for both irrigated and dryland agriculture. Class I includes the best agricultural soils, which are highly suited to irrigation and to intensive dry land farming. A large part of this Class of land is flat terrain consisting of well-drained upland soils which are sandy loams overlying sandy clay loams. These soils have low natural fertility, which is normal for the region, but can be expected to respond well to fertilization and other scientific management practices. A wide variety of crops such as sorghum, millet, wheat, groundnuts, and many vegetables and legumes, can be grown on these soils. During the rainy season there is usually sufficient rainfall for most crops. Irrigation is ordinarily being practiced during the dry season.

The upland soils have moderate permeability and moderate water holding capacity. Salinity and alkalinity problems have not being very serious problems yet with the introduction of irrigation. Low-lying regions, on the other hand, which comprise a small part of Class I lands, usually have sandy clay loam to sandy clay textured, somewhat poorly drained soils. Rainfall flooding is widespread because of a lack of natural surface drainage. As a result, these soils are now used mainly for gazing, but are also being used to produce cultivated crops where adequate artificial drainage has been provided. Poor aeration is a limiting factor, therefore, they are capable of carrying crops like rice, sugar cane and cotton, which can tolerate flooding during the rainy season. Diversified crops can be grown during the dry season, since water additions can be regulated. Subsurface horizons in some of the soils are moderately alkaline, although it will be wise to carry out further investigations to ascertain the extent and seriousness of this problem. Permeability rates are slow to moderate; water storage capacity is moderate.

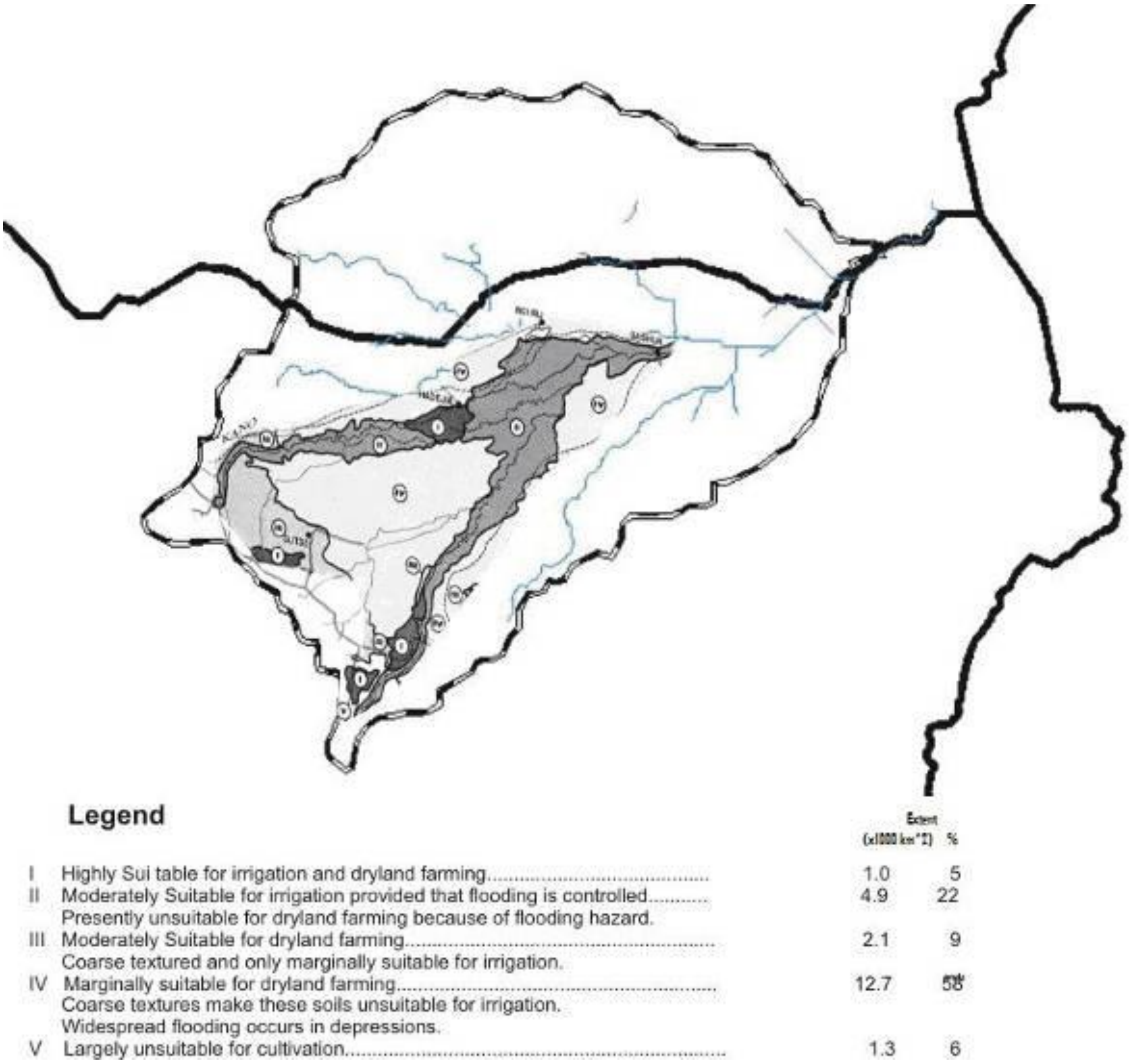


Figure 3.9: Land Capabilities of Core KYB (After Schultz, 1976)

Class II lands in the basin are characterized by widespread river and rainfall flooding making them ordinarily unsuitable for extensive dryland farming without drainage works. They are better left as natural woodland and used mainly for dry season grazing. With proper flood control, irrigation and drainage, much of these lands are capable of being cultivated during both the rainy and dry seasons. Many different soil types occur, but the most extensive are somewhat poorly drained sandy clay loams. These are developed on older alluvial deposits. About 70% of them have normal chemical properties; the remaining 30% are characterized by moderately alkaline or saline subsurface horizons. Lands in this Class are capable of carrying such rainy season crops as rice, cotton and sugar cane, which are tolerant to flooding and poor aeration. They can also carry a fairly wide range of crops during the dry season. Surface and internal drainage are critical, so the success of any irrigation project has so far depended and will in future depend to a high degree on the design of the flood control and drainage systems. Soils with serious alkalinity or salinity hazards should be avoided.

The recent floodplain deposits found in the present meander belts of the rivers consist of stratified sands, silts and clays with variable drainage. Water-holding capacities and permeabilities are moderate and chemical properties are considered normal. Many 'shadoof' irrigation schemes are already established on these soils as they are well suited to small irrigation projects and a wide range of crops could be grown throughout the year. Dykes are needed to control river flooding during peak flows, otherwise soil drainage is not expected to be a problem. With few trees growing on these soils, land clearing and land levelling are minimal.

Clay and heavy clay textured, somewhat poorly and poorly drained soils are also included in Class II lands. They normally occur in depressional basins within the floodplain and they turn out to be swamps or lakes during the rainy season. These soils have very low permeabilities and moderate to high water storage capacities. Thus, they are suitable for crops such as rice, cotton and sugar cane, which are tolerant of these conditions. Chemical properties are normal but poor aeration is logically a limitation, even with proper surface drainage. Isolated longitudinal dunes with deep sandy soils are also found in Class II lands. General characteristics and uses of these soils are the same as described for the dunes in Class IV lands discussed later.

Class III lands are moderately suitable for dryland farming and at present are mostly cultivated. Textures are usually moderately coarse, therefore the soils are considered only marginally suitable for irrigation. The main soils are deep, loamy sands and sandy loams. Natural fertility of these soils is low and in some instances aluminium toxicity and nutrient deficiencies related to low pH may be present.

A significant portion of Class III lands is comprised of irregularly distributed soils that are similar to those in Class II above but underlain by ironstone within a depth of one metre; similar to the upland soils discussed under Class I; or somewhat poorly drained sandy clay loam to sandy loam soils similar to the low-lying soils of Class I lands. Priority should be given to improving agricultural production on the better soils, which are the well-drained, deep sandy loams and the sandy loams over sandy clay loams. A wide variety of crops can be grown, including sorghum, millet, groundnuts, vegetables, and legumes.

Class IV lands consist of dunefields and small river floodplains. These soils are generally considered marginally suitable for dryland farming, however, a small percentage are well suited to dryland farming and irrigation. The crests and upper slopes of the longitudinal dunes are characterized by sand and loamy sand, somewhat excessively drained soils. Well-drained sandy loams are common on the lower slopes. All these soils have low natural fertility and low cation exchange capacity but no serious problems related to chemical properties, such as alkalinity or extreme acidity. Because of their coarse texture, they are rapidly permeable and have low water-holding capacity. The dune soils are subject to drought, and in the northern part of the basin drought hazards are severe. Only drought tolerant crops, such as millet, and cowpeas can be grown successfully. Fertilizer losses due to leaching are high. The soils commonly occurring on the lower slopes of the dunes are comparable to those of Class III lands. Similar crops and management practices apply.

Interdunes and included floodplains contain a wide variety of soil types. Within small geographic areas, textures vary from sand to sandy clay loam while drainage ranges from somewhat excessive to somewhat poor. Rainfall ponding occurs frequently on the depressional, usually finer textured soils, and river flooding is widespread on the floodplains. Most of the soils have normal chemical properties but some have moderately alkaline subsurface horizons. Interdune and floodplain soils are either sandy, in which case they are practically the same as dune soils, or they are loams and sandy clay loams subject to frequent flooding. The flooding usually precludes dryland farming and the feasibility of large-scale drainage and flood control schemes has not been confirmed. In suitable areas, grazing and dryland farming have been going on.

Most soils in Class V lands are unsuitable for cultivation. Isolated tracts of arable soils are scattered throughout the basin. Generally, the Class V lands carry shallow soils, underlain by laterite or bedrock, which are common on the slopes of the undulating plains. Depressions and low-lying regions are frequently flooded and the soils may be alkaline and/or saline. The upper slopes and crests frequently have rock outcrops. Extensive mountainous areas occur and the soils on these rocky lands are shallow. Soils in Class V lands are being and should continue to be utilized for wildlife, forestry, watershed and grazing purposes. The isolated tracts of good agricultural soils are similar to, and can be managed in the same way, as those of Class III.

3.9 Land Tenure

The land tenure situation in Nigeria is based on the imposition of modern legal tenet on the customary laws. Traditionally, land titles could be acquired in two ways: by cultivating virgin land or where the initial title is relinquished to another person who thus acquires the right to exploit it. However, such rights are not exclusive; rather these land tenure systems are based on the understanding that land was a community and rarely family property. Consequently, land control resides with the community head but individual could apply and be granted rights to cultivate or use the land not belonging to any clan or family, provided it is for beneficial purposes. Generally, authorization to occupy available land is given to men and rarely women who have family relationship, mostly from the paternal side with the community. Such individuals could continue to possess such lands for as long as they use them to the benefit of society. Furthermore, land could be passed on to heirs or pledged to satisfy a debt, but could not be sold or mortgaged (Geomatics International, 1998).

This arrangement remained until 1978, when the problem of lack of uniformity in the laws governing land-use and ownership, population pressure and increased urbanisation, as well as trends towards uncontrolled speculation in urban land led to the promulgation of Land Use Decree No 6 of 1978. The Land Use Act of 1978 as it is now referred to, approaches these issues via three related strategies: the nationalising of propriety rights in land; "the granting of usufructuary rights in land to individuals; and the use of administrative system rather than market forces in the allocation of rights in land" (Uchendu 1979; Francis, 1984). Part I sub section A.49 of the Act state that:

> *subject to the provisions of this Decree, all land comprised in the territory of each State in the Federation are hereby vested in the military Governor of the State and such land shall be held in trust and administered for the use and common benefit of all Nigerians.*

Apart from the vesting of all land in the State, the Act also distinguishes two types of land, namely; urban and other lands (presumably rural lands). The urban lands were placed under the control and management of the State Governors to be advised by a 'Land Use and Allocation Committee'. On the other hand, the 'other lands' were placed under the control and management of the Local Government in which the land is situated with a 'Land Allocation Advisory Committee' as the advisory body. Consequently, the community's trusteeship of land were denied or frozen and the Act replaced these local sovereignties with a single national sovereignty (Uchendu, 1979).

The part II of the Act provided a new tenure system that is not only contractual but also dependent. It is such that while Governor is empowered to grant statutory rights of occupancy within his State, the Local Governments may only grant customary rights of occupancy essentially for agricultural purposes which shall not exceed 500 hectares or 5,000 hectares for grazing land after cumbersome process. As a result of these, rural land which although inherited on the basis of customary rights, could be claimed on the basis of occupancy (Renne, 1995). Part V of the Act, however, empowers the Governor to revoke rights of occupancy for reasons of overriding public interest, which may arise from unauthorised alienation of the land by the occupier or requirement of the land for public purposes. In such cases, compensation would be paid, but only for 'unexhausted improvements' on the land, but not for the land itself (Mamman, 2000).

The Land Use Act administration has proved complicated, and as a result many transactions go unreported and undocumented, and customary tenure has continued to prevail in many localities. Land development and management, especially for agriculture, have been identified as the major constraints that face Nigerian farmers, particularly the small-scale farmers owning 2-5 ha per family (Lombin, 1996). The constraints of customary laws and practices include lack of security of tenure, land fragmentation, distinction between the rights to trees and land, as well as unfavourable legislative treatment of customary tenure for forest and grazing land. The security of tenure is an important incentive to farmers to invest in the land. Consequently, the lack of recognised title on customary tenure means that the land which is the farmer's most important asset cannot be used as equity for raising credit through formal financial institutions.

Clearly, the legal, institutional and technical frameworks for land management should be linked based on clear policy choices. It is important to note, however, that the Land Use Act, institutional and technical frameworks alone should not and do not determine the policy choices, but rather these should define the framework with which to design appropriate system of land management. Obviously this has not been the case in the foregoing.

It is also significant to note that the provisions of the Land Use Act of 1978 have been enshrined in the Constitution of the Federal Republic of Nigeria 1999. Consequently, the provisions of the Act cannot be amended or expunged, altered or repealed except as provided in the constitution, and these conditions are stringent.

3.10 Vegetation

Sudan Savannah area is characterised by shrubs and dense grasses with a sprinkling of trees. Much of the natural cover, however, has been tampered with by human activities, especially agriculture. Today the remaining woodland can only be found in the south-western parts of the basin (IUCN, 1997). Figure 3.10 shows the land use pattern of the basin.

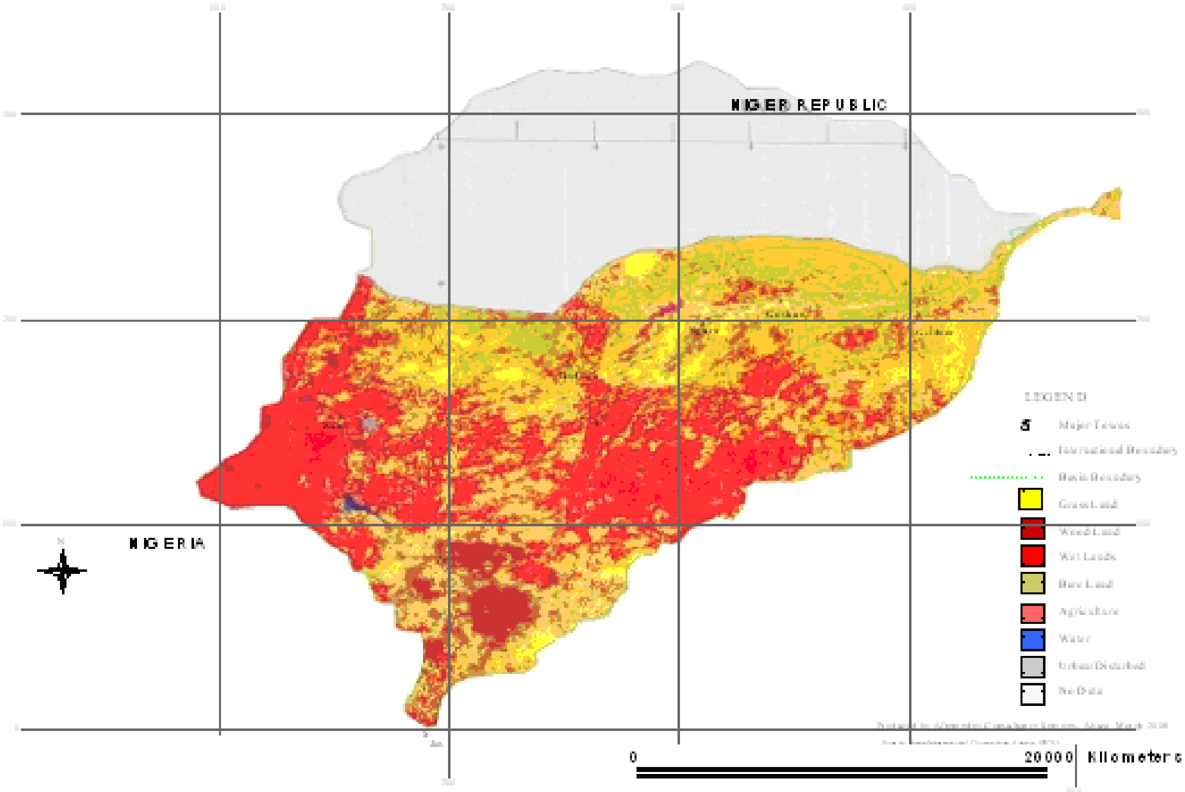


Figure 3.10: Vegetation and Land Cover

3.11 Invasive Water Weeds

The changes in flow regime of the Hadejia-Jama'are and Gana-Yobe Rivers have in recent times witnessed an explosive growth of aquatic weeds. The invasive weed is particularly visible at the Hadejia-Nguru Wetlands and the flow contributing channels. The water bodies have become overgrown by the *Typha* spp or 'cat-tail' particularly the *Typha domingenis* (Goes, 2001). *Typha* is not an exotic species of weed to Nigeria. It is found all over the country, where the environmental conditions are favourable for its survival. The rapid invasion is probably due to its reproductive characteristics which is both sexually (through seed dispersal and colonization) and asexually (through rhizome which takes place within the immediate area) resulting in denser coverage.

The history of *Typha* invasion in the Hadejia-Jama'are and Gana-Yobe River sub-systems could be traced back to the early part of the 1990s when it was first observed in the Hadejia barrage. The weed thrives well in shallow (less than 1.5 m deep water) but more permanent water bodies. It hardly survives in seasonal rivers with marked period of dryness. It has been observed that the construction of dams, which diverts wet season flows for releases during the dry season, has created favourable condition for the development of the invasive weed. Goes (2002) reported the following circumstances as favouring the development of the invasive weed.

- The absence of fast flowing water (due to silt blockages and aquatic vegetation growth).
- Continually moist soil (due to wet season diversion and dry season releases from dams).
- Relatively nutrient rich water (due to nutrient rich irrigation water from the fields).

All the above circumstances occurred at various points and stretches within the Hadejia-Jama'are and Gana-Yobe Rivers, hence the rapid invasion.

3.11.1 The Impacts of Invasive Water Weeds (*Typha* spp.)

The invasions by *Typha* spp. in the Hadejia-Jama'are and Gana-Yobe rivers have produced visible impacts on the ecology and socio-economic activities in the basin. The noticeable hydrological impacts include blockage of river channels (which reduces and diverts river flow), increased siltation, overflooding and loss of farmland and settlements, extension of riverbanks and reduction of river channels. These have resulted in less water contribution by the Hadejia River to the Yobe River sub-system within the last two decades (Goes, 2002).

The invasion of the water bodies by the *Typha* grass, which leads to flow reduction, particularly, at the downstream sectors of the Komadugu Yobe Basin prevents access to farmers, pastoralists and fishermen to open water. It, thus, constitutes a serious threat to the ecology as well as economy of the area as large parts of the river channels, lakes, fadamas and potential grazing lands have been taken over by the weeds.

Furthermore, the proliferation of the weeds provides habitat for mosquitoes, snails and birds leading to diseases like malaria, bilharzias, liver fluke (in livestock) and crop damage. In the Hadejia-Jama'are and Gana-Yobe Rivers, infestation by quelea birds and damage to farmlands and other infrastructures have reached alarming proportions so much so that the local communities have continuously laid their complaints to the relevant authorities or agencies for intervention.

3.11.2 Utilization of Invasive Water Weeds (*Typha* spp.)

DFID-JWL (2003) reported that to date no viable economic or ecological use of *Typha* ssp. has so far been identified. All efforts so far made yielded negative results and rather compounded the problems than saving the situation.

3.11.3 Control of Invasive Water Weeds (*Typha* spp.)

Various methods of controlling the water weeds (*Typha* spp) have been identified. These include biological, chemical, physical and mechanical control. The use of *biological* control method involving the use of species of fish that grazes on *Typha* is found to be ineffective in many trials in West African invaded waterbodies, though no evidence of such trials have been made in the Hadejia-Jama'are and Gana-Yobe rivers.

Regarding the use of c*hemical* control method, to date no specific herbicide for *Typha* control has been identified. This difficulty is partly expressed due to the nature of the weed, which thrives in water, and the fear of causing more damage to other life forms in water bodies in the process of controlling the weeds. However, the possibility of using non-selective herbicides such as "Round-up under drained and dry conditions" is there and may yield positive results.

The *physical* measures to control *Typha* include the use of fire, hand cutting and shading. Shading involves replanting cleared sites with trees or covering up irrigation channels to create dry conditions that is not favourable for the survival of the weeds. These measures, particularly, that of cutting and burning, have been attempted in the Hadejia-Jama'are and Gana-Yobe rivers but achieved virtually no success.

Mechanical control of *Typha* can be very expensive especially in terms of acquisition of the necessary machines and accessories. It can be controlled by mowing, excavation and dredging which require the use of boats, excavators and dredgers. The use of this method has not yet been tried in the Hadejia-Jama'are and Gana-Yobe rivers.

For proffer utilization of the land and water resources of the Hadejia-Jama'are-Gana-Yobe Basin and realizing that the challenge posed by *Typha* is too enormous for individual, communities, Local Government Areas and State Governments to control, the need for concerted action with the Federal Government towards these efforts is most desirable. This calls for a revisit of the suggestions arrived at the "*Typha* Roundtable" held in Hadejia on 17th July 2003 (DFID-JWL, 2003). Specifically, the call for integration of mechanical-physical control of *Typha* and the need to tackle the problem in stages as follows:

- Opening up of existing water channels to increase flow rates and reduce unwanted flooding (this was discovered to be responsible for the siltation/blockages and development of *Typha*).
- Structural changes in the river system in form of control mechanism to distribute water more evenly along different channels (this can be achieved by river training).

- Management of dam releases integrated into mechanical control of *Typha* through dyke construction, drainage, burning, cutting and re-flooding.

4 Socio-Economic Characteristics

4.1 Preamble

Apart from quantitative and qualitative assessment of the physical conditions (temporal and special availability and use of water), an assessment of the present socio-economic characteristics is also necessary before any intervention directing to IWRM can be made. A understanding of these situation are prerequisite for assessment and analysis of institutional framework and the potential water use conflicts between stakeholders that would done in the next chapter.

The people of KYB have over the past eked out a living through exploitation of natural resources. The principal economic activities of the basin are **agriculture, fishery, animal husbandry, and commerce. All of which are invariably dependent on access to water.** Water is life – safe drinking water is essential for health but increasing the level of access to water is also important for income generation. The occurrence of repeated drought and expansion of Sahel, has led to increased southward migration of human and their domesticated animal in search of fundamental natural resources for survival. The conventional wisdom therefore suggests that water is a major constraint to the basin's rural economic growth (finite land and water resources versus growing demand). These have escalated the natural resources degradation arising mainly from overexploitation. The river systems have been the refuge and thus the main victim of degradation (UNEP, 2004). Consequently, the predominant concentration of the population is in the southwestern parts of the basin, where most of the economic developments are also centred.

The quality of socio-economic data was limited until the late contribution of the study commissioned by KYBP (Aminu *et al.,* 2006). Socio-economic statistics were nevertheless still limited except countrywide figures. Regards to regional and basin specific disparities were thus considered.

4.2 Population Dynamics

According to the World Bank (2002b), the annual growth of the population in the region has ranged between 2.5 and 3.0%. The current total population of the basin is variously estimated to be between 20.8-25.0 million (GIWA, 2004) representing almost 60% of the Lake Chad Basin's population. Table 4.1 shows how the basin's population is unevenly distributed between the states. Considering that Maiduguri and Bauchi, which are the main concentration of population in Borno and Bauchi States, respectively, are located outside the basin, Kano State, one of the most populous states in Nigeria hosts more than 70% of the population of the basin. The KYB of the larger Lake Chad Basin is the most populated.

Table 4.1: Projected populations of five out of the six riparian States of the KYB for 2000

State	Total Population			Rural Population			Urban Population		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Bauchi[4]	1,872,64	1,833,067	3,705,531	1,572,682	1,539,593	3,112,276	229,781	293,474	593,256
Borno[4]	1,680,935	1,602,717	3,283,653	1,082,018	1,031,669	2,113,687	598,917	571,048	1,169,965
Jigawa	1,888,011	1,835,200	3,723,211	1,756,983	1,707,837	3,464,820	131,628	127,363	258,391
Kano	3,837,205	3,686,227	7,523,432	2,306,928	2,216,160	4,523,688	1,530,277	1,470,067	3,000,345
Yobe	926,937	885,395	1,81,332	701,228	669,801	1,371,029	225,709	215,594	441,303

(Retrieved from Aminu *et al.,* 2006 with source: NPC, 2002)

Population densities are greatest in Kano State and surrounding states of southern portion of Jigawa and northern portion of Bauchi States. It decreases towards the more arid North east areas of Jigawa, Yobe and Borno States. The

[4] Most of the population of Borno and Bauchi States are located outside the Komadugu Yobe Basin

rural demography of the riparian communities in the basin is reported to be characterized by changing population patterns, with many people migrating from other communities to the settlements on the shores of the rivers in order to engage in the productive activities provided by the river resources (Aminu *et al*., 2006). Overall, there has been a large influx of immigrants from the northern fringes of the basin into the floodplains and near water sources due to prolong drought and desertification that has forced communities to leave the increasingly arid northern portion. This has significantly increased conflicts between nomadic pastoralists who are moving southwards and the sedentary farmers along their path (LCBC, 2000b).

The rural people are predominantly nomadic pastoralist and fishermen. The rivers and pastures of the floodplains and wetlands are the resources that attract people from various places especially the other northern parts of Nigeria. The recent persistent incidence of excessive flooding and cat-tail or *Typha* invasion, which has been severe has led to some members of communities (those around downstream Jigawa and upstream Yobe i.e. Hadejia-Nguru wetland areas) migrating to other places. This has further accentuated the rapid urbanisation, as destitute rural communities search for an improved standard of living in the swelling southwestern cities such as Kano, Hadejia and Katagum. This has further depleted population to the northeast of the basin as such they have relatively lower population density.

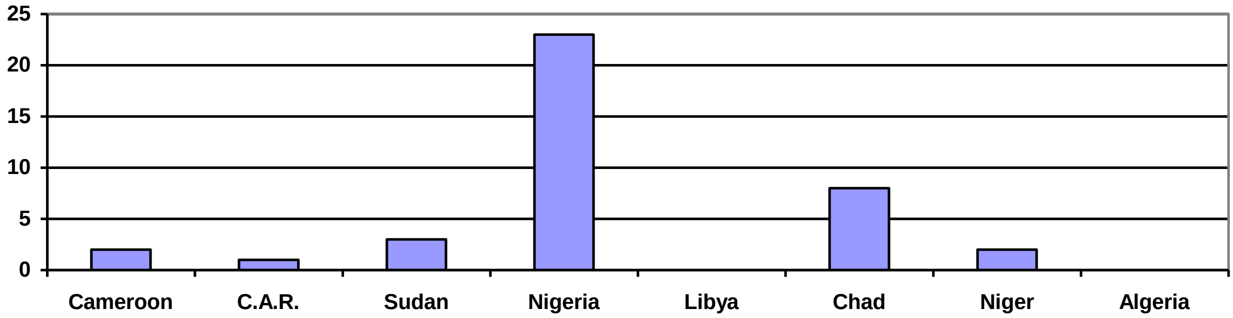


Figure 4.1: Estimated population in Lake Chad Basin (for 2002)
(Source: Based on GIWA, 2004)

4.3 Population Structure

The basin's population is characterised by a young age structure, with the male population being marginally higher than those of female (UNEP, 2004). The population statistics of the five riparian states are predominantly rural. According to projections by NPC (2002) the percentages of the total population leaving in rural areas in mid-2000 were 84.0, 64.4, 93.1, 60.1 and 75.7 for Bauchi, Borno, Jigawa, Kano and Yobe states, respectively.

Table 4.2: Demographic Characteristics of some Riparian Communities of KYB

Riparian communities	Ethnicity	Literacy level	Enrolment into primary school
Kano State			
Upstream LGA (Runa, Tsakuwa, Muras)	Hausa	Low	High
Midstream LGA (Katai, Kausani, Tsibiri)	Hausa	Low	Low
Downstream LGA (Kadiri, Katirshe, Cincimi)	Hausa, Fulani, Hausa-Fulani	Low	Intermediate
Jigawa State			
Upstream LGA (Miga, Hanzu, Kware)	Hausa-Fulani	Intermediate	High
Midstream (Auyo, Zumoni, Gamsarka)	Hausa	High	High
Downstream (Kardigi, Bulinceri, Saleri)	Kanuri	Low	Low
Yobe State			
Upstream (Garbi, Zabarmawa, Araro)	Kanuri	Intermedeate	High
Midstream (Wusir, Asbak, Kazir)	Badde	Low	Intermediate
Downstream (Balle, Canlori, Dambaram)	Kanuri	Low	Low
Borno State			
Upstream (Damasak, Joka, Meleiri)	Kanuri	Intermediate	High
Midstream (Jabulam, Yau, Fogwa)	Kanuri		
Downstream (Abadam, Doron Baga, Malamfatori)	Kanuri/Hausa	Intermediate	Intermediate
Bauchi State			
Upstream (Kari, Pastoralist community, Pastoralist community)	Hausa-Fulani	Low	Low
Midstream (Zigau, Desina, Tsibiri)	Hausa	High	High
Downstream (Jama'are, Yola, Aniferi)	Fulani	High	High

(Source: Aminu *et al.*, 2006)

The local populations around the shores of the Hadejia-Jama'are river systems from the upper reaches around Kano city in Kano State to the downstream fringes of the Lake Chad shores in Borno State, share some common demographic characteristics, in terms of ethnicity, literacy level, primary school enrolment, predominantly below 60 years, combination of farmers, fishermen and nomadic pastoralists. Although females may constitute about half the total population, the main economic activities are usually dominated by the males (Aminu *et al.,* 2006).

4.4 Social and Cultural Aspects

The basin exhibits a socio-cultural unity based on shared history by the established population groups of Hausa and Kanuri (Kindler *et al*., 1990). Hausa is the dominant language in most of the communities, especially around Kano, Bauchi and Jigawa States, but in Yobe and Borno States and some few communities around the downstream of Jigawa State the use of Kanuri language prevails over Hausa (Aminu *et al*., 2006). The old Islamic States (the Kanem-Borno and the Sokoto Caliphate) are largely responsible for present distribution of populations in the basin. Migration during the latter part of the millennium has brought Shuwa Arabs from the east and Fulani pastoralists from the west (Neiland and Verinumbe, 1990).

There are other numerous pockets of ethnic groups, each attracted by the opportunities to exploit the natural environment through a range of activities. The majority of the populations speak Hausa and an official language. The main languages used in the area reflect the political roles exercised during the pre-colonial period. The English and French colonial powers have also imposed their languages, legal and administrative systems, upon the traditional ones in Nigeria and Niger portion of the basin, respectively. Nevertheless, customary laws, regulations and structures still determine land use systems in large measure.

4.5 Economic Activities

The river is the single most important economic resource with more than 90% of the population depending on the river resources for their livelihood (Aminu *et al*., 2006). It is so central to the livelihoods such that who ever controls it in these communities controls life. Water is life could not be truly typified than in the basin. The ecosystem of the wetlands and other floodplains adjoining the communities in the basin yield a wide range of goods and services, many of which have a high economic value. Consequently, the economic costs of upstream water diversion can be substantial, particularly in a semi-arid environment where downstream uses of water are critical to the economic livelihoods of a large number of rural households. Table 4.3 gives a summary of the main economic activities in the basin.

The economic production activities are dominated by the informal low productivity primary sector in which technical input has been slow. The primary sector employs more than 70% of the population and comprises primarily agriculture, livestock rearing and fisheries (UNEP, 2004). Upland farming is for food while *fadama* and irrigation perimeters are used for cash crops especially rice in the wet season and vegetables in the dry season. Agriculture is the main economic activity and the most commonly grown crops are maize, rice, wheat, cotton, groundnuts, cassava, sorghum, millet, onions and garlic. Most farming systems are subsistent in nature, rainfed, cultivated and harvested manually and grown with insufficient use of fertilizers and other agrochemicals.

Following the Sahelian drought of the 1970s, irrigated agriculture was seen as the main solution to increased agricultural production and improved food security in the region. It thus enjoyed priority funding from both State and Federal Government of Nigeria. Close to 20 dams were constructed by the then government of Kano State (comprising the current Kano and Jigawa State) mostly for irrigation schemes. At the time, inadequate attention was paid to valuation of environmental goods and services, consequently the essential income and nutrition benefits from agriculture, grazing, non-timber forest products were not taken into account. As a result the Hadejia-Nguru wetlands have declined by 210,000 to 230,000 ha., with an estimated economic loss of between 7.1 and 11.7 million USD. It is however pertinent to note that part of the economic losses is also from climatic variability. There is insufficient evidence that the irrigation schemes and water development structure contributed equal economic benefits to counter these losses.

Fishing prospect has been diminishing due to recent changes in environment and ecosystem as a result of deterioration in water quality especially around Kano and changes in the river flow. Livestock rearing is usually more intensive along the floodplains adjoining the rivers. The communities along the shores of Jama'are River are engaged in fishing during the wet season when the river flow is still adequate, but in the dry season when the river dries-up they turn to irrigated farming using underground water resources from tube wells lifted up using motorized pumps (Aminu *et al*., 2006).

Table 4.3: Summary of economic activities in the Komadugu Yobe Basin

Communities	Location	Main Economic activities	Main agricultural outputs produced	Other economic activities
Runa, Tsakuwa, and Muras	Dawakin Kudu LGA: Kano upstream	Crop production and fishing	Onion, sugar cane, tomato, carrot and Pepper in dry season. Sorghum , millet cowpea and cassava in wet season	Livestock rearing; Trading and Hunting
Katai, Kausani and Tsibiri	Wudil LGA: Kano midstream	Crop production and fishing	Sugar cane, onion, pepper, tomato, garden egg in dry season. In the wet season: rice, maize, cowpea and millet	Commerce
Katirshe, Kadiri and Cincimi	Agingi LGA: Kano downstream	Crop production and fishing	Tomato, onion, pepper, carrot, wheat in dry season. In wet season rice, millet, sorghum	Livestock rearing; Trading
Miga, Hanzu, And Kware	Miga LGA: Jigawa upstream	Crop and livestock production, and fishing	Rice in the wet season, tomato, pepper, sugarcane dry season	Commerce
Auyo, Gamsarka and Zumoni	Auyo LGA: Jigawa midstream	Crop production, fishing and livestock	Rice, sorghum, millet and maize in wet season. In dry season, tomato, onion, pepper, garden egg, maize	Commerce
Kardigi, Saleiri and Bulinceri	Kirikasanmma LGA: Jigawa downstream	Crop production	Cassava, but before flooding and *Typha* spp. invasion millet, G/nut and cotton in the upland and livestock.	Potash sale (obtained as a deposit due to flood)
Garbi, Zabarmawa and Araro	Nguru LGA: Yobe upstream	Crop production, livestock and fishing	Millet, sorghum and Groundnut before flooding, but now flood	Commerce

Communities	Location	Main Economic activities	Main agricultural outputs produced	Other economic activities
			overtakes 90% of the farmland.	
Wusir, Asbak and Kazir	Bade LGA: Yobe midstream	Fishing and Crop production	Rice in the wet season, vegetables such as tomato, onion, and pepper in dry season but dry season cropping and fishing have decline due to water stress	Commerce; Government work
Dambaram, Balle and Canlori	Geidam LGA: Yobe downstream	Crop production and fishing	Rice, okra, G/nut in wet season, onion, tomato, pepper in dry season. Fishes resources decline due to water shortages	Livestock production
Damasak, Meleiri and Joka	Damasak LGA: Borno upstream	Crop production and fishing	Pepper, Wheat in dry season. Rice, millet, cowpea in wet season.	Livestock production; Commerce
Jabulam, Yau and Fogwa	Abadam LGA: Borno midstream	Crop production and fishing	Rice in wet season. In the dry season rice, wheat and vegetables in the Yau irrigation project	Livestock production
Abadam, Doron- Baga and Malamfatori	Abadam LGA: Borno downstream	Crop production and fishing	Maize, cowpea using residual mixture (lake Chad), rice in rain fed. Pepper, tomato, onion, sweet potato, in dry season	Livestock production; Commerce (local and cross-border); Transportation using canoes across the borders
Kari, Pastoralist community and Pastoralist community	Darazau LGA: Bauchi upstream	Livestock rearing, fishing in wet season, upland crop production and few vegetables in dry season	Sorghum, rice, maize wet season. Tomato, pepper in dry season	Sales of drinking water using tube wells along the shore of the river
Zigau, Desina and Tsibiri	Shira LGA: Bauchi midstream	Crop production and fishing in wet season	Rice, maize in wet season. Sweet pepper, hot pepper, tomato in dry season	Livestock rearing
Jama'are, Yola and Aniferi	Jama'are LGA: Bauchi downstream	Crop production and fishing	Sorghum, rice in wet season. Sugarcane, onion, tomato, garden egg, lettuce, wheat in dry season	Livestock rearing

(Source: Aminu *et al*., 2006)

In the wetlands and the downstream communities on the shore of Lake Chad (Doron Baga, Malamfatori),in addition to fishing, they use the residual moisture provided by the receding wetland and the Lake to practice recession farming to grow crops such as cassava. The communities residing near the floodplains and the wetlands use the *fadama* land around the river in the wet season to cultivate crops such as rice, maize and sorghum. However, in the upstream parts of Kano, rice and maize are the main wet season crops, but in places downstream rice seems to be the only wet season crop. The rice serves as a cash crop and provides a source of capital for dry season activity during which wheat and assorted vegetable is cropped. The upland is cultivated in the wet season for food crops, mainly maize, sorghum, millet and cowpeas. The main agricultural production which is taking place around the shore of the lake, include the production of crops such as maize, pepper, cowpea, onion, sweet potato. Bird infestation is one of the major problems of wet season cropping around the shore of the lake. Wheat was a major crop but because of the problem of bird infestation the crop is now not produced in the locality. Other income generating activities provided by resources in the river and Lake Chad include fish processing and marketing, construction and sale of canoes, local restaurants, fabrication of fishing equipment and net, cross border commerce with Niger, Cameroon and Chad involving vegetables such as tomato, onion and other agricultural commodities. The Doron-Baga has become an important cross-border trading port with boats linking Nigeria, Chad and Niger with very high volume of transaction.

The dry season vegetables and wheat are irrigated through conjunctive use of direct pumping using small petrol driven pumps from the river or using underground water from tube wells. The construction of the two major dams in Kano State (Tiga and Challawa Gorge) to feed irrigations near Kano and Hadejia while supplying raw water for Kano City has altered the hydrological flows of the Hadejia river system. Before the commissioning of Tiga in 1974 and even a few years after, fishing was the main income generating economic activity among most communities in the Hadejia river sub-basin. Due to changes in river flow associated with these dams, coupled with the water pollution from industrial waste discharge into the river from textile mills and tanneries in Kano, fish population has declined considerably thus making fishing less attractive as an economic activity. The reduced flooding has also led to decline in flood recession farming and the extent of land suitable for dry season agriculture. Food insecurity has consequently been accentuated in the basin (Nami, 2002).

Over-abstraction of water by upstream communities, especially in the years when there was substantial decrease in precipitation has led to reduction of the supplies for downstream users. Although attempts were made to correct this imbalance through increased releases from the dams to compensate the precipitation, this has only led to the worsening of ecological changes, with increase infestation of aquatic weeds. Siltation and aquatic weeds has led to unintended flooding of communities and farmlands and less floods in the wetlands where they are needed. In particular, there has been substantial reduction in the Hadejia-Nguru Wetlands surface areas, which has resulted in economic losses that was estimated at between 7.1 million USD (Barbier *et al*., 1997).

4.6 Access to Water Supply, Sanitation and Health

Access to safe drinking water supply is essential for health but increasing the level of access to freshwater is equally critical for livelihood. Water uses in the basin include domestic, industrial, agricultural (flood cropping, recession farming, small and large-scale irrigation), livestock, fisheries and ecological. More than 70% of the freshwater withdrawal in the basin is used for agriculture followed by domestic use. The indiscriminate discharge of effluents into the river has restricted the use of river flow for economic productive purposes, while safe drinking water is obtained mostly from dug wells and or boreholes. The river flow is however an important source of recharge of the underground water. Although, the general believe is that the river flows are unsafe for domestic uses even by upstream communities (Kano and parts of Jigawa), yet the use of water in the irrigation canal was rampant by communities adjoining these structures. The explanation was that they were using the raw water as a last resort because they have no other option.

The sanitary conditions for rural dwellers are particularly poor. The sanitation rate was barely up to 40% in 2000 and has not improved by much since then. The development of disease vectors in swamps and irrigation fields coupled with deterioration of drinking water quality as a result of some hydrological changes and improper conservation has resulted in health concern in basin. The health status of the people in most communities (particularly those that suffer less severity of flood) can be described as average. Most of the population (estimated at about 80%) were judged to be healthy enough to work in the farms and also engaged in other economic activities such as fishing and livestock rearing (Aminu *et al.,* 2006). Around Hadejia Nguru wet lands, the problem of flooding has resulted in water logging and severe salinity of the soil, which has affected the quality of the underground water. Consequently, even though water is readily available from tube wells and local wells, the quality has been impaired by the excess potash and sodium. In those communities, especially where severity of flood has been more (such as those around Jigawa downstream and Yobe upstream (Hadejia-Nguru Wetlands areas)) the health status of the people was weak (Aminu *et al*., 2006). Many of the inhabitants of these communities suffer from cold related illnesses such as rheumatism and pneumonia and this seems to affect their livelihood.

Other water-related diseases such as bilharzias and worms are not common in the basin, although some communities suffered such ailments in the past (such as those around Jigawa upstream). The affected communities are reported by Aminu *et al*. (2006) to have now found a cure through the use of modern and alternative therapy. In most of the riparian communities access to medical facilities (hospitals, clinics and dispensaries), remains inadequate and in some cases completely absent.

4.7 Poverty

Safe drinking water is essential for health but increasing the level of access to water is critical for income generation. Level of access to water determines the productive activities and livelihood the communities in the basin can pursue. For instance, the upstream communities whose access to water was boosted with the construction of hydraulic structures and development of public irrigation schemes such as the Kano River Irrigation Project (KRIP) and Hadejia Valley Irrigation Project (HVIP), have higher per capita income and enjoy higher standard of living when compared to their counterpart downstream. Communities downstream especially in Yobe and Borno states have complained seriously over their increasingly poor access to water (Aminu *et al*., 2006). Overall, the Lake Chad region has been trying to cope with mass poverty. Figure 6.2 represent the relative proportion of the various countries in Lake Chad Basin fall below both the

USD 1.00 and USD 2.00 international poverty line. Nigeria's poverty has steadily grown worse since 1980s and World Bank (2002b) estimated that as at 1997, 90.8% of the population was below the USD 2.00 per day international poverty line. Of the estimated 90.8% of Nigerians affected by poverty the northern states especially the northeast which is within Lake Chad Basin accounts for the largest share of the country's poor people (World Bank, 2002b).

Poverty is generally more acute and widespread in rural areas. Single women, mostly widows and divorcee that are also orphan are identified as the most vulnerable and impoverished groups, who often have dependent children and with scant resources. In addition, women and children needing special protection, the disabled, demobilised military personnel, senior citizens and persons living with HIV are the socio-economic groups that are most vulnerable.

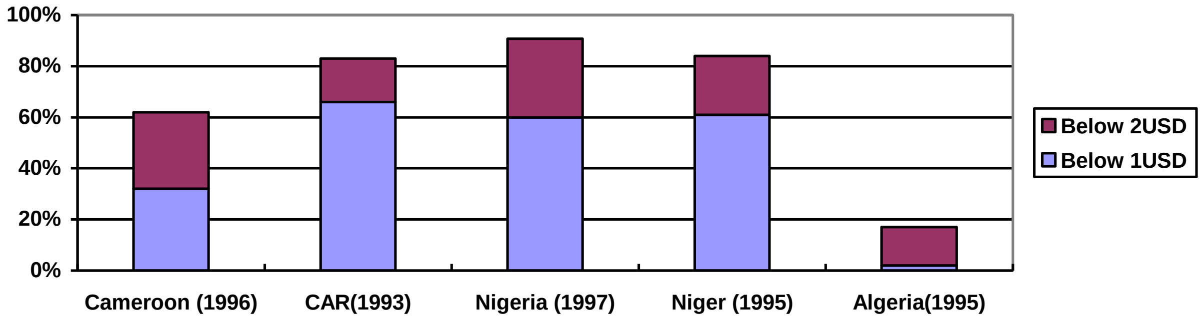


Figure 4.2: Population below international poverty line

Note: No data for Chad, Libya and Sudan. (Source: World Bank 2002b)

The unsatisfactory and uncoordinated management of the reservoirs coupled with profligate operation and maintenance of the irrigation schemes as well as Kano city water intake structures has led to over-abstraction and at time destructive river-flow. The fresh water scarcity in the basin has not prompted authorities to manage the utilisation of the resources that are available more efficiently. There is general lack of incentives and other economic instruments to promote environmentally sound practices. Farmers on the KRIP and HVIP have no incentive to conserve water, as the water charges are low and often the farmers do not pay and they are not sanctioned. These factors have contributed in making access more difficult downstream, which in turn has affected the productive activities and the general ecosystem as well as the human settlement dynamics. Some communities have been temporarily migrating to other places where access to water for productive purposes is more readily available, especially for dry season cropping.

The people of Komadugu Yobe Basin are facing endemic poverty. This has been the catalyst for environmental degradation. They resort to unsustainable exploitation of natural resources for their short-term survival. For the last forty years most communities have endured the effects of freshwater shortage largely caused by unsatisfactory management of the water resources of the basin (UNEP, 2004). Increased diversion to meet the need of the upstream communities has led to many people residing downstream experiencing freshwater shortage. The prevalence of endemic poverty in the basin especially the downstream communities requires special attention to be paid to improving water allocation.

4.8 Education

Illiteracy is a hindrance to development in the basin. In terms of literacy the adult members are generally illiterate in terms of western education, but majority can write in *ajami* (writing in Hausa using Arabic alphabets). Primary school enrolment rate is generally low (around 60%) with the exception of Kano State, consequently, the literacy rate is among the lowest. In a few communities around upstream Kano where access to primary school is difficult the level of primary school enrolment was as low as 20% only. There is also a sharp disparity between literacy levels of girls from boys. Among the factors that discourage primary school enrolment are the long distance to the few schools, falling standard of education and the problem of unemployment of graduates. The children who attend school have to cope with little resources and dilapidated facilities. It is however, encouraging noting that despite the decline in economic living standards, yet illiteracy rates has fallen by almost 30% for both males and females between 1990 and 2000 (World Bank 2002b).

The poor literacy level has made many of the communities disadvantaged, as a result of their inabilities to liaise or negotiate effectively with their elected local administrators, State and Federal government agencies, NGOs and donors. It may also be responsible for the weak advocacy group, farmer organisations, cooperatives and professional associations in the basin.

4.9 Gender Role and Participation in Decision-Making

The roles and responsibility of women and men varies among the communities. In most of the communities except around Yobe (midstream) the participation of women in economic activities is restricted to food processing and handicrafts aspects. For instance, fish drying, the fabrication of local fishing tools, baskets making and threads for tying farm produce, as well as threshing and winnowing of harvest of crops are women dominated activities. The main economic activities are being dominated by men and this is not unrelated to the social and cultural norms of the people based on religious considerations. In midstream Yobe, most women, especially the middle aged, owned and manage their farms especially in the dry season, in addition to partaking in fishing. The dwindling access to water resources is gradually changing the pattern, with women are now less actively involved in fishing because of the inadequate water in the river which has made the enterprise less economically attractive and more tasking. In places where the effects of flood has led to salinity soil, women are have resorted to collecting the potash deposit for sale to outside communities. The problem of potash intrusion has created another enterprise even if it is economically less promising than the farming under previous condition.

Exploitation of child labour especially in planting and harvesting operations is common. The women in addition to their participation in various productive activities are also responsible for most of the childcare and household chores in general. The traditional land tenure system in all the communities allows both sexes the right to own land, but often the right to control the land is usually vested with the men. For instance while a woman can inherit or buy a farm land, yet where she chooses to use the land for productive purposes the husband or a male relative could control and take decision on her behalf (Aminu *et al*., 2006).

4.10 Needs and Priorities

The needs and priorities of the communities interviewed by Aminu *et al*. (2006) varies from maintaining a steady and adequate flow of water along the river particularly in the dry season, to control of excessive and persistent flood events and the issues of water recession and desertification which had effected the ecosystem and economic productivity. The needs and priority issues were obtained based on preference ranking by the communities. The upstream communities in Kano and some parts of Jigawa States, where access to water is reasonably adequate, the major problems cited include that of maintaining a steady and adequate flow of water along the river particularly in the dry season and controlling the direct effluent discharge from tannery into the river that deteriorated the quality of water (killing fishes), harming the environment and the health of the people. The problems associated with flooding events which usually destroyed crops and houses, was chosen among the priority issues by the communities.

On the other hand, the communities around downstream Jigawa and upstream Yobe (Hadejia-Nguru Wetlands), their priority issues were regulation of excessive and persistent floods which has overtaken more than 70% of their farmlands including the upland area. This was reported to have made agricultural production almost impossible for both wet and dry seasons. The flood was also reported to have caused the emergence of *Typha* grass that not only block river flows but serves as habitat for quela birds, and worsening salinity and high water table in the area. As a result of these issues a number of the people in this area have had to migrate to other places within and outside their locality to get access to farm lands.

In communities downstream (from midstream Yobe and up to around mid stream Borno) the priority issue and need was that of water recession and desertification which had effected their ecosystem and economic productivity. The flow of the river even during the wet season was inadequate and in many cases is no more than a flash flood and thus farmers had to use tube wells and water pumps to secure water for supplementary irrigation and such process is cost intensive. The intensity of dry season cropping has declined seriously in these communities and fishing which was one of the major economic activity has also declined thus affecting the income level of the people especially the women who were participating intensively in fishing during periods of water adequacy in the past. In the rainy season the main crop grown hitherto was rice but because of the decline in the annual floods, the productivity of rice fields have declined. Consequently, maintaining adequate river flow in both dry and wet seasons is the most important needs among these downstream communities.

Assessment of IWRM Institutional Framework 5

5.1 Preamble

Land and water need careful husbandry and integrative management in order to serve humanity and nature renewably and sustainably. Protecting the resources, while coordinating and reconciling, sometimes conflicting social and economic needs and demands are at the heart of integrated land and water resources management for sustainable development. This requires favourable policy environments and institutions conducive for development that are consistent with the interests of all stakeholders. Effective governance and good institutional framework are essential to ease the tension and delicately balance the competing uses of these resources and the various interests of stakeholders involved in their management.

The attainment of an appropriate and effective plan to reform and strengthen the integration of land and water resources management, requires that the stakeholders, agencies and interest groups involved be identified with their functions, role, awareness of Integrative Natural Resources Management (INRM), financing and capacity appraised. Thus, the requirements for integrative management of land and water resources management in KYB would be examined in this chapter to identify those activities which need to be reformed. The extent to which these activities are being integrated within the mandates of various stakeholders would be determined to enable the capacity building interventions that are required and appropriate to be ascertained. Specifically the chapter would cover the following: stakeholders and their functions; status of policies and legislations; status of stakeholders at river basin level; land and water service providers for agriculture; and the challenges posed by all of these and the chequered history of water resources related institutional changes as shown in Box 5 below.

Box 5. History of Water Resources Related Institutional Changes

Period	***Development***
1959	Creation of the Inland Waterways Division of the Federal Ministry of Communications based in Lokoja with responsibility for monitoring levels in the Niger/Benue system
1960-66	Formation of Hydrological Unit under the First Republic
1960s	Creation of Water Resources Division in the Ministry of Agriculture and Formation of the Geological Survey Department of the Federal Ministry of Mines and Power
1970s	Creation of State Water Boards or Corporations
1970s	Creation of Kainji Lake Development Commission and the Chad Basin and Sokoto Rima River Basin Development Authorities in the Second National Development Plan
1975	Creation of the Federal Ministry of Water Resources (FMWR)
1976	A further nine (9) RBDAs were established (3rd National Development Plan)
1977	FMWR disbanded and absorbed into Federal Ministry of Agriculture
1979	Re-creation of the Federal Ministry of Water Resources
1984	FMWR merged with the FMA&NR to form Federal Ministry of Agriculture, Water Resources and Rural Development
1984	Creation of 18 RBDAs , and change of name to River Basin and Rural Development Authorities (RBRDs) with one for each State except Ogun and Lagos that shared one
1987	Mergers of 18 RBRDAs to the former 11 and the name reverted to RBDA with reduction of functions to only provision of water for multipurpose usage
1989	Re-creation of FMWR again
1990	Partial Commercialization of RBRDAs by Technical Committee on Privatisation and Commercialisation (now Bureau of Public Enterprises (BPE))
1992	Re-merger of FMWR with FMARD
1994	Re-creation of FMWR which was merged with Directorate of Food Road and Rural Infrastructure (DFFRI) thus renamed FMWR&RD
1994	Change of the name from River Basin Development Authorities to River Basin and Rural Development Authorities and creation of Upper and Lower Niger RBRDAs out of Niger RBRDA
1999	The Department of Rural development was transferred to FMANR and renamed FMARD and FMWR

5.2 Stakeholders and their Functions

5.2.1 Integrative Natural Resources Management Functions

The major integrative natural resources management functions identified in this study are categorised as follows:

- Policy, legislation, institutional development and capacity building.
- Coordination, guidance, dispute resolution
- Monitoring, data/information management and auditing (Knowledge base)
- Research and research coordination
- Bulk water allocation and water rights authorisation/administration
- Integration of resources management and interests in various sectors
    - National and multi-basin
    - Basin/sub-basin/catchments long range
    - Multipurpose project planning, design, construction and operation (seasonal and real-time) and maintenance
    - Environmental Impact Assessment
- Demand management and cost recovery
- Environmental Conservation and resource quality management (protection, restoration) - watershed management
- Groundwater management
- Development and management of multipurpose projects
- Public Safety and disaster prevention and management such as floods and drought management
- Public education and awareness
- International and intra-national cooperation

These can further be grouped into three main functions, namely policy and legislative (providing enabling environment), organisational (providing institutional framework for Resources Administration) and operational functions (provision and management of services) functions. These functions are interrelated, with general flow of activity from one category to another leading to specific decisions and actions. Figure 5.1 illustrates these relationships.

5.2.2 Stakeholders, Agencies and Interest Groups

Stakeholders in the process of integration of land and water resources management for sustainable agricultural development comprises of those actors involved in decision making at various levels; all interested and affected parties as well as those others such as farmers, who regrettably are often not considered as a factor in policy-making (CTA, 1999). To ensure sustainability, agriculture requires holistic approach, balancing the competing needs on the resource which could be domestic, municipal, agricultural, industrial, and environmental in nature. The stakeholders must therefore be extended to include those actors involved in land and water related sector that are in competition for finite land and water in a basin.

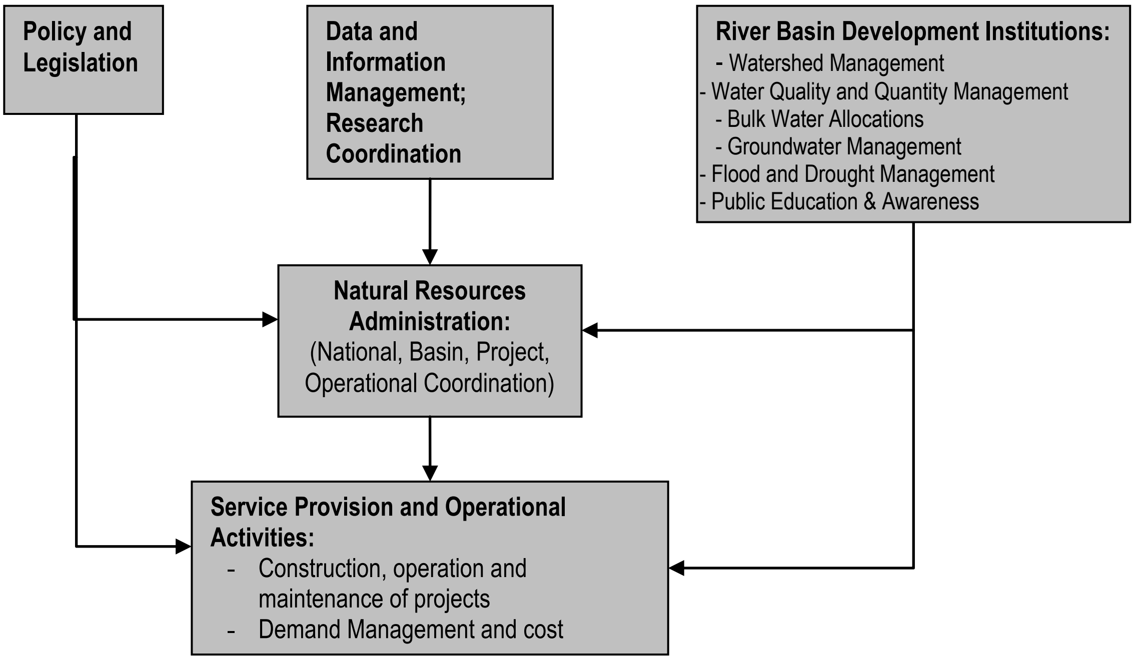


Figure 5.1: Relationship of the Integrative Natural Resources Management Functions

Although there is a large number of land and water management agencies, administrative units, land and water users and other stakeholder groups, not all of these play a significant role in the allocation and conservation of these resources. Such institutions would therefore not be strategic to the success of the integrative arrangement of natural resources at operational level especially for agriculture even though they should be consulted when formulating policies and programmes. A general distinction could, therefore, be made between **operational partners** who are involved in the integrative processes and the **consulting partners** that should be consulted in the decision-making process on policy, legislation and plan/programme development as well as in the provision of relevant data and information for INRM. These stakeholders are all important in the shared responsibility for integration of land and water resources management for sustainable development of agriculture. It is also pertinent to state here that it is not very easy to come out with a complete list of the institutions involved in all aspects of land and water resources management in a basin as vast as the KYB. Land and water are pervasive resources and their management and uses touch almost all aspects of society, the economy and the environment.

In particular, it is worth mentioning the national, the state and the local departments within the ministries, the NGOs, CBOs or private sector firms. It is important to note that, in addition, there are currently at least eight apex organs of government which have statutory responsibility for policy formulation, approval and/or coordination for land and water resources management through out the federation. These are the National Assembly, the National Council of State and at least six National Councils of Water Resources; Housing and Urban Development, Transport, Environment, Aviation as well as Agriculture and Rural Development. The advisory role and the day to day implementation of the decisions of National Councils of Water Resources, Housing and Urban Development, Transport, Aviation, Environment as well as Agriculture and Rural Development are vested in the Federal Ministries of Water Resources, Housing and Urban Development, Transport, Aviation, Environment and Agriculture and Rural Development respectively. Due to the dependence of other sectors of the economy on these critical resources, however, several other statutory and non-statutory institutions are active in either policy, organisational, and operational aspects of the management of land and water resources. These other institutions include:

- State Houses of Assemblies of Bauchi, Borno, Jigawa, Kano and Yobe;

- Federal Government and State Executive Councils of Bauchi, Borno, Jigawa, Kano and Yobe states;
- Federal Ministries of Solid Minerals, Finance, Economic Planning, Industry, Culture and Tourism, Federal Capital Territory
- National Emergency Management Agency (NEMA), and Office of Minister for Special Duties (Ecological Funds).

From all of the foregoing it is obvious that land and water resources management is currently fragmented. It remains to be seen whether they have been adequately performed. The subsequent sections would describe the current status of the discharge of these functions in the interviewed agencies and civil societies. This will enable us to identify the gaps or deficiencies, especially those that could have important implications for integrative management of land and water for sustainable development in the basin.

5.3 Status of Policies and Legislations

5.3.1 The Constitution of the Federal Republic of Nigeria

There are currently several basic policies, rules, regulations, laws and factors which influence the governance of water resources management. These range from the constitution, specific federal government policies, to non-statutory documents, such as NEEDS document and UN summit and conference declarations such as MDG, NEPAD etc, both of which influence the integrative natural resources management and decision-making process. All of these are however, fairly recent development, dating back to 1992 and onwards (Musa, 2003).

The constitution is the supreme law of the nation and therefore any law or conduct that is not consistent with the constitution is invalid. Essentially, therefore all provisions and especially constitutional obligations must be mandatory. It should be noted that unlike the 1979 Constitution that was in tandem with integrative principles and the then "Water Resources Decree 101 of 1993", the current constitution is silent on many aspects of provision of water services and on water resources management. The legislative list on aspects of water resources development and management as contained in 1979 and 1999 constitutions are shown in Box 6.

Water Resources Act cap. W2 of 2004 was first promulgated and published in the supplement to official Gazette No. 27, Vol. 80, September 1993. It is the highest extant legislation governing water resources management in Nigeria. It confers on the Federal Government represented by the Federal Ministry of Water Resources (FMWR) the responsibility for controlling the use of both surface and groundwater resources **traversing more than one state** throughout the Federation. It is based on three important principles:

- ✓ a link between the right to use water and the ownership of land adjacent to that water (the riparian principle),
- ✓ a separation between private (water drawn from small streams or wells which gave too little water to have potential for communal benefit) and public water; and between water in the rivers that are restricted to a state and those traversing more than a state, and
- ✓ the African customary law which saw rivers and the water in them as common good which belongs to the nation as a whole and are available for common use by all citizens, but which should be controlled by the state in the public interest.

5.3.2 Land and Water Resources Related Policies and Legislations

The current land and water related policies and legislations have been oriented to specific resource or institutional mandate. Furthermore, the policies are for specific land and water-using sub-sectors. Although these sub-sectoral policies remain important, they have not been coordinated under national land and water resource policy and legislation. Each Federal Ministry is responsible for the development of the necessary policy and legislation, mostly on the basis of specific sub-sectors within its mandate. For instance, in the water resources, there are specific policies on water supply and sanitation; irrigation and drainage; flood, erosion control and drought management among others. These policies were developed after the promulgation of Water Resources Act 101 of 1993.

Box 6. Legislative List on Land and Water Related Functions as Contained in the Constitution

1979 Constitution

➢ **State Legislative List**:
- Fishing and fisheries in rivers, lakes, waterways, ponds and other inland waters in the State.
- Land that is to say, rights in or over land, land tenures including the relation of landlord and tenant, and the collection of rents.
- Production, supply and distribution of goods.
- Public health sanitation and hospitals.
- Water, that is to say, water supplies, irrigation and canals, drainage and embankments, water storage and water power, subject to the provisions of the Federal Legislative list.

➢ **Federal Legislative List:**
- Fishing and Fisheries other than fishing and fisheries in rivers, lakes, waterways, ponds and other inland waters within Nigeria.
- Maritime shipping and navigation including:
  a Shipping and navigation on tidal waters, and
  b shipping and navigation on River Niger and its effluents any such other inland waterways as may be designated by the National Assembly to be international waterway or to be interstate waterways; etc.
- Meteorology.
- National Parks being such areas in a State as may with the consent of Government of that State be designated by the National Assembly as National Parks.
- Water from such sources as may be declared by the National Assembly to be sources affecting more than one State.

➢ **Concurrent Legislative List**
- the regulation of the right of any person or authority to dam up to otherwise interfere with the flow of water from sources in any part of the Federation.
- Environment.
- Tourism.

1999 Constitution

➢ **Concurrent Legislative List**:
- The generation, transmission and distribution of electricity.

➢ **Federal Legislative List:**
- Fishing and Fisheries other than fishing and fisheries in rivers, lakes, waterways, ponds and other inland waters within Nigeria.
- Maritime shipping and navigation including:
  a) Shipping and navigation on tidal waters, and
  b) Shipping and navigation on the River Niger and its effluents any such other inland waterways as may be designated by the National Assembly to be an international waterway or to be interstate waterways; etc.
- Meteorology.
- National Parks being such areas in a State as may, with the consent of Government of that State, be designated by the National Assembly as National Parks.

In its present form, Water Resources Act cap. W2 of 2004 would be difficult to administer, because it vests all the powers on the Minister of Water Resources. Meanwhile, the River Basins that were statutorily empowered to comprehensively plan and develop the Nation's water resources are not delegated any such powers therefrom. Another fundamental flaw of this decree is that it did not flow from an articulate and comprehensive policy or from public debate. It also has no clear provision on quality control, water right transfer and groundwater control, nor did it define criteria within which the Honourable Minister would be committed to carry out the public trust obligations bestowed on him by the decree.

The need for long range planning based on comprehensive and integrative environmental management, informed the water resources decree, but without any reference to Federal Environmental Protection Agency (FEPA) decree of 1988. This creates room for conflict in some of its provisions.

Disturbed by the serious threats to her environment from within and without her borders, the Federal Government of Nigeria formulated a National Policy on the Environment in 1988. The Policy provided specific guidelines for population growth; land-use and soil conservation; water resources management; forestry, wildlife and protected areas; marine and coastal resources; sanitation and waste management; toxic and hazardous substances; mining and mineral resources; agricultural chemical production and use; industrialisation; and air pollution. Central to the implementation of the policy, was the setting aside of a certain percentage of the federation account as Special Ecological Fund and the establishment of FEPA by a Decree No 58 as agency under the presidency. This was modelled on the United States of America Environmental Protection Agency, and charged with the:

> *" responsibility for the protection and development of the environment and biodiversity conservation and sustainable development of Nigeria's natural resources in general and environmental technology, including initiation of policy in relation to environmental research and technology".*

The mandate enabled it to make recommendations to the President on national environmental policy and on the management and conservation of the country's natural resources which include water resources. On the other hand, the Environmental Protection Agency Act, Cap 131, LFN, 1990 (as amended) by Decree No 59 of 1992 which is yet to be repealed or amended, empowers FEPA to establish water quality standards and effluent limitations for existing and new point sources for interstate waters (Afremedev, 1999).

Although FEPA is now defunct, it prepared periodic master plans for the development of environmental sciences and technology, and established national standards for pollution control and procedures for environmental impact assessment for all development projects among others. It was not clear whether these decrees now apply to Federal Ministry of Environment that succeeded the FEPA as from 1999. By the provision of these decrees, FEPA was expected to coordinate the management of the environment across ministries, but it however, had no established mechanism for such interaction with other related institutions and organs of government. Consequently, it sometimes ran parallel course. For instance, in 1991, FEPA published water quality standards without reference or consultation with the Federal Department of Water Supply and Quality Control (FDWSQC) in FMWR which also had the statutory responsibility to operate National Water Quality Laboratories and to engage in water quality control (Musa, 2003). The relationship between FEPA, FDWSQC, NAFDAC and Standard Organisation of Nigeria (SON) on water quality monitoring and control remains fussy. It is however significant to point out that the mandate of FEPA has not been applied to water resource, since the defunct Authority and it successor FME played only an environmental regulatory role.

Similarly, the Land Use Act of 1978 gives the State Governors and Local Governments the responsibility for control, regulation and allocation of land. On the other hand the Water Resources Act cap. W2 of 2004 gives the Minister of Water Resources the powers and responsibility of control, regulation and planning of development of water resources; prevention of pollution and formulation of national policies relating to the control and use of water resources for multipurpose as well as short and long term provision of water for various sectoral purposes. Both decrees have largely remained inadequately enforced.

Another act that is related to water resources management is the National Electric Power Authority (NEPA) Act. It spells the mandate of NEPA to include the formulation and implementation of electricity policy linked to the development, utilisation and management of national power resources, presumably including hydro-electric power generation. This authorisation has not however been interpreted to include integrated and multi-sectoral water resources policy. Although NEPA has developed hydropower installations which are non-consumptive use of water, their operation have not been geared towards multi-sectoral water sharing arrangements with other agencies.

The policy and legal framework for managing the basic natural resources, notably soils, water and vegetation are essentially fragmented, un-harmonised and scattered in the statute documents. Furthermore, they are narrowly oriented to meet sectoral needs and are in some cases contradictory or inconsistent on some aspects of these resources usage. These serious deficiencies have been aggravated by lack of coordination of the agencies within the sector, and the fact that most legal framework did not flow from comprehensive policy. Meanwhile, these policy and indeed the legal instruments have not provided sufficient basis for institutional and technical intervention and action. Accordingly, most of the laws are not enforced, and the alternative policy options of providing economic incentives, user-pays, polluter-pays strategies have not been sufficiently encouraged.

5.3.3 General Policy-Making Framework

Federal Government has the critical role of providing enabling environment. This presupposes that the usual prescriptive central approach to development and management of natural resources be replaced by the creation of a framework by the government within which participatory, demand driven and sustainable development can take place. The reality, suggests that this is only being done selectively. For instance, while Small Town Water Supply Programme and National Fadama Development Project, both World Bank supported projects are demand driven, other projects funded directly by Federal Government remains prescriptive. In the prescriptive projects, the beneficiaries are not consulted nor were the projects planned and designed to meet their wishes.

Government currently combines the functions of policy-making, planning, allocation, monitoring, enforcement and conflict resolution in the natural resources management with that of a service provider. The regulatory and control role of government requires political will, data, decision support system and adequate resources and means to enforce the existing legislation. The biggest problem is not therefore, the absence of adequate legislation but the lack of the political will and these other factors.

Another critically important element of integration is that of harmonizing various sectoral views and interests in decision-making, with due attention given to upstream–downstream relationships. Not enough cross-sectoral integration could be discerned during the field work. The establishment of the basin coordination committee was however a very significant initiative. This was a fall-out of the recommendation of the workshop jointly organised by NIPSS and the IUCN-HNWCP in 1993 in response to the growing tension and conflicts in the basin. The National Council on Water Resources accordingly established a Hadejia-Jama'are-Komadugu-Yobe Basin Coordinating Committee (HJKYBCC) during its sitting in 1999. The HJKYBCC held its first meeting in 2000 during which it established a Technical Advisory Committee (TAC). Both the HJKYBCC and TAC have met only twice, the last being in 2001, and many of the far reaching decisions taken at these meetings remain unimplemented until KYBP, because no budget has been provided for that purpose. Above all, governments have not established the context and framework for action by non-governmental entities. This is a critical element within the enabling environment that should be created by governments at all levels.

Accordingly, policies and legislations have to be supportive of private sector participation to integrate the sector in the management of these vital resources that are critical to almost every economic activity. There have been growing competitions between sectors for scarce resources, against the backdrop of increased pressure for cuts in the budget of the governments, and increasing competition for scarce development assistance resources. When these are weighed against the role of Federal Government to ensure and facilitate the overall investments needed to adequately manage the natural systems, the challenges become increasingly difficult to meet. This situation calls for greater private sector involvement in financing of natural resources related development projects. This can only be achieved, however, if legislation provides for investment security and incentives.

Other stakeholders that need to be integrated are the Community-Based Organizations (CBOs). They could also invest in the development and management of these systems, if appropriate legal empowerment were in place. The land titles and water rights have to be clearly delineated and government or NGOs would have to facilitate the development of effective community institutions and provide catalytic financial assistance. The current precipitate action to divest and transfer the management of public irrigation systems to farmers' organizations without first building their capacity to take on added responsibility has resulted in worsening performances (HJRBDA, 2003). Their capacity to take on the increased responsibility need to be raised and appropriate incentives provided to make it attractive for the community to do so.

In addition, the KYB uniquely covers parts of the territory of Niger and Nigeria, with the parts of the basin in Nigeria, both upstream and downstream. The Downstream riparian (especially Niger Republic, Yobe and Borno States) have been especially vulnerable since the water on which they depend, does not originate within their territory. This issue has created and still creates political tensions and conflicts at intra-national and international level. The Lake Chad Basin Commission (LCBC), of which Nigeria was a founding member and the greatest contributor, as well as the bilateral initiative of the Nigeria-Niger Joint Commission (NNJC) have provided the required special conflict resolution mechanisms with our neighbours. Alarmed by the shrinking of the Lake Chad, the LCBC with the assistance and cooperation of UNEP, UNSO and FAO prepared a Master Plan for environmentally sound management and development of the natural resources of the Lake Chad conventional basin in 1993. The NNJC with its headquarters in Niamey, Niger Republic was established under a bilateral relation to monitor and recommend the development options within the following four major drainage basins common to both countries: the Komadugu Yobe Basin, Baggia Lamido Basin, Gada Goulbi de Maradi Basin, and the Tagwai El Fadama Basin.

In summary, therefore, none of the existing institutions and ministries is responsible for holistic and integrated management of basic natural resources, notably soils, water and vegetation. Although the natural system makes land and water resources inseparable, their policy and legislation are being formulated and implemented in isolation and without adequate coordination and participation of all stakeholders. Ideally, the policy should be handled within one government institutional framework. This may not be feasible because, virtually every sector of the economy depends on these critical resources and as a result, for a single institution to hand all aspects of their policy may be too cumbersome and over centralized.

5.4 Status of Stakeholders at River Basin Level

The general organisational function of integrative natural resources management could broadly be grouped into four, namely: resources assessment; planning and decision-making; implementation; and enforcement. River basins which are characterised by fixed geographical identity and with relatively homogeneous land, soil and water resources have been recognised by planners globally as suitable units for integrated land and water resources development. Consequently, the most central institutions responsible for organisational functions at river basin levels are the RBDAs.

5.4.1 River Basin Development Authorities

Water flows according to natural characteristics that are called river basin which naturally links majority of the area – its land surface – to the highly significant minority area – its rivers and the groundwater (Newson, 1994). It is therefore globally recognized that organisational functions of integrative management of land and water resources management, should best be done at the level of hydrological boundaries, which seldom concur with administrative and/or political boundaries. If these criteria had strictly been observed, only a maximum of eight hydrological regions would have been created in Nigeria and not twelve as is the current situation (Sanyu and Sumiko, 1995). The strict hydrological basins are *Niger-North, Niger-Central, Upper Benue, Lower Benue, Niger South, Eastern*

Littoral, Western Littoral, and Lake Chad. Some even suggest that Niger-North and Niger-Central should ideally be Upper Niger, while the Upper and Lower Benue should equally form one basin thereby reducing the basins to six (Afremedev, 1999).

The number of RBDAs have risen to 18 and fallen to 11 over the years and to the current 12, and their functions expanded or contracted to include rural development according to prevailing political thinking and other extraneous considerations.

In spite of their name, the boundaries of the RBDAs do not correspond with watersheds or catchments of the major river basins. Instead, their boundaries have been determined arbitrarily with concession made to ensure that they coincide closely with the administrative/political boundaries, rather than the hydrological reality. This is responsible for the current situation where Komadugu Yobe hydrological basin, is split between two RBDAs, namely CBDA and HJRBDA. The operational area of HJRBDA comprises the upper reaches of the catchments falling within parts of Bauchi, and the whole of Kano and Jigawa states, while that of the CBDA comprises the lower basin in the catchments falling in parts of Adamawa, and the whole of Yobe and Borno states. They both have responsibility for water management in the basin but with little co-ordination. This clearly reveals lack of awareness of the concept, philosophy and principles of integrative management of land and water resources in contiguous natural system (the river basin) by policy-makers.

This flawed situation is made even more tenuous by lack of reliable and regular hydro-meteorological information on the basin for effective resources assessment. The monitoring networks which used to be effective up till late 1970s, have become inoperative (IUCN, 2003). Meanwhile, the subsisting enabling legislation on the RBDAs is Decree No. 35 of 1987. In spite of several fundamental changes and reforms thereafter, including the partial commercialization of their activities in 1990, the increase in their number from 11 to 12 and change of name to River Basin and Rural Development Authorities

(RBRDAs) in 1994, signifying increased scope of their mandate, the enabling decree has remained the same. The transfer of the Department of Rural Development to FMA in 1999, brought with it a dilemma of whether they were to continue with their role in rural development or not? This situation remains to be resolved. This is another illustration of lack of coordination and appropriate institutional framework at this level. In addition, their functions are distorted and out of tune with the fundamental element for success of a basin as would be shown subsequently. The functions in the said decree are as follows:

- ✓ to undertake comprehensive development of both surface and groundwater resources for multipurpose use, with particular emphasis on the provision of irrigation infrastructure and control of flood and erosion, and for water management;
- ✓ to construct, operate and maintain dams, lakes, polders, wells, irrigation and drainage systems for achievement of the Authority's functions and to hand over all lands to be cultivated on irrigation schemes to farmers;
- ✓ to supply water from completed storage schemes to all users for a fee to be determined by the Authority with approval of the Ministry;
- ✓ to construct, operate and maintain infrastructural services, such as roads and bridges linking project sites, provided that such services are included and form an integral part of the list of approved projects; and
- ✓ to develop and keep up-to-date a comprehensive water resources master plan, identifying all water resources requirements in the Authority's area of operation, through adequate collection and collation of water resources, water use, socio-economic and environmental data of the River Basin.

Experiences have identified a number of common features that are essential for the success of river basin organization (GWP, 2000). Where these elements are lacking or flawed the RBDAs would lack political legitimacy and sustainability. These are:

- A high level of autonomy of the enterprise management and organizations;
- Transparency, accountability and active stakeholder participation in the decision making;

- Availability of reliable information, a good decision-support system and the capacity to use it to anticipate developments; and
- Adequate, reliable and sustained financing.

The RBDAs were supposed to be autonomous entities with high level of administrative and financial autonomy. Each of them should have a Board of Directors comprising a Chairman, the representative of the FMWR, the Chief Executive Officer of the RBDA and some other members, all to be appointed by the President, and answer directly to the Minister for Water Resources. In reality however, the Boards are hardly ever appointed and when they do, rarely do they last more than three years, nor do they meet regularly. In most cases they comprise entirely of political appointees who have no idea of the principles governing INRM, nor the role of RBDA in attaining them. For instance, between 1996 and1999, the RBDAs had no Boards. Instead, they were reporting to the FMWR directly even for routine matters as their financial limit were grossly curtailed to not more than ₦ 300,000.00 per transaction. Today the Boards rarely meet except to award contracts or to deliberate over mundane issues.

Secondly, to ensure transparency and accountability, it is particularly important to separate the role and institution of 'gamekeeper' namely the water resources management institutions/regulator from those of 'poachers', i.e., the water services delivery functions. Separation of regulatory and implementation functions helps ensure transparency and accountability. Currently, the RBDAs are both water resources managers/regulators as well as water services providers (GWP, 2000a).

On the aspect of active stakeholder participation, the decree 35 of 1987 requires each of them to convene advisory committee meeting at least once annually. The Advisory Committees are to be consulted over their annual programme and serves as forum to harmonise their needs and expectations. It is supposed to include the following:

- heads of the Federal government agencies involved with water resources development in the authority's area of operation (to include relevant representative of universities and polytechnic but these are rarely, if ever considered); and

- heads of departments of States Agencies in their domain responsible for agriculture, irrigation, fisheries, forestry and livestock.

These advisory committees have not been reconstituted nor convened by either of the RBDAs in the past 15 or more years. The situation was such that during the interviews, most respondent from the RBDAs did not know they were mandated to have one. The few, who were aware of the provision, complained of inconsistencies of their boundaries and insufficient funds as the reason why they were not constituted. These have created difficulties to full cooperation with other agencies in water resources management and development.

Thirdly, the RBDAs are responsible for the field operation of the Federal Government of Nigeria's (FGN's) water resources and rural development programmes in their catchments. They are intended to have Master Plan for integrated development of the natural resources of their basin. They are required to collect, collate, analyse and disseminate reliable information; update the master plan regularly and develop suitable decision-support system that would facilitate their equitable resources allocation and decision making that are systematic and consistent with sustainable development of their basin. Today, only Hadejia-Jama'are River Basin Development Authority has a master plan, even though it is out of date (Afremedev, 1999).

Government has paid lip service to this very vital function of RBDAs. Inadequate funds are provided for collection and collation of vital hydro-metrological data necessary for such an exercise. It is interesting to note that Kano State Water Board (KSWB) and Water Resources Engineering Construction Agency (WRECA) have well-developed network of hydrological data collection stations while HJRBDA that has the primary mandate for this has been relatively less involved in the state. On the other hand, the situation in Bauchi State is the reverse; the state government agencies have no hydrological data collection stations, and therefore rely on Upper Benue RBDA for their data.

The interview with officials of both RBDAs also revealed that all of their existing dams and irrigation projects were developed without Environmental Impact Assessment (EIA) study, and of these only the KRIP phase 1 has been subjected to environmental impact audit. This was done under the auspices of a World Bank grant to prepare ground for the completion of KRIP phase1 and to identify the problems with existing system and suggest remedial measures to alleviate them. It is significant to note that INRM approach requires that sectoral development be evaluated regularly for possible impacts on the resource-base, identifying the measures necessary to protect the resources and the related ecosystem and ensuring that such measures are implemented. Hence, EIA is central to the cross-sectoral integration. Obviously, the absence of environmental impact audit as a routine and the inability to implement measures recommended even on the only audit concluded in 1992, both represent a significant flaw in the current institutional arrangement.

Risk assessment and management also touches the heart of the need for cross-sectoral integration. Risks in this basin are floods, drought and environmental damage in addition to business related risks. While it is never possible to eliminate or avoid all possible risks, it is however essential, at the minimum, to at least observe the precautionary principle. It was therefore a matter of regret to note that in spite of recent repeated occurrence of floods and observed wetlands damage downstream arising from poor reservoir operation; nothing has been done to avoid this potentially irreversible environmental damage. The shrinking of Lake Chad and its effect on South Chad Irrigation Project (SCIP) and Baga Polder Project has been ignored, with the projects being operated as if nothing has changed. The explanation that scientific research was yet to fully establish the causal link and potential damage, neglected the precautionary principle which requires preventive measures rather than remedying the damage after the event. This further underscores the need for institutional reforms on basic data acquisition and collation, with careful consideration of the relative strength of the agencies in evolving suitable nationwide policy.

Fourthly, the RBDAs are provided subvention directly by FGN, even though they are also supposed to be able to charge fees to recover cost of their operation and maintenance from the beneficiaries of their services. Of the services they render, the most important in terms of revenue is the delivery of water for irrigation using their irrigation infrastructure for which they are required to charge cost recovery fees. The reality however, is that irrigation water fee has remained since 1987 fixed at ₦ 500 per hectare per season. Recently however, some RBDAs, notably SRRBDA and UBRBDA have selectively increased the fees to as high as ₦ 10,000 per hectare per season (FDID, 2000). A publication of FDID (2000) revealed that based on 1999 prices, the minimum charge required for RBDAs to breakeven on their cost of operation and maintenance was about ₦ 7,000 per hectare per season for gravity irrigation system and as high as ₦ 38,000 for sprinkler irrigation systems. The recent increases in fuel cost would further escalate these costs, and unless some form of subsidy and incentives can be introduced, farmers would not be able to make sufficient return on their investment to keep them on the farms.

According to the commercialization programme of Federal Government, HJRBDA and CBDA were classified as category A-RBDAs, along with Sokoto-Rima RBRDA. They were to have been granted complete autonomy and be weaned-off the treasury dole out by 1995. Government reneged on their responsibility by failing to provide the seed capital and the required enabling environment. Consequently, the performance agreement was voided, but not without debilitating destabilisation of the already fragile institutional structure. It made the overhead even the more burdensome, without improving its autonomous sources of finance nor did it rationalise and improve their services.

In summary, therefore, although the establishment of RBDAs between 1973 and 1976, was no doubt a significant stride in the integrative management of land and water resources in Nigeria, the advantages of the policy have however, been grossly curtailed by the distortions in their structure and functions. They are now almost entirely service oriented without adequate regard to integrated and holistic regulatory management functions required for environmental conservation which is necessary for sustainable development. Meanwhile, as was illustrated, there is also little or no coordination between HJRBDA and CBDA except through the FMWR, even though they manage land and water in the same hydrological basin. It remains to be seen whether some other institutions such as Federal Ministry of Environment, the successors to FEPA, are currently filling this gaps.

5.4.2 Federal Ministry of Environment

This study revealed that defunct FEPA commissioned a macro-economic study on EIA of the water resources development projects in the Jema'are River sub-basin, arising from the controversies surrounding the development of Kafin Zaki Dam. Today, Federal Ministry of Environment is the apex institution of Federal Government responsible for the management and protection of the nation's environment, yet the study remains to be completed. It was understood that the study stalled due to insufficient funds but that it was primarily intended to identify suitable strategies for the management of natural resources in the basin that would be economically beneficial, environmentally safe, as well as socially and politically acceptable.

The Federal Government's four-year (2000-2003) programme that was designed to tackle ecological problems in Nigeria at a total cost of ₦ 11.25 billion was equally frustrated by poor funding, even though a system of cost sharing was adopted. Federal Government was to have contributed 60% (about ₦ 6.75 billion) of the amount, the State governments to contribute 15%, the local governments 15% and the private sector, including the local communities, NGOs and CBOs 5%. It was not possible to obtain the status of neither contribution of stakeholders nor the report of progress on the projects.

The transfer of relevant bodies and agencies to the Ministry was reported by the representative of the Ministry to have been completed. These are: department of forestry including wildlife, forestry monitoring, evaluation and coordinating unit (FORMECU) formerly in Ministry of Agriculture and Rural Development; Flood and Erosion Control including desertification, formerly in Ministry of Water Resources;

and the environmental health and sanitation unit of the Ministry of Health. Others are the oil and gas pollution control unit formerly of Department of Petroleum Resources and the coastal erosion unit, environmental assessment division and sanitation unit both formerly of the Ministry of Works and Housing.

Each State has an Environmental Protection Agency (SEPA). These are supposed to be responsible for the preservation and management of the environment in the state but instead they are mostly preoccupied with urban sanitation and solid waste disposal. Consequently, neither the defunct FEPA, nor the FME, nor SEPA is filling the gaps of the regulatory role required to ensure sustainable development and to integrate the development of these resources at river basin level. This was in part responsible for the commissioning of Hadejia-Nguru Wetlands Conservation Project by two NGOs.

5.4.3 Other Institutions

The interviews conducted at the HJKYBCC secretariat in FMWR revealed that a project titled "Improving Land and Water Resources Management in the Komadugu Yobe Basin" aimed at improving the institutional framework for water resources governance in the region is in the offing. Based on the comprehensive study of the basin carried out by Afremedev Consultancy Services Limited commissioned by Petroleum (special) Trust Fund (PTF), TAC drafted a Basin Management Plan, which recommended a water audit. The project would comprise of socio-economic and environmental situation analysis, water audit, development of water management options and development of an agreed charter for management of the basin. The proposed project would therefore implement some of the decisions of HJKYBCC and the LCBC sponsored Komadugu Yobe Basin component of the GEF-supported Lake Chad Initiative Programme. It would seek to address many of the challenges identified at a Stakeholders Consultative Workshop convened in January 2003. The following synthesis of challenges and issues that emanated from the workshop was instructive and revealing:

- Capacity-building of the stakeholders for optimum utilisation of the resources in the basin

- Data collection, rescue, update and dissemination
- Stakeholders participation, commitment and coordination
- Establishment and implementation of enabling legislation and policy
- Establishment of the necessary institutional framework for the integrated natural resources management and sustainable development of the basin
- Establishment and enforcement of environmental quality standards for planning, design, construction and operation of dams as well as for special multiple uses of water

Another significant development has been the Lake Chad Basin Commission Initiative, which is a collaborative programme of LCBC with the World Bank, UNEP and UNDP. It is implementing a GEF-supported programme for integrated management of Lake Chad and associated river systems. One of the components of this programme is the integrated management of the KYB, focussing on wetlands of the basin. Although these would be helpful in actualising integrated management of land and water resources in the basin, their benefit would be short-lived unless they can be institutionalised and made to last beyond the project live-span.

5.5 Land and Water Services (Operational Functions) Providers

5.5.1 River Basin Development Authorities

The two RBRDAs in KYB have independently been harnessing and abstracting water in the catchments principally for irrigated agricultural development in their domain. Currently, HJRBDA has developed Tiga, Ruwan Kanya and Challawa Gorge reservoirs, as well as Kano River Irrigation Project – Stage 1 of Phase I (KRIP 1-1). Meanwhile the development of Hadejia Valley Irrigation Project Stage 1 of phase 1 (HVIP 1-1) and the stage 2 of KRIP 1 are on-going. The development of Kafin Zaki and Kawali Diversion structures along with their downstream irrigation development although planned, have remained controversial and have generated considerable tension. The proposed dam would lead to the control of flows in the Jama'are River system, and Yobe and Borno States believe that it would exacerbate their water scarcity, as the upstream states (Bauchi, Kano and Yobe) would utilise the water without any regard to their needs and aspirations.

On the other hand, CBDA has most of its development on the fringes of Lake Chad. To date, it has developed South Chad Irrigation Project (SCIP) phases 1 and 2 and Alau Dam but without downstream irrigation development - that is currently on the drawing board, and has partially developed Baga Polder Irrigation Project.

A large gap exists between irrigation potential and actual utilisation of the available irrigation water. Reservoirs and waterways are being damaged by heavy siltation, sedimentation and weed infestation. Most of these projects with possibly the KRIP as the only exception are not performing satisfactorily, for three main reasons, namely: poor planning and design from the onset; poor funding and attention to operation and maintenance; and finally insufficient beneficiary participation in their development and management. Poor planning and design was as a result of insufficient and unreliable information used, which led to wrong decisions. Afterwards, the situation was compounded by paternalistic approach to the management of these schemes. The hasty programme to transfer management of these formal irrigation schemes to the farmers without adequate capacity building, only made the situation worst. Many of the RBDAs have built sizable manpower that is not in tandem with their achievements.

The study further revealed the following major constraints that are militating against effective provision of irrigation services by the RBDAs:

- Shortage of staff with capability in operation, maintenance and management (OMM) of irrigation schemes.
- Severe funding constraints. They hardly receive any funds other than for salaries. The last subvention received being that of October 2001.
- Lack of effective extension services on their schemes arising from policy inconsistencies.
- Absence of effective mobilisation of farmers' resources towards OMM.

- Inadequate tractors and implements that would enable them ensure compliance with cropping calendar.
- Scarcity of spare parts, especially for SCIP with high electromechanical components, while scarcity and high cost of AGO (diesel) has led to the frequent failure of the system and hence poor performance.

5.5.2 The North East Arid Zone Development Programme

The North East Arid Zone Development Programme (NEAZDP) is an integrated rural development project, for the northern fringes of the semi-arid zone of Yobe State. It covers 20,000 km^2 in 9 Local Governments Areas with estimated population of 1.2 million people as at 1992. It started as a joint FGN-Yobe State Government-Euporean Union (EU) project with linkages to University of Maiduguri, through its Centre for Arid Zone Studies (CAZS), and Ramat Polytechnic in Maiduguri. EU, however, suspended their aid in 1996 as part of the economic and political sanction by the body. Since then the Federal Government has been responsible, although not satisfactorily, with funds not being released when due and not fully. This has drastically affected the performance of the project.

The mission of the programme has been "to motivate and assist the rural population to improve their standards of living through proper use and management of natural resources". The programme has encouraged villages to prioritise their needs; has given credit, technical assistance and advice to owners of productive projects such as irrigated agriculture; and has provided support to social projects such as provision of hygienic and reliable water supply, and improved nutritional and health standards under full management of the communities.

NEAZDP operates 19 hydro-meteorological stations out of which 14 are manual gauging station installed along the Komadugu Yobe river system while 5 automatic gauging stations are installed at bridges at Hadejia, Katagum, Gashua, Geidem and Dapchi. Thus, they are essentially engaged in organizing and assisting farming communities within its operational area to abstract both surface and groundwater for irrigation and domestic use.

5.5.3 State Government Agencies

The State Ministries of Agriculture and Natural Resources (SMANR) and Ministries of Water Resources and Rural Development (SMWRRD) play similar roles in land and water resources management to those of FMARD and FMWR respectively at the State level. The operational difference is in the emphasis of their activities on service provision rather that on regulation, control and natural resources management. The State Irrigation Department (SID) and the ADPs belong to SMANR in some States, while in some others SID and state-wide coordination of water resources development and management belongs to SMWRRD (e.g. Kano and Katsina).

Like elsewhere, the advent of HJRBDA and CBDA has eclipsed the role of SIDs in their area of jurisdiction. These SIDs however, continue to maintain sizable staff, in spite of the limited funds that has rendered them virtually idle. Kano State government has nonetheless managed to remain relatively active. It has developed several dams, including the Bagauda, Gari, Tomas and Watari medium and small-scale dams for domestic and agricultural water requirements. It would appear that an informal division of responsibility exists in which irrigation projects of more than 500 ha are generally handled by the RBRDA, while those that are less are managed by SIDs. Even then, there is apparently no forum for formal discussion and coordination of activities between the RBRDA, ADPs, WBs and the SIDs within any of the states in the basin. Although, the approved organisational structure of the ADP requires the Chief Executive Officer of the RBDA of that domain to be a member of the governing board of the project, in reality this has been ignored for the past fifteen years or more. Furthermore, the new centralised agricultural extension policy requires ADPs' to provide all extension services, both for rainfed and irrigated agriculture including RBDA schemes, but this too has been observed more in breach.

The Agricultural Development Project (ADP) deals mainly with rainfed agriculture even though some of them (particularly those of Bauchi, Kano and Jigawa States) became involved in the National Fadama Development Project (NFDP) Phase 1 in the early 1990's. These three and, to a lesser degree, those of the Yobe and Borno are now promoting small scale, farmer owned and managed irrigation using petrol-driven pumps to exploit shallow aquifers of the *fadama* under the auspices of the World Bank through NFDP. The farmer acquires the pumping systems on loan, but the washbores and tubewells are drilled by the ADPs. This project has been tackling some of the institutional issues faced by HJRBDA, such as cost recovery and provision of credit for small farmers, and some of these farmers are also participants in the schemes operated by the HJRBDA.

The responsibility for provision of municipal and rural water supply and sanitation services lies with the State governments. It was indicated that one of the conditions before the World Bank intervention in the National Water Supply Rehabilitation Programme (NWSRP) was the existence of a state agency that was solely responsible for water supply, while the requirement of the FMWR Nationwide Rural Water Supply Programme was the responsibility of an agency for the development, operation and maintenance of rural water supply schemes. Consequently, almost all the states in the basin now have State Water Boards (SWBs) for urban water supply and Rural Water and Sanitation Agency (RUWASA) for rural water supply and sanitation. The SWBs are involved in water resource development and have some reservoirs, and treatment plants with reticulation networks to provide water supply services to towns with population of more than 1,000. They are also involved in hydro-meteorological data collection and have monitoring network.

The SWBs degree of interaction with the FMWR varies, depending on whether the State is a beneficiary of the NWSRP. The FMWR coordinates the funds and by implication this has improved harmonization and cooperation with the SWBs that are beneficiaries of the Fund. Unfortunately, because FMWR itself does not seem to recognize the resources management functions of RBDAs, they were not consulted on the NWSRP. This has tended to further distance the SWBs from the RBDAs.

5.5.4 Other Institutions and Agencies

More than 149 Local Government Authorities have their domains within the KYB. It was gathered that they are all involved in one way or the other in the abstraction of water for small scale irrigation purposes. Nonetheless, even if it were not so, the involvement of the Local Governments and District Authorities in irrigation development projects would be vital especially in the mobilization of farmers.

Other stakeholders involved in land and water resources management and development are shown in Table 4.1. Many of these institutions operate independently of each other and from the FMWR except for limited and ad-hoc inter-ministerial and inter-departmental fora which are often restricted in scope and depth of discussion.

5.6 Water-Related Functionality of Village Level Institutions

Evidence exists that village level institutions have been formed in the basin, especially at the two major irrigation projects. However, either that the formation had been haphazardly done or they were not empowered enough at the very beginning because they are not active now. The participation of water users and other village level institutions must be thorough to be effective. One does not expect the water users to accept new added responsibilities without any privileges attached to it. The leadership must be fully involved in planning, designing, operation, maintenance, financing and policy matters if the aim is to transfer complete responsibility to users in the long run.

Outside the major irrigation projects, several village level institutions are also springing up as a result of several disasters facing communities. Water scarcity, flood and *Typha* grass invasion have all forced communities to rise up and formulate ways of solving their problems.

Most donors require that the grassroots lay some foundations before coming in to assist them to strengthen such foundations. As such, the worst affected members of any community in the basin are now forming self-help groups for the various problems. In this regard DFID and the DFID-JWL Project are assisting communities to form such groups. Groups such as Marma Channel Flood Protection Groups and Pastoralists Group now abound. The DFID-JWL Project is assisting such groups to identify and articulate their goals. Critical areas of action are identified. The opportunities, such as helping factors and constraints, hindering factors and group workplans are all identified and articulated.

In one community, a group with flood and *Typha* control as their ultimate goal, priority has been given to the clearance and opening up of the main river channels blocked by floating grasses, *Typha* grasses and siltation. The group worked tirelessly for three months and thereby cleared the mouth of their channel at the Gubusum bifurcation. All this was done by hand. Sometime you can see a group of more than one hundred able-bodied men working from sunrise to sunset. Public authorities need to come in at this stage to encourage and empower these CBOs by helping them out with the work that is beyond them and handing it over to them as their property after proper training in Operation and Maintenance (O&M) for sustainability. Public authorities must do it because NGOs are too few in the basin.

To achieve Integrated Water Resources Management (IWRM) in the KYB, the management of land, water and human society, governments, NGOs, local groups, private companies and donor agencies in consultation with all other stakeholders in the basin must jointly develop and implement an ecosystem based catchment management plan. For the sake of conservation, this approach will promote the protection and rehabilitation of the catchment.

5.7 Functionality of State Level Participatory Forum

The village level groups mentioned above know fully well that the tasks and goals they set for themselves are enormous and cannot be achieved by hand alone, the self-help groups have sought support from state level participatory foras, local authorities, regional political representatives and numerous other stakeholders for assistance. The group were able to get a mechanical excavator from the state ADP. These state level participatory foras made possible worksite visits by commissioners, deputy governors and emirs. They also made possible media coverage of the community problems and efforts. News correspondents from Radio Jigawa, DW, BBC and VoA have all visited the site of the work and reported on the on-going community level activities.

The state level participatory foras have also facilitated the identification of more permanent solutions to the problems. One way identified is the construction of flow proportioning structures at critical positions in the river system. Through the operation of these structures, water flows can be proportioned between the various channels in order to mitigate lack of water in some channels, and control excess in others. These structures are also expected to help control *Typha* as well as arrest potash intrusions and restore regular seasonal flows into Yobe River and the Lake Chad.

The state level participatory foras is also planning the replication of these structures elsewhere if the first two prove successful and also planning to establish suitable joint local management arrangements of the structures. The foras are also working towards the establishment of good working relations with the managers of upstream control structures (Tiga and Challawa Gorge dams). It is also trying hard to establish regular information channels on upstream water releases and influence in the planning of dam operation procedures (i.e. basin-wide water sharing arrangements) which will serve the purpose of controlling floods and *Typha*.

5.8 Summary of Challenges of Human System Integration

Generally, the sectoral approaches to land and water resources management remain the dominant practice. These have led to the prevailing uncoordinated and fragmented development of these resources. Their management are usually top-bottom, with legitimacy and effectiveness of the RBDAs being increasingly questioned. Data and information management are very poor and conducted for the needs of individual agency. While this was not entirely a bad arrangement, they were irregularly done and without coordination or exchange of data. There were no clear priorities in the basin and sub-basins. Similarly, more than one institution, were found to be involved in many other functions without coordination, with many other functions, such as bulk water allocation through water entitlements not performed. In areas such as watershed management and public education and awareness, better coordination was needed. In many cases the integrated natural resources management principles was not known to many of the respondents.

Consequently, the institutional challenges to integrated management of land and water resources in the KYB can be summarised as follows (Musa, 2003):

- ***Improving land and water governance:*** The natural resources situation when compared with the population and socio-economic situation as shown in Chapter 4, suggests that water crisis may be eminent. This crisis could be minimised or averted if governance could be improved and political will found to take appropriate but painful decisions to ensure equity in the allocation of water as well as enforce the legislation. The strategic improvement required involves governments at all level creating an enabling environment and introducing appropriate institutional reforms that would facilitate mobilisation of all stakeholders' knowledge and resources for effective management of natural resources to meet all needs and interests.

- ***Creating awareness and greater stakeholder participation:*** Ignorance prevails as to the importance of environmental conservation and the need to accommodate the interest of all stakeholders. To create institutional harmony would require applying useful experience and knowledge in pursuit of integrated land and water management for sustainable development of all sectors and raising awareness of its importance.

- ***Tackling conservation, achieving water for food and sanitation while improving flood management as urgent priorities:*** Conservation is a major challenge and integrated management of the basin is required to conserve the limited available water resources. Measures have to be taken to protect the rivers, aquifers, aquatic ecosystems from pollution, invasive aquatic weeds, siltation and overexploitation and to use water sources optimally for food production and other uses. Flood management and protection of some delicate ecosystems used for traditional methods of flood recess agriculture would have to be better managed. Greater and regular dialogue between upstream and downstream would enable compromise ranking of these urgent needs.

- ***Generating the required investment for future:*** Tackling these challenges and issues would require substantial increase in investment for integrated management of the basin, which would have to be harnessed from various investor groups – public and private sector; domestic and international; individual and institutional – and will have to be pooled in financing a more secure basin for the future.

The sum total of all of these is that there are now many public institutions involved in the planning, financing, construction, operation and maintenance of land and water resource associated systems at various levels - Federal, State and Local. This has resulted in some uncoordinated and fragmented decision-making, inconsistent policies, overlapping and duplication of functions, or even competition for same water as has become manifest in the basin in recent times.

6 Status of Water Resources

6.1 The Sub-basins in KYB

About 57% of the Komadugu Yobe catchment lies in Nigeria, and the sector contributes 95% of the water resources of the basin. Four sub-basins are identified in the Nigerian sector of the basin. These are: Hadejia, Jama'are, Gana and Yobe sub-basins. The catchment area of Hadejia is 16,380 km^2, while Jama'are sub-basin has an area of 7,980 km^2 and 15,000 km^2 at Bunga and Katagum, respectively. The area of Gana sub-basin is 5,865 km^2 at Kari and Yobe sub-basin has an area of 62,150 km^2 at Gashua.

6.2 Surface Water Resources

6.2.1 Rainfall

Monthly rainfall data were collated from stations within and near the basin. Table 6.1 shows a summary of the record. Data quality analysis was carried out using double mass analysis technique, and the data were found to be of good quality. The records (Appendix 2) were used to construct isohyets for mean annual rainfall for the basin.

On the average, the annual rainfall varies from 1,200 mm at the upstream part of the catchment to 500 mm at the downstream end of the basin. Rainfall in the basin is characterized by inter-annual variation. Figure 6.1 shows the isohyets of mean annual rainfall. Annual rainfall at Hadejia sub-basin varies from 700 mm and 1,200 mm, while mean annual rainfall in Jama'are sub-basin varies from 800 mm to 1,200 mm. Mean annual rainfall for the Yobe sub-basin varies between 250 mm and 600 mm. There was a persistent decline in rainfall in the 1980s and the rainfall did not recover until mid-1990. The declining trend in rainfall was more pronounced in the Yobe River sub-basin than the Hadejia and Jama'are sub-basins. In addition, the declining trend commenced earlier in the sub-basin which is attributed to the southward migration of the Sahelian drought.

Table 6.1: Summary of Rainfall Data collated

Station	Period of record
Balle	1992 – 2004
Borno water works	1995 – 2004
Bula Bguwa	1992 – 2004
Dagona	1992 – 2004
Dapchi	1992 – 2004
Degeltura	1992 – 2004
Futchimiran	1992 – 2004
Garin Alkali	1992 – 2004
Geidam	1992 – 2004
Gwoi Kura	1992 – 2004
Potiskum	1936 – 2004
Nguru	1942 – 2004
Bauchi	1906 – 2000, 2002, 2003
Kano airport	1905 – 1994 (daily rainfall for the 1970s)
Kano – IAR	1974 – 2005 (daily rainfall)
Zaria	1943 – 1994
Jos	1922 – 1992
Maiduguri	1909 – 1994
Kachia	1975 – 1987
Kanamma	1992 – 2004
Kara	1992 – 2004
Kaska	1992 – 2004
Kurkushe	1992 – 2004
Machina	1992 – 2004
Mugu	1992 - 2004
Samaru	1928 – 1999
Warodi	1992 – 2004
Yunusari	1992 – 2004
Yusuf	1992 – 2004
Monthly rainfall for Jigawa State per LGA	1988 – 1998

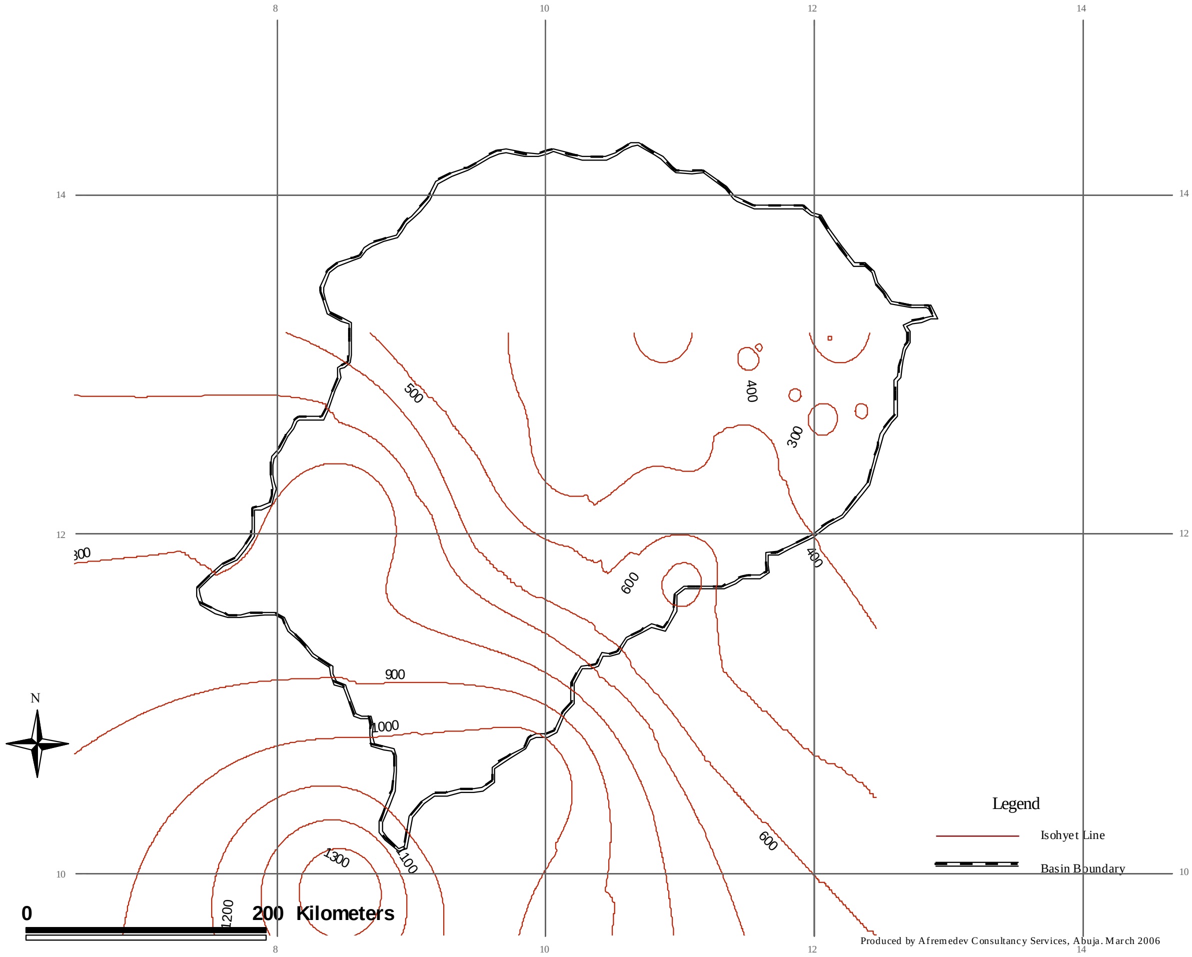


Figure 6.1: Mean Isohyets of KYB

The period, 1931 to 1960, is classified as the period of climatic normal. The mean and standard deviation of the rainfall series of this period was used to standardize the rainfall series at each sub-basin. Figure 6.2 shows the standardized rainfall index of Tiga and Challawa sub-units in Hadejia sub-basin, as well as rainfall index in Jama'are sub-basin. The figure confirms the persistent decline in rainfall in the basin since the 1980s when major water resources development projects were carried out. The implication of the declining rainfall in the basin is that inflow into Tiga and Challawa Gorge reservoirs were based on high rainfall that occurred in the pre-1980s. Thus, the reservoirs would not be filled as expected during the planning stage. This observation is confirmed by the ratio of storage volume to average annual inflow of 2.5 and 1.6 for Challawa Gorge Reservoir and Tiga Reservoir respectively. Silt deposited in the useful storage zone of the reservoir gives a false impression of water stored in the reservoir, since elevation-storage and elevation-area characteristic curves of the reservoir did not account for such situation.

6.2.2 Evaporation

Evaporation in the northern part of Nigeria is a function of location (radiation ratio), temperature and relative humidity. On the average, the computed rate of potential evapotranspiration, using Blaney-Morin-Nigeria equation (Duru, 1984) varies between 3.7 mm/day and 8.2 mm/day with a mean annual value of 2,200 mm. The implication of this is that the rate of evaporation is higher than rainfall in the basin, especially in the Gana and Yobe sub-basins. The phenomenon also accounts for high losses from impounded water in the Hadejia and Jama'are sub-basins.

6.2.3 Stream Flow

Spot discharge measurements taken in 2005/2006 season have been used to construct rating curves for the purpose of updating the existing discharge data. Table 6.2 shows the summary of discharge record in the basin. However, current records of gauge height are not available for most of the gauging stations.

Rating curve of the form (1) was used to convert available stage record to discharge.

$$Q = A(H-h_0)^n \quad \text{.............................} \quad (1)$$

where Q is the discharge in m^3/s, H is the stage (water level) in m, A and n are coefficients and ho is the zero flow depth. The estimated coefficients based on the 2005/2006 session are summarised in Table 6.3. IUCN (1999) presented the rating equation for gauging stations in KYB (Appendix 3). The result of Diyam (1996) showed that the relationship between stage and discharge differs with season. The result of this study confirmed the earlier finding. This might be due to hydraulic characteristics of the river channels or due to variation in level of commitment of the gauge readers. In view of the unstable hydraulic characteristics of the rivers in the basin, the Consultant cannot use the

2005/2006 rating curve to determine the reliability of the earlier curves. Neither can the curve be used to convert stage readings during the previous season to corresponding discharge. This suggests that continuous monitoring of river gauging in the basin is important.

Table 6.2: Summary of Discharge Record in the Basin

Type of data	Period
Discharge Record	
Challawa George	1971 – 1992
Challawa Bridge	1964 – 1992
Chiromawa	1963 – 1992
Wudil	1963 – 1992
Gaya River at Chai Chai	1964 – 1991
Hadejia Bridge	1963 – 1996
Kafin Hausa	1973 – 1996
Marma Channel at Likori	1973 – 1997
Bunga	1964 - 1996
Katagum	1975 - 1996
Gashua	1963 – 1996
Bagara Diffa	1968 – 1991
Likori	1992 – 1996
Kasaga	1994 – 1997
Gabarau	1994 – 1996
Daily Gauge Height Record	
Hadejia Bridge	2002 – 2003 , Sept. 2005
Kafin Hausa	Apr. 1998 – Oct. 2001 with some missing months, Sept. – Oct. 2005
Nahuche (Jigawa State)	1992 – 1997, Oct 1999 – Apr. 2002 (with some missing months)
Wudil	Apr. 1981 – Feb. 1982, Apr. 1983 – Oct. 1991 (Mar. – May 1989 missing), Apr. 1999 – Dec. 1999, Apr. 2001 – Oct. 2001, Jun. 2004 – Jan. 2005
Marma	Oct. 1991 – June 2002 with some missing months, Apr. – July 2004
Jekarade	1993 – Mar 1998
Suntulmawa	July 1992 – Sep. 1998, Dec. 1998 – Feb. 2003 Dec. 2004 – Jan. 2005

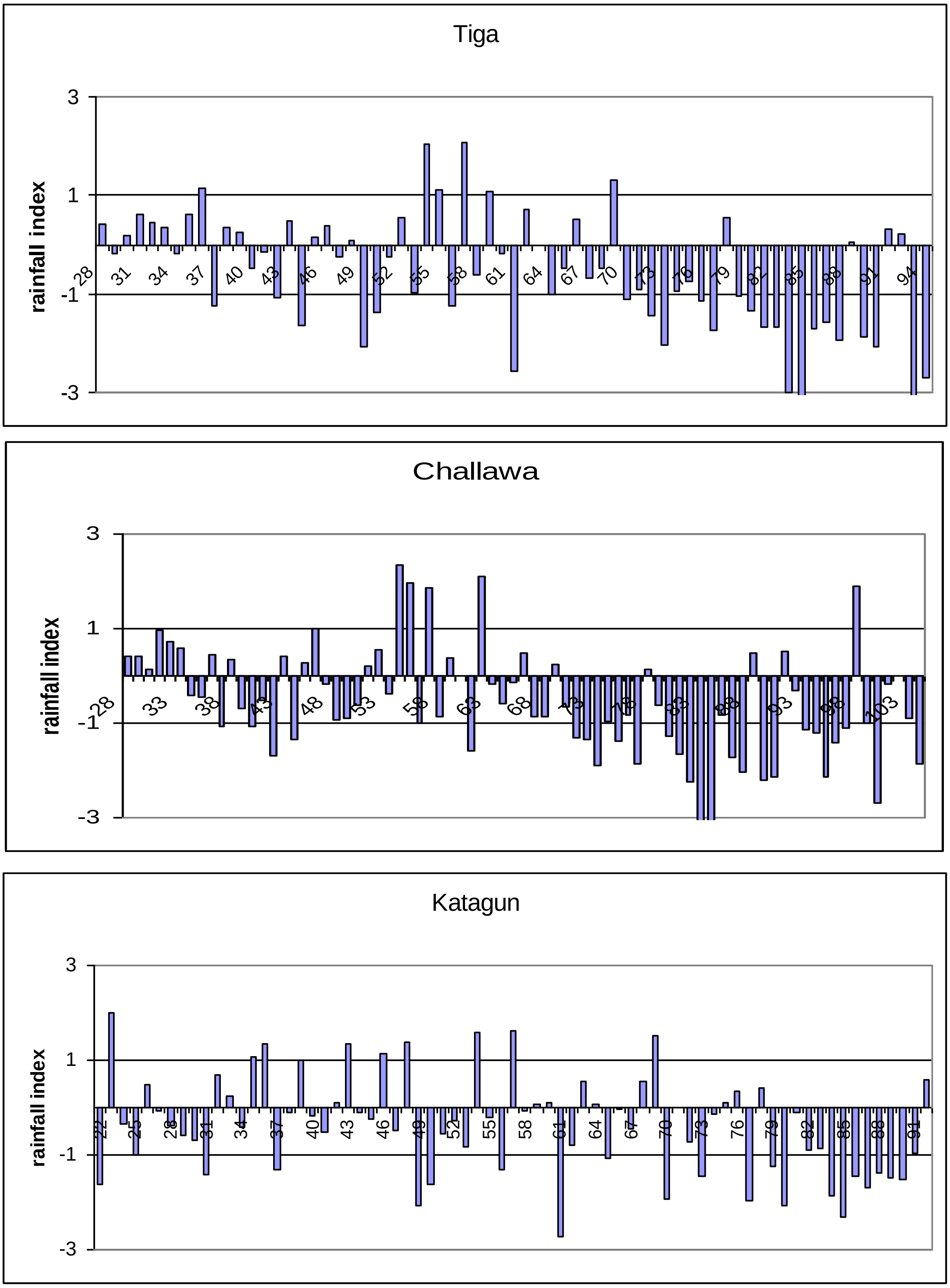


Figure 6.2: Normalised rainfall index for KYB

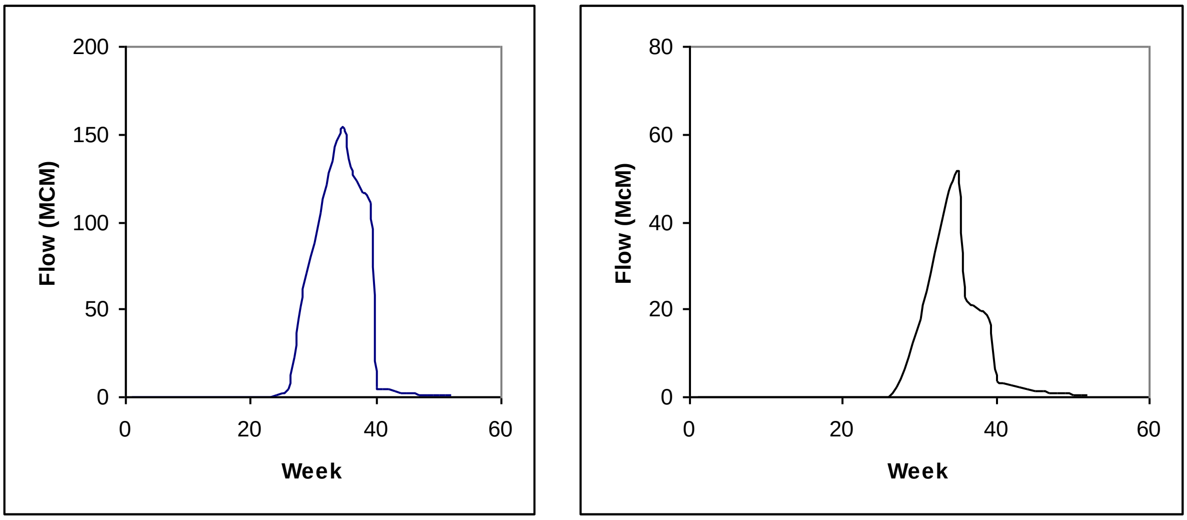
Based on the available records, the surface water resources of the basin is summarised below in Table 6.4. The table shows that the mean annual flow at Wudil reduced from 1,906 Mm^3 during pre-Tiga Dam to 1,264 Mm^3 during post-Tiga Dam. During the same period, the annual flow in Bunga reduced from 1,837 Mm^3 to 1,520 Mm^3. While Bunga had a 17% reduction, Wudil had 34%. If the reduction in flow at Bunga is mainly due to climatic variation, then the extra 17% reduction in Wudil could most probably be attributed to the operation of dams. The streamflow is seasonal, according to the rainfall pattern. Figure 6.3 shows the computed mean inflow into Tiga and Challawa Gorge Reservoirs, while Figure 6.4 shows mean streamflow at Bunga. The variation in flows at Wudil and Gashua during the pre-Tiga and post-Tiga era is presented in Figure 6.5.

Table 6.3: Summary of coefficients of rating curve (2005/2006 session)

Station	Number of data points	Ho	A	N
Dapchi Bridge	3	1.36	16.675722	0.980529
Gadar Maiwa (Bunga) Bridge	3	-0.25	2.080650	2.035251
Gashua Bridge	4	0.60	2.877708	2.545502
Geidam Bridge	3	0.09	31.156736	1.191187
Hadejia Bridge	4	-0.64	9.807255	1.344270
Kafin Hausa Bridge	4	0.57	2.363906	1.328107
Katagum Bridge	3	0.56	84.160141	1.130501
Likori Bridge	4	0.37	1.29141	4.530871
Wudil Bridge	4	0.81	59.643177	1.729168

Table 6.4: Overview of the annual surface water resources in the Komadugu Yobe Basin

River	Site	Catchment area[km^2]	Pre-Tiga Dam construction			Post-Tiga Dam construction		
			Mean annual flow		Mean annual rainfall [mm]	Mean annual flow		Mean annual rainfall [mm]
			[10^6m^3	[mm]		[10^6m^3]	[mm]	
Hadejia	Wudil	16,380	1,906	116	1,046	1,264	61	883
Jama'are	Bunga	7,980	1,837	230	1,271	1,520	179	1,149
Gana	Kari	5,865	542	92		176	30	
Yobe	Gashua	62,150	1,118	22	570	925	15	460



(a) Tiga Reservoir (b) Challawa Gorge Reservoir

Figure 6.3: Mean Inflow to Tiga and Challawa Gorge Reservoirs

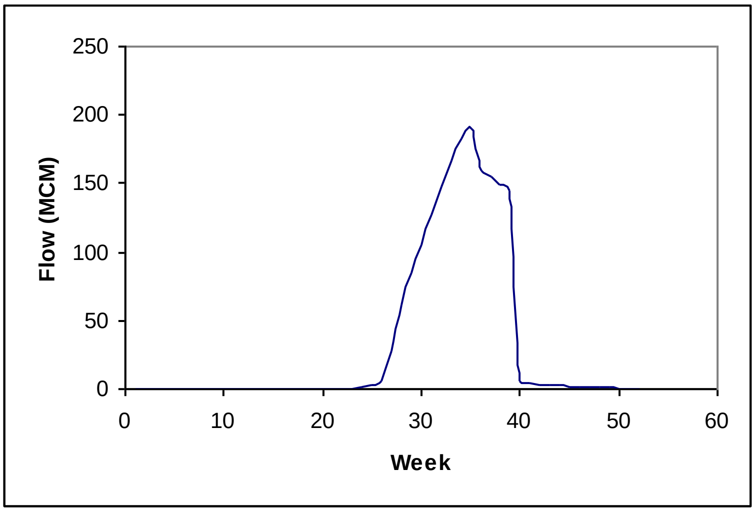


Figure 6.4: Mean Stream Flow at Bunga

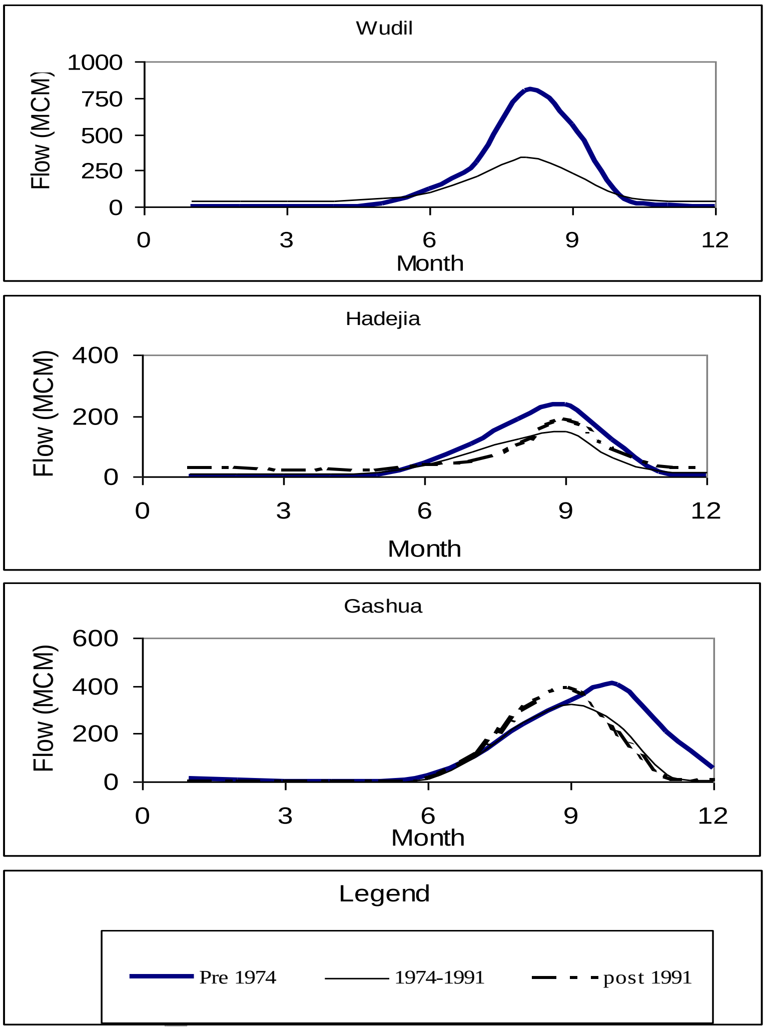


Figure 6.5: Flow along the KYB River System

6.3 Groundwater Resources

6.3.1 Hydrogeology

All the four sub-basins (Hadejia, Jamaare, Gana and Yobe) are covered by the superficial alluvium and/or aeolian deposits, underlain by the Chad Formation. In the southwestern Chad Basin, groundwater occurs in the Quaternary Chad Formation and recent superficial deposits. In the Chad Formation, groundwater occurs under both confined and unconfined conditions. Barber and Jones (1960) have demarcated three aquiferous zones, which they named the Upper, the Middle and the Lower aquifers (Figure 6.6). The Upper aquifer is generally unconfined and semi-confined, while the Middle and Lower aquifers are confined. In the superficial deposits, groundwater is mainly unconfined, although it may be semi-confined locally where clay beds overlie the aquifer.

South-western part of the Hadejia sub-basin is underlain by the Basement Complex rocks, which are composed of gneisses, migmatites and granites. A weathered zone up to 12 m mantles the Basement Complex, and this zone accumulates groundwater. The porosity and hydraulic conductivity of the weathered zone is highly variable depending on the composition, texture, structure and degree of weathering. Residual joints and fractures may provide secondary hydraulic conductivity. Generally, the weathered basement complex is a poor source of groundwater, with an average yield of 3.6 m^3/hr (Diyam, 1987).

The alluvial aquifer in these sub-basins has a thickness of about 30 m. Permeability of the alluvial aquifer based on grain-size analysis gives a typical mean value of 100 m/day (Diyam, 1987). Similar value (100 m/day) was obtained using pumping test analysis (Diyam, 1987). The corresponding transmissivity value average 620 m^2/day, while storage coefficient of about 5 x 10^{-4} has been measured (NEAZDP, 1990). These hydraulic parameters are very similar to those obtained by Schultz (1976). Pumping test analysis carried out using discharge rate of 0.45 m^3/min and 1.35 m^3/min give the following values for the hydraulic parameters: the transmissivity ranged from 240 m^2/day to 710 m^2/day, hydraulic conductivity range from 80 m/day to 235 m/day and storage coefficient ranged from 1.4 x 10^{-4} to 4.4 x 10^{-4} (Schultz, 1976). The aquifer has sufficient thickness of permeable strata to yield 3 l/s (Diyam, 1987).

The Upper aquifer of the Chad Formation underlies the alluvial aquifer in most places. This aquifer has a permeability of 13 m/day, transmissivity of 9 m^2/day and a storage coefficient of 6-9 x 10^{-4} (Schultz, 1976).

6.3.2 Groundwater Levels

Groundwater level in the shallow floodplain aquifer shows a wet season rise ranging from 0.5 m to 2 m (Diyam, 1987). This rise is highest close to river channels and floodplains. The amount of rise reduces with distance away from the floodplain. Water table in the Hadejia-Nguru Wetlands has decline by about 3 m over a decade (Figure 6.7), although, other reports indicate that water levels in general do not show consistent change. In the upland aquifer, there are indications that groundwater has been declining, which is likely attributable to reduced recharge due to reduced rainfall.

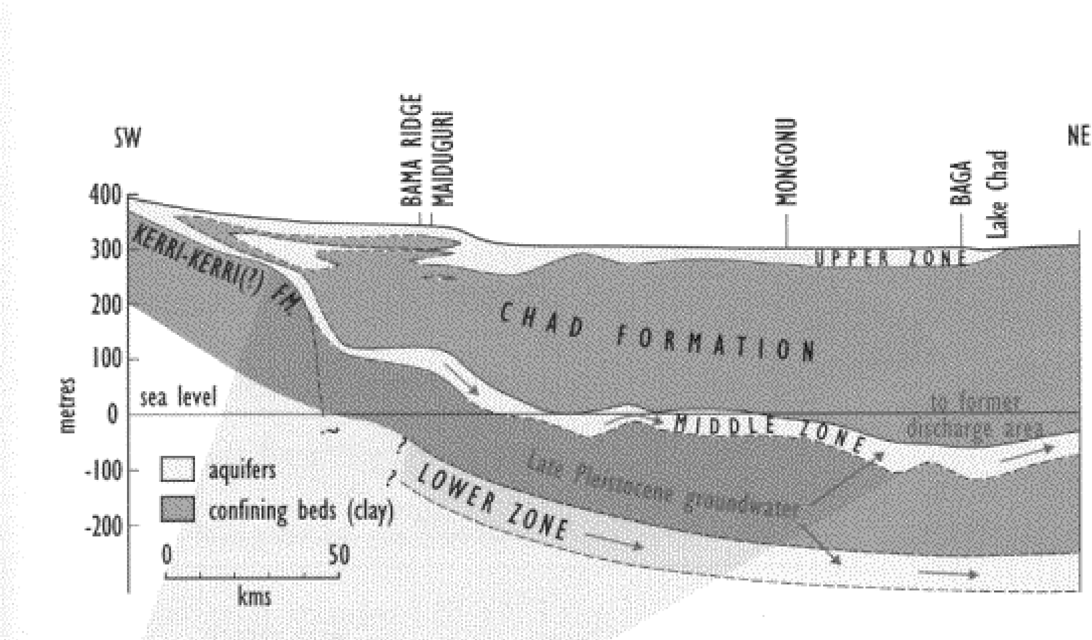


Figure 6.6: Geological cross-section of the Chad Formation with the three aquifer zones
(Source: Barber and Jones (1960))

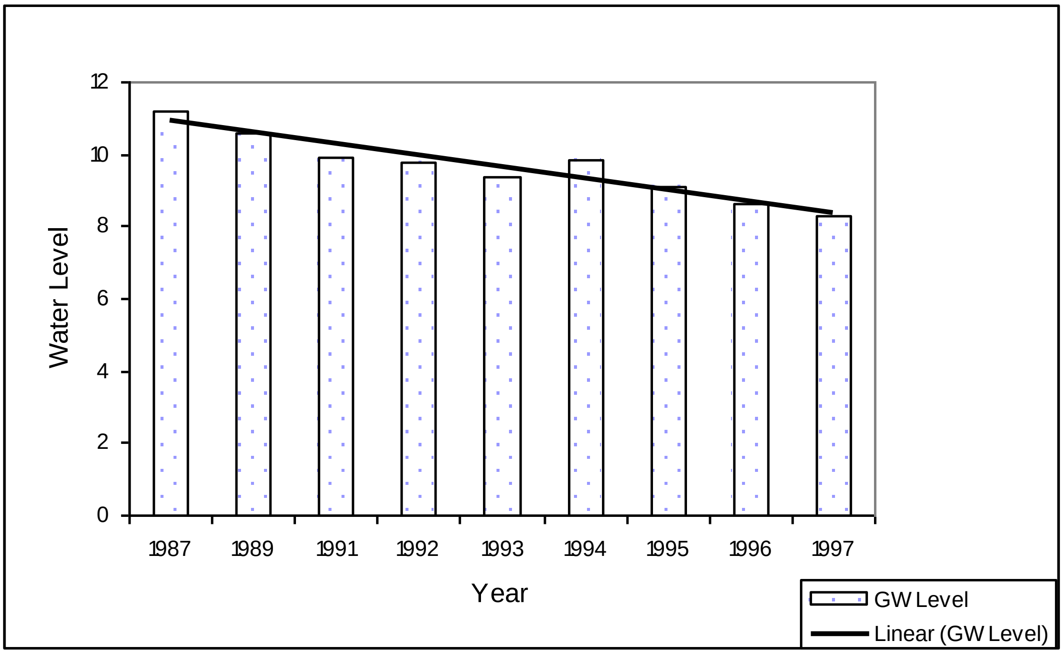


Figure 6.7: Water table change over a decade in the Hadejia-Nguru Wetlands

6.3.3 Groundwater Abstraction

The main means of groundwater abstraction of shallow aquifer are the dug wells in the uplands and washbores and tube wells in the floodplains. There is limited data/work available that give actual rates of abstraction. However, it is worth noting that the techniques used for abstraction has the effect of limiting the amount of water taken. In the case of the dug well the labour requirements, while that of the tube well or washbore is the suction limit of the pumps (about 6 m). This has the advantage of conserving existing groundwater resource. Proxy data such as population, irrigation activities, etc. have been used to estimate water demand of an area, which may not be the quantity of abstraction. This requires a lot of field data collection. Figure 6.8 shows the location of wells in the basin.

6.3.4 Recharge

Recharge to the shallow aquifer underlying the floodplains in these sub-basins could be by river channel seepage, floodwater infiltration, or direct rainwater infiltration, or combination of all three. Floodplain recharge is the major mechanism of recharge to the shallow floodplain aquifer. This extends to only 2-3 km upland, beyond which no effect of floodplain recharge. In the uplands, direct infiltration is likely to be the dominant mechanism of recharge, especially in the aeolian dune areas with unconsolidated sediments.

In the Hadejia and Hadejia-Nguru Wetlands the shallow aquifer is unconfined and high recharge via floodwater infiltration is expected. Goes (1999) has estimated recharge in this sub-basin to range between 73-197 mm.

In the Yobe sub-basin, Carter and Alkali (1996) have mentioned the presence of clay layer confining the shallow aquifer and thus recharge is dominantly by channel seepage. They estimated recharge rate of 1 mm/annum for the Yobe sub-basin (from Gashua to Yau). However, other information from drilling team indicates that the clay cover is likely to be limited and that floodwater is an important recharge source and mechanism even in the Yobe sub-basin. Hassan *et al*. (2004) have shown that water-table rise of 0.92 m and 2.4 m have been observed when the floodplain is dry and flooded respectively (Table 6.5). Therefore a higher recharge rate (not less than 50 mm) is likely to be more realistic. This is based on the similarity of the floodplain areas with the other sub-basins and similarity in behaviour of piezometers.

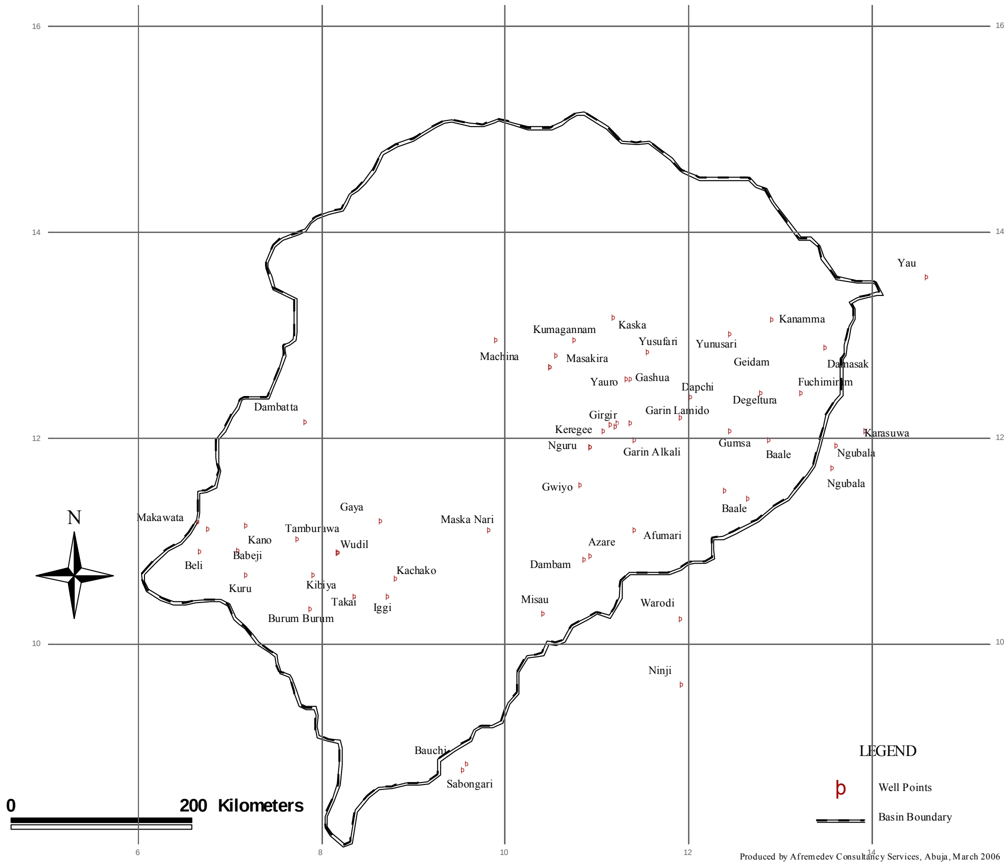


Figure 6.8: Location of wells in KYB

Overall, in the Hadejia-Nguru Wetlands an area of about 1,250 Km^2 have an estimated recharge rate of 132 mm. Yobe sub-basin with an area of about 1,150 km^2 has an estimated recharge rate of 50 mm. Jama'are sub-basin with an area of about 500 km^2 has an estimated recharge rate of 100 mm. The total recharge to the shallow aquifers in the floodplains of all the sub-basins is estimated at 250 Mm^3. Figure 6.9 shows the water levels in hand-dug wells in KYB.

Table 6.5: Groundwater response in piezometer P1 (100 m form the Yobe River)

Time	Recharge Mechanism	Rain days	River condition	State of floodplain	Total rainfall (mm)	Change in water table (m)
10 June-20 July	River	12	Flowing and gaining	Dry	173	No change
20 July-10 Aug.	River	5	Losing	Dry	82	0.92 rise
10 Aug.-10 Oct	River, rain and floodwater	11	Losing	Flooded	202	2.40 rise
10 Oct.-10 Feb.	Flood recession	1	Gaining	Dry	7	2.40 fall

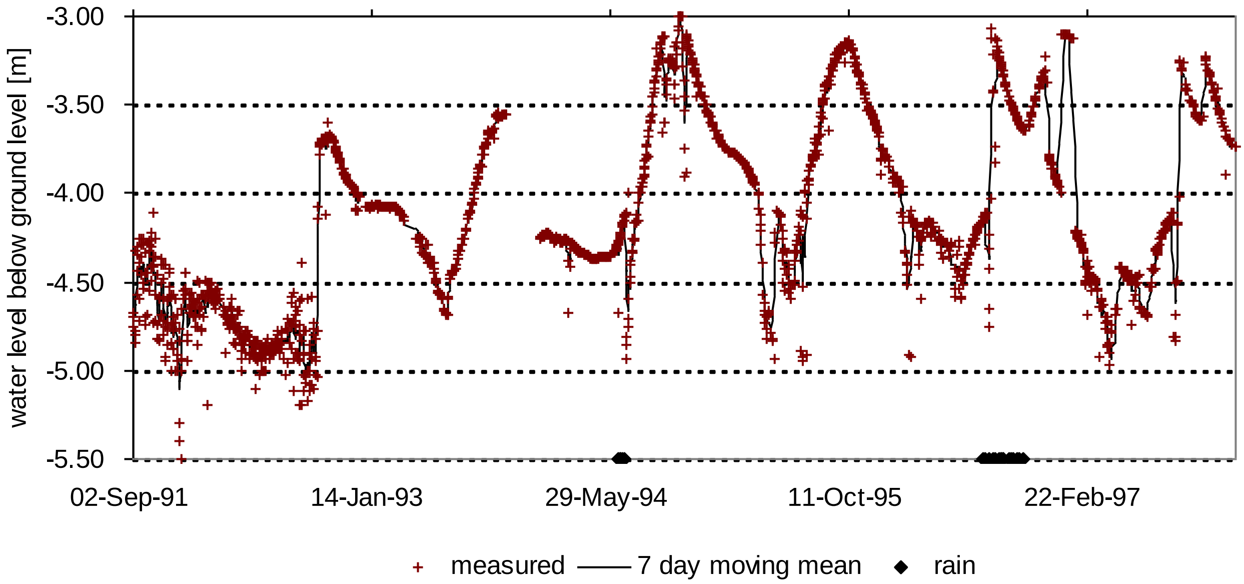
(Source: Hassan *et al*., 2004)

Recharge to the upland aquifer is dominantly by direct infiltration of rainwater and varies widely. In the aeolian dune areas with unconsolidated sediments recharge rate as high as 60 mm has been report. Whereas in areas underlain by argillaceous sediments it may be insignificant. In these areas other mechanisms of recharge may be taking place. Annual recharge rate estimated to the whole Nigerian sector of the Chad Basin is 23 mm (Goni, 2005), which using an area of 152,000 km^2 translate to about 3,500 Mm^3.

6.4 Water Quality

The result of the water quality test carried out by KYBP Office during the year 2005 and 2006 is presented in Table 6.6. Except for one small tributary on the Hadejia River, all nitrate values are above the accepted WHO limits of 10 mg/l. The rivers with the least population and the least agricultural activities, the Jama'are and the Gana Rivers, have the lowest nitrate content (20 to 30 mg/l). The Hadejia and Yobe River (at Gashua) have slightly higher nitrate content (generally ~40 mg/l). The highest nitrate contents were measured in upstream part of the Hadejia River sub-system (50-65 mg/l at Wudil, Kano-Kura Bridge, and in Challawa Gorge Reservoir) and in the main drainage canal from HVIP (70 mg/l). Upstream of Challawa Gorge Reservoir are a lot of small-scale farms. Wudil and Kano-Kura Bridge are downstream of KRIP and Kano. These results indicate that the large and small scale irrigation projects and most likely also urban waste are contributing to the deterioration of the water quality in the basin. The nitrite values are low in all the tests (<0.5 mg/l).

Level hand dug well Likori 1991 - 1997



Level hand dug well Nguru-WTC 1996-1997

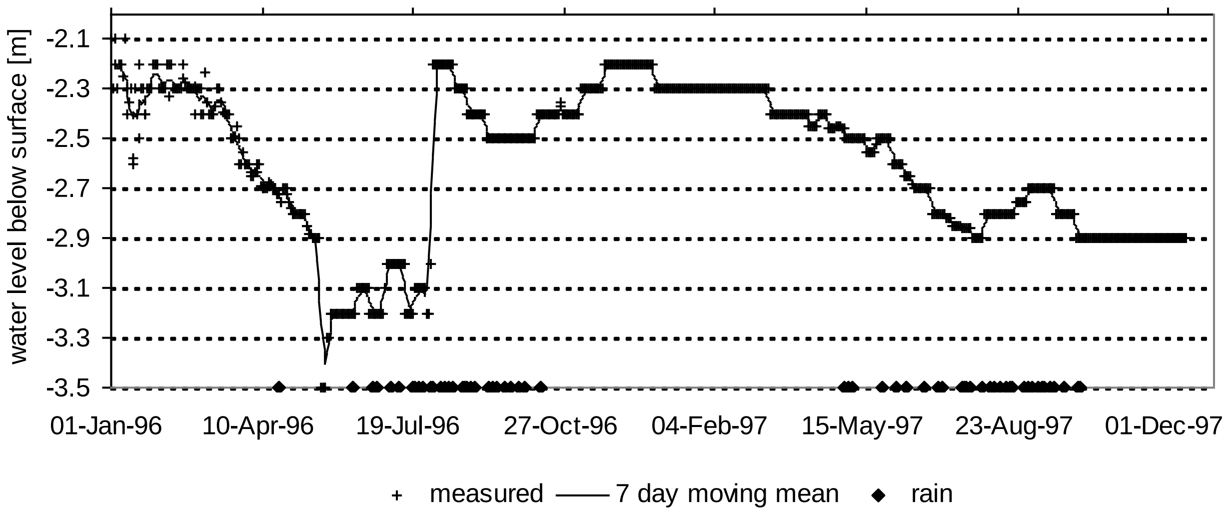


Figure 6.9: Water Levels in hand-dug wells

The Electrical Conductivity is low (<100 µS/cm and often even <50 µS/cm). In some of the samples the pH is a bit low (slightly acidic. pH=6.4). The pH value is similar as measured in the rivers by Schultz (1976). The hardness is well within the recommended limits.

Table 6.6: Water quality parameters in 2005/2006 for KYB

Water quality parameter***	Explanation	Results of field tests	Accepted limits
Electrical Conductivity (EC)**	indication for the amount of ions in the water	< 200 µS/cm	750 to 1500 µS/cm*
pH	acidity of the water, 7 is neutral	6.4 to 7	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)
Nitrate (NO_3)	indicates the presence of biological waste such as manure	10 to70	10 mg/l (WHO) 50 mg/l (EU)
Total hardness	sum of ions which can precipitate as 'hard particles'; calcium, magnesium and sometimes iron	< 90	
Carbonate ($CaCO_3$) hardness	sum of calcium ions which can precipitate as 'hard particles'; influences pH and CO_2	18 to 179	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 HS test strips

The potential sources for surface water pollution in the KYB are mainly in the Hadejia sub-basin, which has the largest irrigation projects, most industries and the most densely populated areas. The potential pollution sources are:

- Drainage water from large (KRIP and HVIP) and small-scale irrigation projects may contain insecticides and nutrients from fertilisers. Especially rice and cotton require a high dosage of fertiliser.
- Waste water discharges from urban areas. Organised sewage collection and/or wastewater treatment is virtually non-existent. The largest urban areas near the rivers are: Kano, Wudil, Ringim, Hadejia, Nguru (Hadejia River System), Gashua, Geidam, Damasak and Diffa (Yobe River). The towns along the Komadugu Gana and Jama'are River are relatively small.
- Industries, especially tanneries, textile mills and abattoirs, in Kano and other urban areas. About 70% of Nigeria's tanneries are located in Kano (World Bank, 1995). At Kano's three industrial estates industrial sludge and liquid waste are routinely deposited in open drains, sewer systems and watercourses without treatment. The waste treatment facilities that do exist are either inadequate or not functioning (Binns *et al*., 2003). The waste by-

products from tanneries have high concentrations of the heavy metals chromium and cadmium.

It should be noted that pollution of surface water with nutrients (nitrate, phosphate) is a favourable factor for the development of aquatic weeds such as *Typha*.

Ahmed (1998 cited in Doody, 2000) reported that there are concentrations of trace elements, such as copper, cadmium and iron that were higher than permissible levels for irrigation in the Hadejia River sub-system. He concluded that this was as a result of industrial discharge upstream of the river system. A 1989 study, which monitored the activities of 15 tanneries in Kano, found that in all cases permissible levels for effluent discharge were violated, with the exception of pH and temperature (World Bank, 1995). Binns *et al*. (2003) measured the surface and groundwater quality at different times at four sites in and near the Jakara River in Kano (40 samples in total). The analysis revealed extremely high (sometimes more than 100 times the WHO limits) levels of toxic waste in most of the surface water and in some of the shallow groundwater samples (e.g. Cd up 28.9 mg/l and Cr up to 49 mg/l). Although, the Jakara River does not directly drain into the Hadejia River it is not likely that the water quality of the tributaries to the Hadejia River originating from Kano will be much better. The KSWB reported that the intakes for KCWS are upstream of the drainage canals from Kano. Still, the shallow (~10 m) tubewells in the bank of the Hadejia River for the domestic water supply of Wudil are downstream of the drainage canals.

Further downstream in the Hadejia River System, Doody (2000) carried out a surface water quality survey at the end of the dry season (May/June) covering 20 sites in the Marma Channel and Nguru Lake in the HNW. The conductivity varied between 100 and 210 µ cm^{-1}. Nitrate (<2.5 mg/l) and phosphate (<1 mg/l) levels were low at all the sample sites. Arsenic (mean 0.018 mg/l, maximum 0.03 mg/l) was the only trace element recorded in concentrations higher than the WHO limit (0.01 mg/l). The most likely source was pesticides on crops or birds (*Quela quela*). The conclusion of the study was that the surveyed waters were unpolluted but that there are indicators of threats to the water quality of the wetlands from agrochemicals such as fertilizers and pesticides.

The most important factors that can cause deterioration in the groundwater quality in the basin are:

- the presence of natural minerals especially in the deeper aquifers;
- the use of fertilisers and agrochemicals for large and small scale agriculture;
- leakage due to poor sanitation and waste dumps in densely populated areas; and
- leakage from industrial waste.

A shallow groundwater quality field survey on 72 hand pump equipped wells in and around the HNW had the following worrying conclusion (Goes and Zabudum, 1998). More than half (57%) of the surveyed wells in Nguru and Gashua, and 11% of the surveyed village wells were polluted (nitrate content: 50 to over 500 mg/l, EC 600 to 3,000 µS/cm). The high nitrate concentration, which exceeds 5 to over 50 times the accepted WHO drinking water limit (10 mg/l), is a potential health hazard. The most important cause of the high nitrate levels in the surveyed wells is probably poor sanitation because, generally, the wells in densely populated areas are the most polluted. Nitrate contamination of shallow aquifers in northeast Nigeria was also observed along the Yobe River by IWACO (1985b). Out of 85 samples taken from mainly open wells in the phreatic aquifer north and south of the Yobe River, 51 samples showed nitrate level of 10 to 100 mg/l. In 7 samples values above 100 mg/l were measured. Even the eight village wells in the basin measured in 1974 showed that nitrate content varied between 7 and 374 mg/l with a mean value of 90 mg/l (Schultz, 1976). In shallow boreholes used for irrigation at the HVIP also high nitrate levels were found indicating groundwater contamination from fertilisers (Essiet and Ajayi, 1995 cited in Doody, 2000).

The water from some of the boreholes from the deeper aquifers have a high (natural) iron, sulphate and/or manganese content (Bunu, 1999; Oteze and Fayose, 1988; Maduabuchi, 2005).

6.5 Rainfall-Runoff Model

6.5.1 Basis of the Rainfall-Runoff Model

The basis of the model is a water balance between the following:

(i) Input to the catchment as rainfall

(ii) Output from the catchment as evapotranspiration loss, surface runoff and sub-surface flow.

These are summarized in the equation

$$P = E_t + Q_i + Q_s + DS \qquad \text{.............. (2)}$$

where P is rainfall, E_t is evapotranspiration loss, Q_i is Surface runoff, Q_s is subsurface flow, and DS is the change in storage (positive or negative).

6.5.2 Structure of the Model

The model is conceived as a linear combination of four storage elements identified as:

(i) Surface storage

(ii) Channel storage

(iii) Soil moisture storage

(iv) Groundwater storage

The detailed definitions and/or explanations of these elements are presented in Appendix 4.

6.5.3 Routing Procedure

At the beginning of the first interval, the potential evapotranspiration (a function of the meteorological parameters) is estimated. The loss is satisfied from the rainfall (if the rain is sufficient) or from the soil moisture storage, if the rainfall is insufficient. The amount of water that is lost as infiltration from the effective rainfall (rain less potential evapotranspiration) is evaluated depending on the state of soil moisture. A simple budget gives the amount of water left in the surface storage. The surface runoff is evaluated as a proportion of the excess surface storage over the maximum storage value the unit can hold. The subsurface flow is evaluated from the groundwater storage depending on the capillary rise and deep percolation between the soil moisture storage and groundwater storage.

The sum of the surface and subsurface flow gives the discharge at the catchment. The next data for the next time interval is used to repeat the cycle of operations.

6.5.4 The Model Parameters

The water budget model has nine parameters, and they are listed in Table 6.7. The codes used for the parameters in the computer program, and their units are also indicated.

Table 6.7: The model parameters

s/n	Parameter	Code name	Unit
1.	Threshold value of surface storage	TVSS	Metre
2.	Maximum infiltration rate	FMAX	Metre
3.	Infiltration Coefficient	HINFEL	Per unit time
4.	Channel storage constant	CHSTK	Fraction
5.	Threshold value of soil moisture storage	TVSM	Metre
6.	Maximum capillary rate	CMAX	Fraction
7.	Rate of evaporation from subsurface zone	PCUS	Fraction
8.	Groundwater storage constant	GWSC	Fraction
9.	Threshold value of Groundwater storage	TVGW	Metre

6.5.5 Parameter Optimization and Sensitivity Analysis

The parameter optimization involves inputting the values of the nine parameters, running the model and checking the goodness of fit. The parameters are modified as required, and the whole procedure is repeated. An automatic optimization technique is adopted. This involves setting a range of values for each parameter. The range of values is received by the computer interactively or obtained from the working file. A value within the range of values for each parameter is selected, the model performance R^2_{log} is found.

The search involved setting an arbitrary length for the parameters in 9–orthogonal direction. The movement in a direction is termed successful when the resulting R^2_{log} is an improvement over the previous value. The step is increased and the routing process is automatically repeated. If the movement is a failure, the arbitrary length is reduced and the routing process is repeated for the 9–orthogonal directions. The range of values of the parameters is subject to physical constraint. The behaviour of the parameters during the search for the 'best –fit' serves as the sensitivity analysis for the catchment model. Values of parameters and the model performance are printed out for assessment.

The model uses rainfall and runoff records to estimate model parameters which are subsequently used to simulate weekly runoff for different rainfall patterns.

6.5.6 Data Preparation

The available rainfall record (see Table 6.1) for each station was either summarised from daily time step into weekly rainfall or disaggregated from monthly rainfall into weekly record. Hadejia sub-basin was divided into three units in line with the current water resources development situation, while Jama'are sub-basin was considered as a unit up to the Bunga gauging station, where the proposed Kafin Zaki Dam is located.

The units within the Hadejia sub-basin are:

(a) Tiga - area contributing to Tiga Reservoir
(b) Challawa – area contributing to Challawa Gorge Reservoir
(c) Unregulated area – that is area within the Hadejia sub-basin that does not drain to the two reservoirs.

Weighted average technique was used to determine the area rainfall for each sub-unit. Table 4.8 shows the weighted coefficient adopted for the study. The rainfall-runoff relationship was established for the pre-dam period (before 1971) in the Hadejia sub-basin. The catchment's rainfall for each sub-basin is presented in Appendix 5.

Table 6.8: Weighted coefficient for catchment

Catchment	Long term rainfall record	Weighting
Bunga	Bauchi	0.4
	Jos	0.6
Challawa	Kano airport	0.25
	Kano IAR	0.25
	Samaru	0.25
	Zaria	0.25
Tiga	Kano	0.4
	Jos	0.4
	Samaru	0.2

The monthly streamflow records at Chiromawa on Kano River (1963 to 1973), Challawa Gorge (1975 to 1991) and Bunga (1964 to 1995) were presented as text file (in-disch.txt) – see Appendix 6.

Rate of evapotranspiration from the basin is dependent on relative humidity, temperature and radiation ratio. The radiation ratio for Kano was used for Hadejia sub-basin, while the record for Bauchi was used for Jama'are sub-basin. The temperature records for Kano airport, Tiga Reservoir and Kadawa within Kano Irrigation Project were collated and the average value used as mean temperature. Similar exercise was carried out for the relative humidity. The data (temperature, relative humidity and radiation ratio) were prepared as text file (tempe.txt) as presented in Appendix 7.

6.5.7 Output from the Rainfall-Runoff Model

The model was applied to Tiga and Challawa sub-units of Hadejia sub-basin and the Jama'are sub-basin. The optimum model parameters for Tiga, Challawa and Bunga area are presented in Table 6.9. The optimum model parameters for Tiga and Challawa areas were adopted for the unregulated area of the Hadejia sub-basin. The estimated average annual flow differs from the observed value by 28% in Tiga sub-unit, 10% in Challawa sub-unit and 0% in Bunga sub-unit.

Similarly the estimated annual peak flow differs from the observed value by 21%, 12% and 48% in the respective sub-unit (Table 6.10). While the model performed better in estimating average annual flow in Bunga, it performed better in estimating annual peak flow in Challawa sub-unit. For the observed series, peak flow occurred between week 30 and 39 (that is late July to late September) while estimated peak flow occurred between week 32 and 39 (that is mid-August to late September). The model performed better in estimating the time of occurrence of peak flow in Challawa sub-unit. A plot of historical and simulated flows at Tiga sub-unit is shown in Figure 6.10. The respective plots for Challawa and Bunga sub-units are shown in Figure 6.11 and Figure 6.12. The correlation coefficient of the estimated flow in Tiga sub-unit is 0.77, while that of Challawa and Bunga sub-units are 0.44 and 0.75 respectively. The model performed fairly well in Tiga and Bunga sub-units. Figure 6.13 shows the estimated inflow from the unregulated unit of the Hadejia sub-basin.

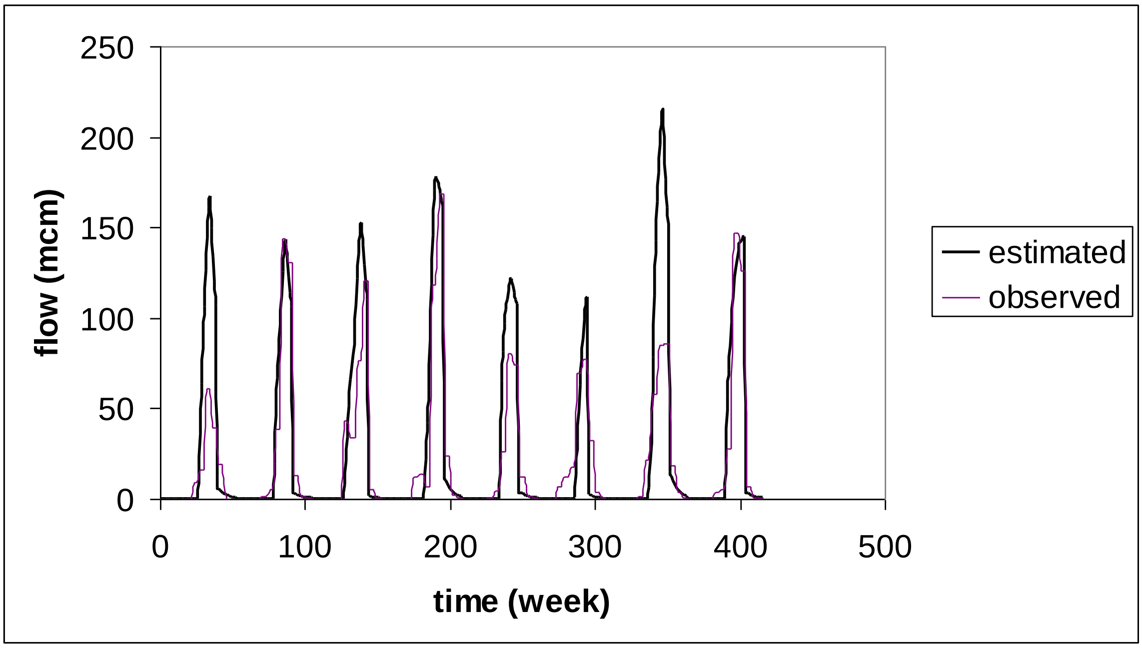
The model was not applied to Gana and Yobe sub-basins because evaporation loss in the respective basin exceeds the rainfall.

Table 6.9: Optimum parameters of rainfall-runoff model

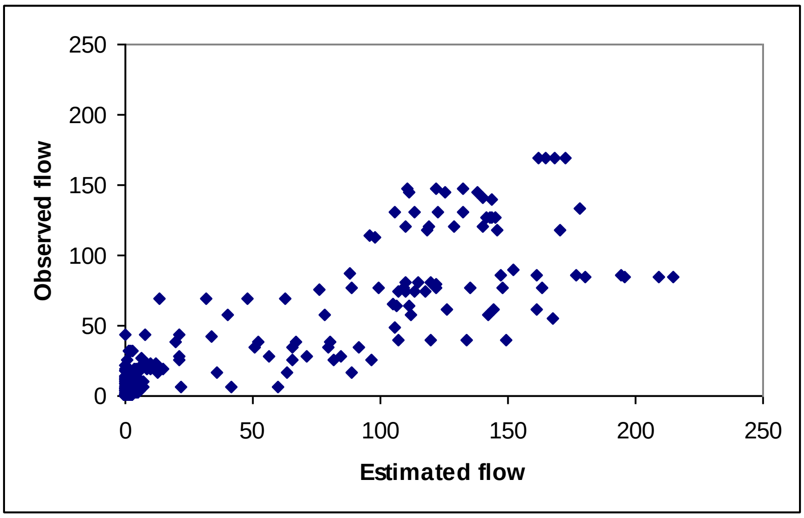
s/n	Code name	Optimum values		
		Tiga	Challawa	Bunga
1.	TVSS	0.01	0.02	0.01
2.	FMAX	0.2	0.2	0.2
3.	HINFL	0.2	0.1	0.1
4.	CHSTK	0.2	0.1	0.1
5.	TVSM	0.04	0.04	0.04
6.	CMAX	0.1	0.1	0.1
7.	PCUS	0.065	0.085	0.115
8.	GWSC	0.0115	0.085	0.075
9.	TVGW	1	1	1

Table 6.10: Summary of observed and estimated flow statistics

	Average annual flow		Annual peak flow				Period of occurrence peak	
Sub-unit or sub-basin	Observed Mm^3	Estimated Mm^3	Observed Mm^3 max	min	Estimated Mm^3		Observed (week)	Estimated (week)
Tiga	1,035	1,419	169	44	214	111	34 – 39	35 - 39
Challawa	374	339	84	14	75	5	30 – 39	32 - 39
Unregulated		559			64			35
Bunga	1,733	1,740	390	15	262	84	30 – 39	35 - 39

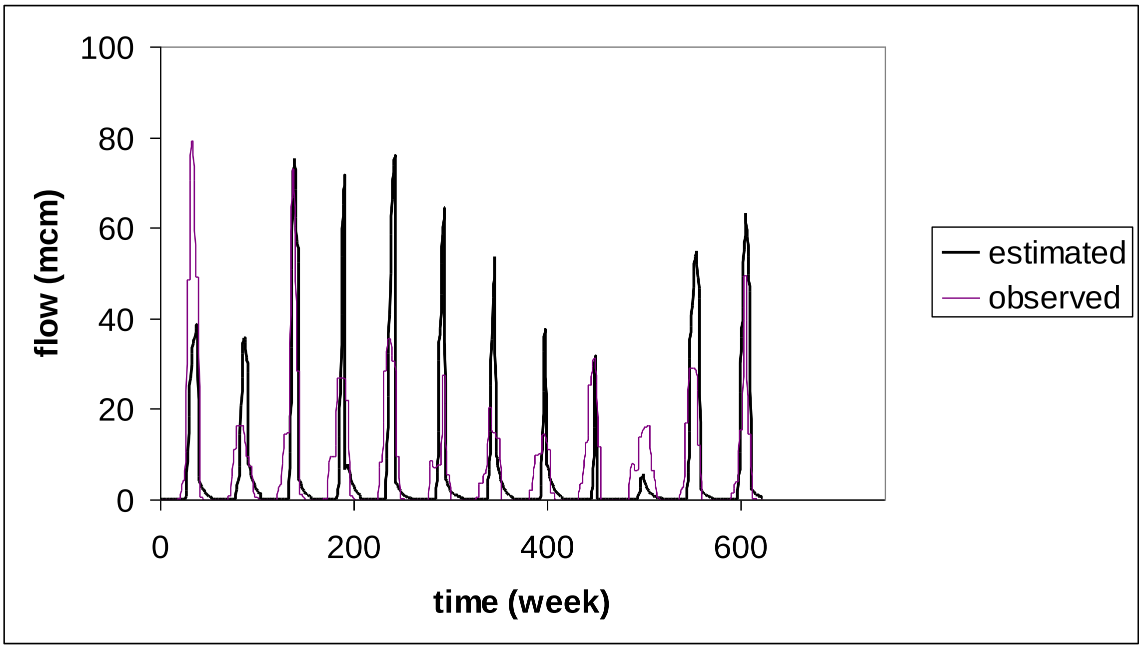


(a) Observed and estimated inflow to Tiga Reservoir

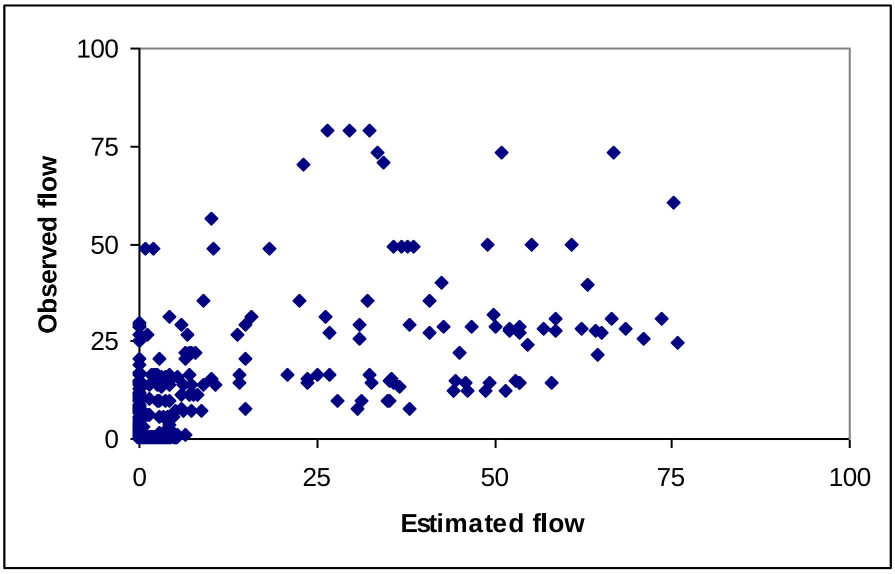


(b) Scatter diagram of observed versus estimated

Figure 6.10: Performance of rainfall-runoff model at Tiga Unit

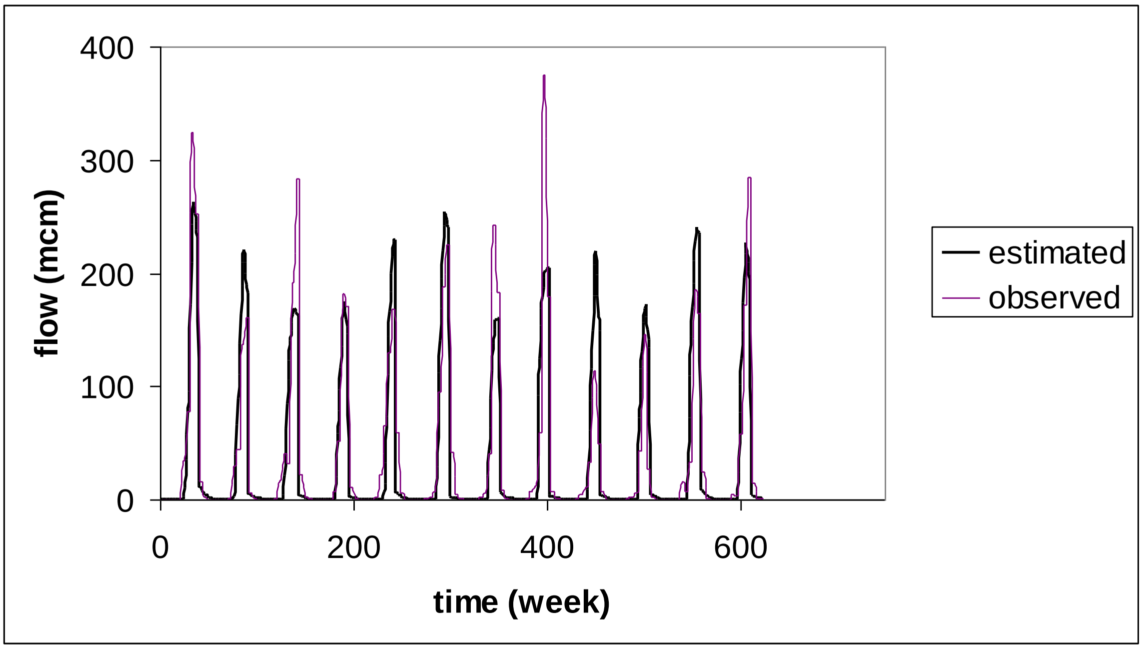


(a) Observed and estimated inflow to Challawa Gorge Reservoir

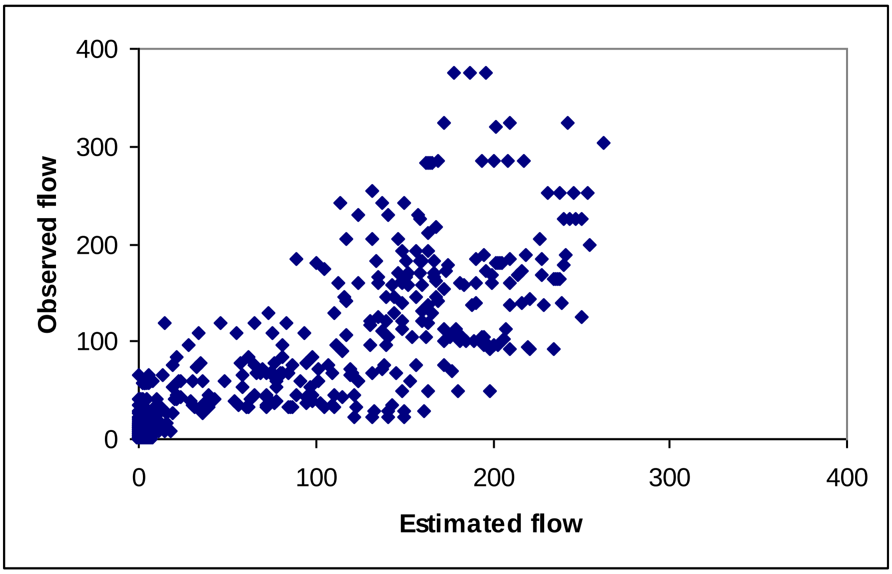


(b) Scatter diagram of observed versus estimated

Figure 6.11: Performance of rainfall-runoff model at Challawa Unit



(a) Observed and estimated flow at Bunga



(b) Scatter diagram of observed versus estimated

Figure 6.12: Observed and estimated flow at Bunga

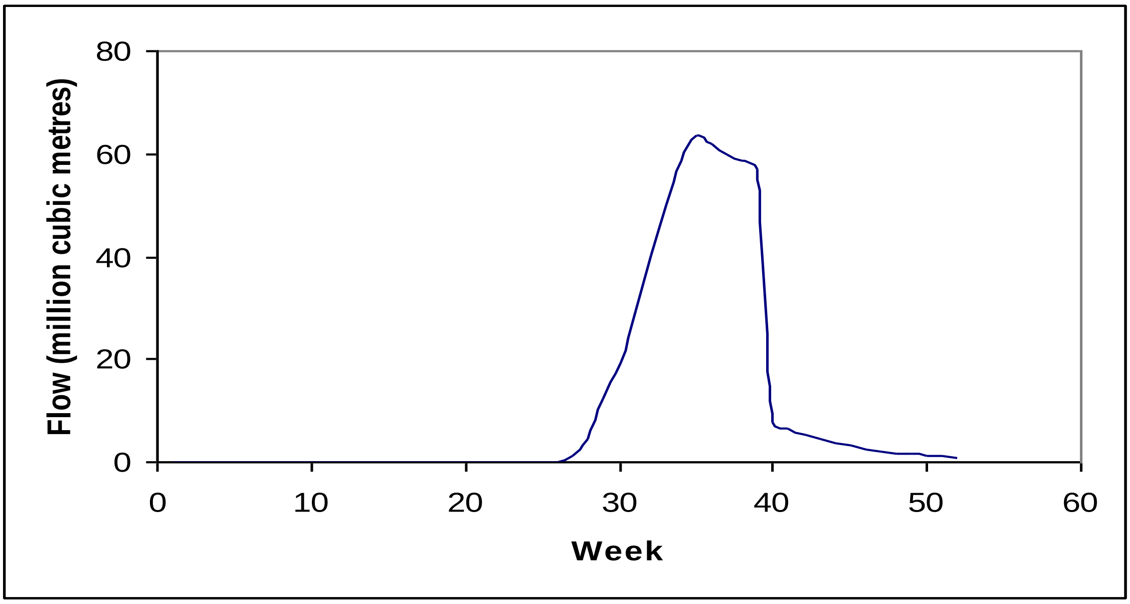


Figure 6.13: Simulated Stream Flow from Unregulated Unit of Hadejia Sub-basin

The amount of water that will be available in future is discussed based on six climatic indices as shown in Table 6.11.

Table 6.11: Climatic rainfall pattern

Climatic pattern	Rainfall Index
Prolonged dry climatic year	Less than -3.0
Very dry climatic year	-2.0 to -2.99
Dry climatic year	-1.99 to -1.0
Normal climatic year	-0.99 to 0.99
Wet climatic year	1.0 to 2.0
Very wet climatic year	Greater than 2.0

Available surface water during the six climatic patterns is summarized below in Table 6.12. The estimate is based on the contributions from Hadejia and Jama'are sub-basins. The table shows that available surface water during a prolonged dry season could be as low as 51% of the long-term mean of available surface water. The implication of this is that water management option that is based on long-term mean will fail to meet water demand of the basin, especially the tail end of the basin. In addition, the analysis shows that available water in KYB during a wet season will be 40% above long-term mean. This could result in flooding of floodplains. It was observed that available surface water in a very wet year is less than that of a wet year. An appraisal of rainfall record in the Hadejia and Jama'are basins shows that the difference in annual rainfall of wet and very years is that very wet year has high early rainfall (Figure 6.14), and the early rain does not result in runoff because of dry soil condition. This finding suggests that groundwater recharge during this season (early rainfall period) will be dependent on climatic pattern. This result highlights the importance of appropriate water management plan for the basin.

Table 6.12: Available surface water resources in KYB

Climatic pattern	Available water resources Mm^3
Prolonged dry climatic year	2,609
Very dry climatic year	2,609
Dry climatic year	3,660
Normal climatic year	4,292
Wet climatic year	5,845
Very wet climatic year	5,785

*estimate based on Hadejia and Jama'are sub-basins

The contribution of the units (Tiga, Challawa Gorge and unregulated) of Hadejia sub-basin as well as that of Jama'are sub-basin is summarised below in Table 6.13. The table shows that Hadejia sub-basin contributes 60% (30% from Tiga area, 20% from Challawa Gorge area and 10% from unregulated area) of the surface water resources, while Jama'are sub-basin contributes 40%. The amount of water contributed by each sub-basin varies with climatic scenario. The proportion of water contributed by each sub-basin varies slightly with climatic scenario. This is because the influence of Sahelian drought is much pronounced in upper Hadejia than the Plateau area of Jama'are sub-basin.

Table 6.13: Summary of Annual Surface Water Resources in KYB

Climatic Pattern	Normal		Wet		Extra wet		Dry		Extra dry	
	Annual	Ratio	Annual	Ratio	Annual	Ratio	Annual	Ratio	Annual	Ratio
Tiga Unit	1,343.28	0.31	1,711.37	0.29	1,753.81	0.30	1,307.31	0.36	1,040.10	0.40
Challawa Unit	651.52	0.15	907.32	0.16	851.26	0.15	429.60	0.12	150.86	0.06
Unregulated Unit	558.74	0.13	773.37	0.13	726.48	0.13	378.52	0.10	130.11	0.05
Jama'are Sub-basin	1,738.23	0.41	2,453.25	0.42	2,453.25	0.42	1,544.32	0.42	1,287.84	0.49
Total	4,291.77	1.00	5,845.31	1.00	5,784.80	1.00	3,659.75	1.00	2,608.91	1.00

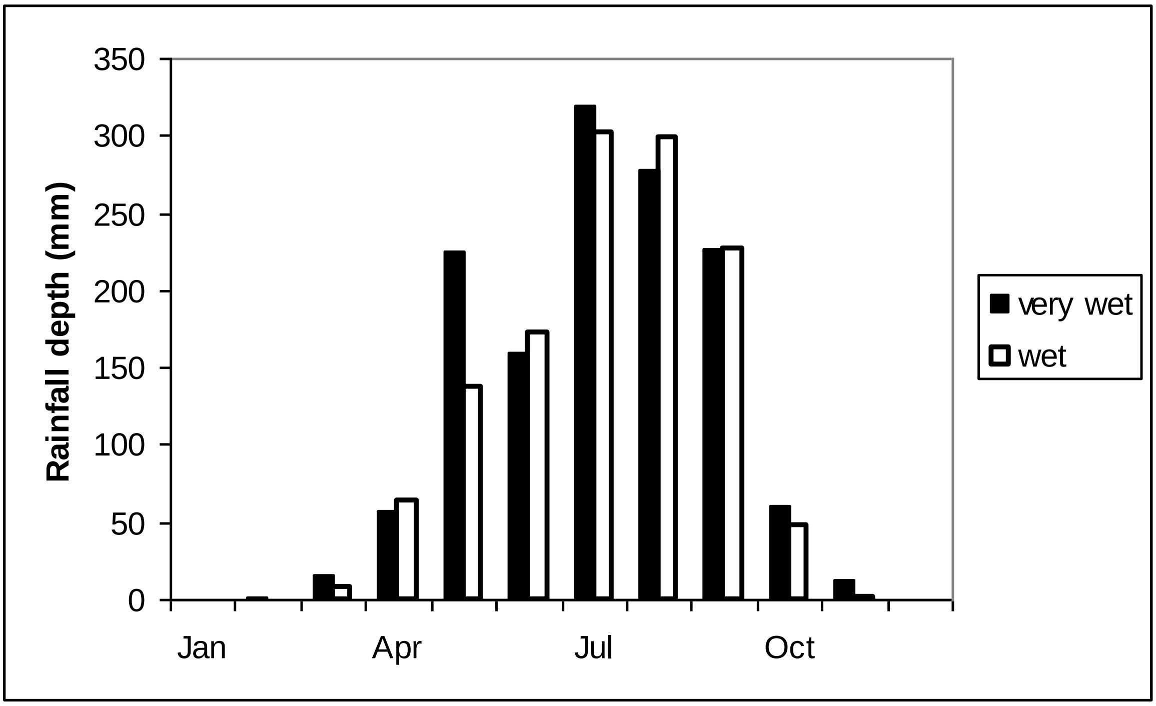


Figure 6.14: Monthly Rainfall in Tiga Catchment Unit

6.6 Water Resources Infrastructure

Most of the water resources infrastructures in the basin suffer from a massive backlog of neglected maintenance. Periodic and routine maintenance, by far the most cost-effective form of infrastructure expenditure is almost nil. Instead, the norm is to wait for an infusion of capital for rehabilitation. In effect, it has become more convenient to replace than to maintain. But declining financial resources is making this less and less feasible. As a result, deterioration is setting. If the infrastructures were to be refurbished, then operated and maintained properly, most of the problems of the basin will disappear. This is of course in addition to the needed new structures. The few addressed below are selected because their problems are most severe and if addressed will have an immediate impact on the economic and social development of the basin.

Major water users in the basin are Kano City Water Supply (KCWS), Kano River Irrigation Project (KRIP), Hadejia Valley Irrigation Project (HVIP), and farmers and pastoralists in the Hadejia-Nguru Wetlands. Before evaluating the infrastructures of these four major users, let us first examine the infrastructures of the two reservoirs of Tiga and Challawa Gorge which store and supply all the water used in the basin.

The annual yield of Tiga and Challawa Gorge reservoirs is 997 Mm^3. The principal operational requirements of the two reservoirs are to store the rainy season inflows and to provide regulated releases to meet downstream requirements in both the dry and wet season.

6.6.1 Tiga Dam

Tiga Dam is situated about 60 km south west of the city of Kano in Kano state at approximately 8°24′ East and 11°28′ North. The dam is owned and operated by Hadejia-Jama'are River Basin Development Agency (HJRBDA). The HJRBDA is responsible to the Federal Ministry of Water Resources (FMWR) which is the apex organ of the Federal Government of Nigeria in charge of water resources.

The dam was built between 1971 and 1974 and impounds the water of River Kano, about 40 km upstream of its confluence with River Challawa. The resulting reservoir originally had a surface area of about 189 km^2 with a total storage capacity of 1,974 Mm^3. However, in 1988, the top water level was reduced from 527.3 m to 523.7 m. The reservoir, currently, has a surface area of about 140 km^2 with a total storage capacity of 1,345 Mm^3 Water for use by Kano River Irrigation Project (KRIP) is released into a conveyance canal while water for other uses is released into the river for subsequent abstraction. The reservoir storage is so large in relation to the river flows that even with a reduced storage capacity, the dam only spills once every two or three years. Hence, the possibility of restoring the design top water level or even significantly raising the current level is not an option to be considered for improving the water resources of the basin. This is because the concerns regarding the integrity of the embankment, which led to the reduction in the first place, still remain. Furthermore, the reservoir presents a high hazard in terms of the consequences should failure occur. This was the conclusion of dam break analysis done by ACS in 1998. Extensive damage and significant loss of life is expected. The population downstream is dense.

Tiga Dam impounds most of the Kano River sub-basin, having a catchment area of about 6,550 km^2. The mean annual rainfall, which occurs between May and October, varies from about 1,240 mm in the headwater area to about 1,050 mm at the dam site.

The dam is an embankment structure about 6 km long. The dam has a maximum height of about 48 m above the lowest foundation level and the volume of fill is about 12 Mm^3. The crest of the dam has a nominal level of 530.96 m. It is about 12 m wide and carries an unsurfaced access road. The upstream face has a nominal slope of 1 in 3 (i.e. 1 vertical to 3 horizontal) and is protected by a layer of rip-rap underlain by filter layers. The downstream face is grassed and has a nominal slope of 1 in 2.5. Some features of the dam are outlined hereunder.

(a) *History of maintenance:* The post-construction events could be summarised as follows:

- The downstream face of some sections of the embankment was reported to have visibly deteriorated within three years of completion, and the first safety evaluation was carried out in 1978 by Haskoning. This highlighted several design and construction inadequacies and Haskoning recommended certain remedial measures, including lowering the top water level. Not many of these were carried out.
- In 1986, Engr. Umolu and Dr. Okoye of the Nigeria Sub-committee on dams and in 1987, the U.S. Bureau of Reclamation both expressed

concern for the safety of the dam. The top water level was subsequently lowered by 4 m to 523.7 m in 1988.

- In 1989/90, Babtie was commissioned by ODA to implement short-term remedial measures aimed at improving the drainage of the downstream toe. Also Babtie instigated a dam monitoring programme and dam safety training for the staff of HJRBDA.
- In 1988, Afremedev also undertook a dam safety review of the dam for the now defunct PTF. In its recommendations as to measures to be taken in the interests of safety, it gave sixteen-point measures to be taken. Some have been implemented while some are outstanding. The outstanding ones include the following:
  - i) Installation of upstream controls for the left side and river diversion outlets.
  - ii) Removal of the over steepening of the downstream face at Ch 3+500 m by infilling the access track with well compacted graded rockfill.
  - iii) Analyse the orange brown seepage in to the access gallery to determine its origin.
  - iv) Improve the monitoring system should be implemented immediately.

(b) *Instrumentation*: A series of observation and relief wells were installed at the time of construction. They are functioning satisfactorily and measurements are taken according to the dam operations manual. The maximum capacity of the main outlet is 43 m^3/s at the current top water level. However, its ability to sustain releases in excess of 25 m^3/s without damaging the canal is questionable. Similarly, the maximum capacity of the left side outlet is 3.75 m^3/s while that of the diversion outlet is about 5.25 m^3/s. Assuming no inflows to the reservoir and all outlets fully opened, it would take 95 days to lower the reservoir by 3 m from the top water level. The combined discharge capacity of the outlets is therefore of little use to lower the reservoir in an emergency and of no value in controlling water levels during floods. Thus, interventions are required urgently in this regard.

(c) *Operation and Maintenance:* The operation and maintenance manual should be updated after all interventions are implemented. What is urgently needed is reservoir release rules.

Plate 3: Siltation and *Typha* Invasion of Ruwan Kanya Reservoir

6.6.2 Challawa Gorge Dam

This reservoir is situated about 60 km south west of Kano City, in Kano state, at approximately 11°44′ North and 8°02′ East. The reservoir is owned and operated by Hadejia Jama'are River Basin Development Authority (HJRBDA).

The dam impounds River Challawa which was closed in 1992. The resulting reservoir has a surface area of about 100 km^2 and a total storage capacity of 930 Mm^3 at top water level of 523.76 m. Water from the reservoir is released into the Challawa River for subsequent diversions from an outlet structure located on the left bank of the gorge. Releases from Tiga Dam and from Challawa Gorge Dam converge at Tamburawa and flow down to the Hadejia–Nguru Wetlands.

The dam has a catchment area of about 3,859 km^2. The mean annual rainfall which occurs between May and October is about 910 mm. The dam is an earth fill embankment structure about 7.8 km long with a 600 m free-overflow spillway. It has a maximum height of 42 m at the river gorge and it is penetrated by two outlet conduits. The crest of the dam is about 10 m wide and carries a stone surfaced access road. The upstream embankment face has a slope of 1 (vertically) to 3.5 (horizontally) and is protected by a layer of hand placed granite rip-rap underlain by a filter layer. The downstream face has a slope of 1 (vertical) to 2.5 (horizontal) and is protected by a layer of coble-sized stones underlain by a filter layer. Its history of maintenance and instrumentation are outlined hereunder.

(a) H*istory of maintenance:* There are no known modifications to the structure since its final completion in 1992 nor has any remedial works been required in terms of dam safety. The dam has had an apparently normal history and there are no records of any events exceeding design assumptions.

(b) *Instrumentation:* A series of surface movement monuments to monitor the vertical and horizontal movement of the embankment surface were installed. Five inclinometers/vertical extensometers to monitor the vertical and horizontal movements of the embankment have also been installed. A total of 84 stand pipe and 10 pneumatic piezometers to monitor pore water pressure and the phreatic surface within the embankment are also in place. Reservoir levels can be recorded manually by a staff gauge on the draw-off tower as well as automatically by a chart recorder. All measurable data are collected and recorded as per the O&M manual.

6.6.3 Kano City Water Supply

Water for domestic and industrial uses of Kano City is supplied by Kano State Water Board. The total estimated current demand of Kano City is 222 Mm^3/year but the infrastructures on the ground can only supply 124 Mm^3/year. Thus, about half of the city lives permanently without water. But the situation is worse than that because a lot of the time the operational capacity is less, with only half of the pumps working at times. Table 6.14 shows the capacities of the intake structures for Kano City Water Supply (KCWS).

Another problem with the KCWS is that all three of the water intakes on Kano River as well as the single intake on Challawa River suffer from the same problem of abstracting from shallow and meandering rivers where there is no control of water levels other than that induced by the quantity of flow. Under this configuration, the intakes are incapable of abstracting more than 5% of the flows being released from the dams. The remaining 95% is not all wasted, of course. Some of it is used by other users downstream. But an estimated 137 Mm^3, representing 14% of the total annual average yield of Tiga and Challawa Gorge dams, is wasted. This excess water is causing a lot of damage at Marma Channel and Nguru lakes. There is already a need to increase the capacity of the intakes five fold. The waste and damage shall increase correspondingly (D. F. Neville Jerry 2005).

Interventions are urgently required to remove this constraint of over–releasing water. First, the over-release is causing a wasteful depletion of an already inadequate reserve. Secondly, it is maintaining a detrimental dry season flooding at the middle reaches of the basin with its attendant consequences. Some of the consequences are *Typha* growth with its own several consequences, the loss of fadama cultivation, the loss of the recession cultivation cycle and of the valuable grazing lands which the flood recession use to provide are a few of the consequences of *Typha* growth. These dry season releases also, in addition to their significant depletion of a limited resource, increase the chances of the dams' failure to meet their supply commitments especially in not releasing wet season flows to the wetlands downstream to maintain their livelihoods. The future of IWRM in KYB is very bleak without lasting solution to these unnecessary releases.

Table 6.14: Raw Water Intake Stations at both Kano and Challawa Rivers

Number	Intake No.	Location – river	Type of Intake	No of pumps	Capacities (10^{-3} m^3/s)	Total Capacity (10^{-3} m^3/s)
1	6	Challawa	Surface	6	200	800
2	7	Kano	Groundwater	7	22	154
3	8	Kano	Surface	4	45	180
4	9	Kano	Surface	4	45	180
5	11	Kano	Surface	4	50	200
			Surface	2	90	180
			Groundwater	27	22	594
6	12	Kano	Groundwater	30	16	480
7	Tamburawa	Challawa	Groundwater	30	14	420
8	Wudil	Challawa	Groundwater	30	14	420
9	Joda	Challawa	Groundwater	15	22	330
					Total surface capacity	1,540
					Total groundwater capacity	2,398
					Combined total capacity	3,938

Surface: directly from the river
Groundwater: from tubewells in the floodplain alluvials.

The distribution system in Kano City also is in extremely poor condition with approximately half the system not receiving water. Unaccounted for water is estimated to be well in excess of 60% of total production. The system is plagued by many problems. Some of these problems are:

i. Old-ageing equipments at both the raw-water sources and within the treatment plants. Most of the raw-water and high lift pumps have outlived their design useful ages. Most of their rotating parts have worn-out.
ii. Undersized water-mains that were laid several years ago when the demand was very low.
iii. Blocked water mains which were laid over fifty years ago. All the iron pipes have blocked as a result of rust, sediments, etc., and coupled with low pressure such that very little quantity of water passes through.
iv. Uncontrolled population growth as a result of rural-urban migration.
v. The reticulation system has become quite inadequate. Most of the illegal layouts within the periphery of Kano metropolitan area have no

reticulation system. Very small diameter pipes are illegally laid for a very long distance which yields no result but serious leakages.

vi. Expansion in both commercial and industrial activities, especially the sudden springing up of industries, like the tanneries and other 'wet' industries e.g. the bottling companies, textile industries, etc.

vii. Insufficient number of treatment plants to cater for the corresponding increase in demand.

Financial and Institutional position of the Water Board: The Board, despite its numerous problems both financial and institutional, is able to maintain a 'reasonable' level of supply. So many problems are militating against the smooth running of the Board. For example:

- The high cost of treatment chemicals. The Board spends over One Hundred and Thirty Million Naira (₦ 130 Million) per annum on chemicals alone.
- The National Electric Power Authority (NEPA) bills are over ₦ 6 Million per month. The Board owes NEPA over ₦ 90 Million.
- Payment of staff salaries and allowances, which was until February 1996, has not been paid by the Government.
- Procurement of other chemicals apart from Aluminium Sulphate (Alum), the only form of subsidy from the Government is the procurement and supply of Alum to the Board.
- Illegal water consumers: In many remote areas of the metropolitan area, some people construct underground tanks illegally and sell water. This has a bearing on the revenue generation and even the hydraulics.
- Illegal connections: There are quite a number of connections that are not on the record of the water Board. This happens to be more rampant in the city where one connection is legally registered and is extended to more than five families.
- Unaccounted for water.
- Lack of metering: A lot of consumers are charged on flat rate.
- Inadequate billing and collection system.

New infrastructures required for KCWS are:

(1) A permanent concrete pump station in addition to dredging the river to give a wider, smoother waterway from the river to the intake number 8 and 9 and to the lagoon at intake number 11.

(2) A check weir with stop log control which is a permanent hard concrete structure to form a fixed base on the river bed on which timber stop logs would be placed, spanning between piers during the dry season, in order to control the level of the water upstream.

The benefits of these simple interventions to KCWS and to the performance of the two upstream dams shall be tremendous.

Plate 4: Diversion Structure for KCWS Intake No. 11

6.6.4 Kano River Irrigation Project

The Kano River Irrigation Project (KRIP) is situated in Kano State. KRIP was intended to cover the development of a total of 62,000 hectares in two phases.

KRIP phase 1 was originally planned to command 21,850 hectares net of which approximately 20,230 hectares were to be under gravity-fed surface irrigation and 1,620 hectares under sprinkler. Construction began in 1977 but stopped after only 13,286 hectares were brought under irrigation command due to financial constraints. At present, construction is going on for the completion of phase 1.

The irrigated area is served by a total of nine night storage reservoirs for day time irrigation only. The main and branch canals are concrete lined, generally with precast concrete slabs. The infrastructures of the irrigation project are in need of rehabilitation. The now defunct PTF gave the scheme a partial rehabilitation. But what the project needs is a complete overhaul of the infrastructure side by side with an overhaul of the management and Water Users Association.

Plate 5: Kadawa Sector Turnout with missing metal shutters

6.6.5 Hadejia Valley Irrigation Project

Hadejia Valley Irrigation Project (HVIP) is situated in Jigawa State. It is intended to cover the development of 12,500 hectares in two phases. Phase 1 of the Project (HVIP phase 1) is planned to command 7,013 hectares gross of which 3,000 hectares is complete and is being commanded. Balance of 4,013 hectares as stage II of phase 1 is under construction. The project falls under the control of Hadejia Jama'are River Basin Development Authority (HJRBDA) which has its headquarters in Kano. The authority manages the project through a resident project management team stationed in Hadejia Project Office. The Project Team is responsible for water supply to field edge and maintenance of major infrastructures.

The water released from Tiga and Challawa Gorge dams into Hadejia River flows into a barrage at Hadejia. The release to HVIP is controlled at the barrage. Main features of the project are its headworks, feeder canals, main canals, distributary canals, field channels, drainage system, and road network.

Most of the structures of this project are in good condition except siltation in conveyance canals and erosion of their earthen embankments. The canals are clay-lined which makes it mandatory to keep water in the canal so that the clay material does not crack.

6.6.6 Additional Infrastructures Required

Besides the additional infrastructures needed at KCWS intakes, additional structures are required for apportioning the already overstretched water resources of the basin among the various competing users. These structures are at Miga for the Kafin Hausa bifurcation and at Likori for apportioning flows to the channels of the Marma which supplies Nguru lakes, the Burum Gana and to the lower reaches of Hadejia River.

Since the construction of Tiga and Challawa Gorge dams, the lowland catchment of River Hadejia around the Hadejia–Nguru Wetlands has experienced a much changed hydrological regime. The characteristics of this have been a reduced wet season flood flow which has deprived much of the wetlands of their annual inundation, followed by the introduction of flows in the dry season which have prevented some of the former low-lying lands from experiencing their former annual drying out cycle.

This is in addition to the increased utilization of the water resources in meeting the ever expanding demands of the KCWS, KRIP and HVIP. Of course, the two dams were built for that purpose. With the potential for increase in these demands, the resources need to be wisely apportioned. Hence, the need for the new structures as alluded before.

There have also been some regime changes to the river pattern in the wetlands area, with the three main river bifurcation of Marma, Burum Gana and Hadejia River tending to favour their northern oriented channels, thereby reducing flows in their eastern oriented channels.

Plate 6: Blockage of Water Course resulting in flooding of Hadejia-Nguru Road

The increased proportion of the flows to the Marma channel and Nguru lakes has induced much of the former seasonally flooded wetlands along the Marma to become perennially flooded, thereby adversely affecting the traditional pattern of land use. This was of wet season flood rice cultivation followed by cultivation of dry season crops on the residual moisture from the flood recession. The flood recession also provided extensive areas of dry season pasture. The perennial inundation has also encouraged the spread of *Typha* grass which not only competes with rice but also adversely affects the former fishery activities as well as impeding flow in the water courses. Conversely, the more easterly oriented Burum Gana channel, at the Likori bifurcation, has become progressively more deprived of wet season flows (D. F. Jerry Neville 2003).

A similar pattern of flow division occurs at the upstream of the Hadejia and Burum Gana rivers where the flow has tended to favour the more northerly oriented Burum Gana River, leaving the Hadejia River virtually dry. At the bifurcation of Hadejia and Kafin Hausa rivers, the pattern is repeated.

These complex series of changes have severely and adversely affected the livelihood of the wetlands dwellers. Majority have been deprived of their water supply while some have been subjected to an excess of water. Hence the need to have these flow proportioning structures to address the perversity. But for the structures to be effective, deliberate supplementary releases are required from Tiga and Challawa Gorge dams. Also, an Environmental Management Plan would also be required to ensure the future beneficial use of the flow control facility.

If constructed, the structures will permit the reclamation of some 13,500 hectares of land around Marma and Nguru lakes. About 5,100 hectares shall benefit from the reclamation through irrigation along the Burum Gana channel while the potential benefit along Old Hadejia River is in the range of 20,000 hectares.

Diyam (1999) proposed one alternative and ITAD also commissioned DF Jerry Neville who designed other options. The NEAZDP Irrigation Report (1991) also proposed two alternatives. Whichever alternative is finally adopted, it should be packaged to include guaranteed O&M for the sake of sustainability.

Tiga and Challawa Gorge dams provide a degree of flood control in the basin, but since only 64% of the catchment drains through these reservoirs, flood flows through the remaining 36% of the catchment can be devastating. The 1988 and the 2001 floods are a case in point. Therefore, for the purposes of flood mitigation in the basin, the following suggestions are made:

- First, it is recommended that dam break studies be carried out for all the dams in the basin.
- Secondly, flood forecasting and warning systems are needed in the basin.
- Finally, local flood defence embankments, flood refuges and safe havens are required to protect lives and property. The 2001 floods claimed 200 lives and property.

6.7 Environmental Flow Requirements

6.7.1 The Komadugu Yobe Basin

The Komadugu Yobe basin, which is formed by the Hadejia-Jama'are-Yobe systems, covers a distance of 439 km and has a catchment area of about 148,000 km^2. The river, which begins west of Gashua, drains in a northeasterly direction into the Lake Chad. Komadugu Yobe used to contribute about 1% of the total flows in Lake Chad.

The Hadejia system is historically known to contribute about 40% of the total flows in the Komadugu Yobe system. The Hadejia River receives its water from Kano, Challawa and Watari rivers upstream. It loses much of its water to the series of swamps and lakes before it joins the Yobe system at the confluence upstream of Gashua.

The Jama'are River on the other hand contributes about 50% of the historic flow in Komadugu Yobe system. The river collects its water from the rivers originating on the Jos Plateau, the most important among which is the Delimi River. The

Jama'are system has fairly well defined channel up to Katagum. However, downstream of Katagum it divides into many rivers and lakes typical of which are the Kafin Hausa and Jama'are rivers. The losses in the system are mainly to groundwater.

The entire Komadugu Yobe Basin falls downstream of the Hadejia-Jama'are River sub-basin. The numerous dams constructed from the early 1970's such as the Tiga Dam on the Kano River and Challawa Gorge Dam on the Challawa River were all sited upstream of the Komadugu Yobe system. These may have detrimental effects on the downstream flows and environmental water requirements.

6.7.2 The Downstream River Flows

It has been noted that the desire for dam construction in the 1970's pursued with the expectation of storing enough runoff for irrigation upstream and at the same time achieving normal flows downstream had overlooked many salient scenarios. The construction of the Tiga Dam on Kano River, Challawa Gorge Dam on Challawa River and Watari Dam on Watari River has negatively affected the flows of the Hadejia River. These abstractions have drastically reduced the ratio of the inflow into the Komadugu Yobe system to less than 25% compared to the pre-dam ratio of 40%. The situation would have been worse had the proposed Kafin Zaki Dam was constructed on the Jama'are River as it may result in zero flow at Gashua. This fact makes one appreciate the fears of the communities downstream. The situation therefore makes it clear that the bulk of the present day flows in the Komadugu Yobe system comes from the Jama'are River and tributaries.

A number of Technical Reports on the downstream flow characteristics of Komadugu Yobe system at Gashua indicate decline in flows since the completion of Tiga Dam in 1976. Schultz (1976) had earlier warned that Tiga Dam could reduce annual flows at Gashua by up to 373 Mm^3, Diyam (1987) gave an estimated reduction of flow at Gashua to the tune of 150 Mm^3 per annum, while IWACO (1985) estimated a post-dam reduction in flow of 56 Mm^3 per annum.

The estimated declines in flow attributed to the Tiga Dam construction compound the losses resulting from irrigation. It is worth noting that irrigation agriculture is boosted by the need to feed the teeming population in recent years. In the floodplains of the Hadejia-Jama'are a reduction in flooded area ranged from 2,000 km^2 to 9,000 km^2 depending on the year. Adams and Hollis (1988) reported that the decline in flows has reduced the total volume of water infiltrating the plain to recharge the groundwater by 5 Mm^3. This situation would no doubt have negative effects on the water supply of many villages, which depend, on regional aquifer to cover domestic and agricultural needs.

6.7.3 Downstream Socio-Economic Activities and Water Requirements

The Komadugu Yobe Basin provides vital resources for a multitude of users including local farmers, transhumant pastoralists, fishermen and wildlife. The Komadugu Yobe Basin at first sight seems sparsely populated and relatively under exploited. However, a closer look reveals that several thousands of people are dependent on it for their survival. They use the natural resources made available by the water bodies and seasonal flooding in a variety of ways. The specific uses include domestic requirements, agriculture (in form of formal and small-scale irrigation) especially rice and vegetable cultivation, livestock, forestry, fisheries, groundwater recharge and other ecological uses.

Unfortunately, it has been noted in recent years that the floodplain of the Komadugu Yobe Basin is under threat from periodic droughts combined with the abstractions by the dams. Inefficient water management practices especially at the upstream catchments have also reduced the flow of water thereby frustrating the economic and ecological characteristics of the basin.

Domestic Water Requirements depends on the nature and characteristics of the population in the area. The rural nature of the bulk of the population in the Komadugu Yobe Basin explains the high dependence of the people on surface water resources for domestic purposes. This takes place either in form of shallow wells dug on the floodplains, which are directly recharged by the river or directly from the river.

Water consumption for domestic purposes is dynamic and rapidly changes with increasing population, urbanization and improvement in general living conditions of the people. Being a rural environment the per capita water demand as estimated by NEAZDP (1992) is 30 litres per day while Polet *et al*. (1997) gave their estimates at 50 litres per day. For the purpose of future estimation of the domestic water demand two scenarios identified by IWACO (1985) and adopted by Polet *et al*. (1997) are as follows:

i) Domestic water demand keeps pace with the increase in population only, while per capita demand remains the stable.

ii) Per capita domestic water consumption increases with 5% per year due to urbanization and improvement in services.

Based on the first scenario above while taking the figure representing the total population of the area as base population and 2.5% as the annual growth rate for Nigeria (PRB, 1996) the estimated projected population of the area by the year 2020 will be 230,327. This will give an estimated domestic water requirement of 4.1 Mm^3yr^{-1} in 2020. Table 6.15 presents the estimates.

Table 6.15: Current and Potential Domestic Water Requirements along the Yobe River between Gashua and Mallam Yau

Location	Population	Current Domestic Water Requirements (in Mm^3yr^{-1})	Potential Domestic Water Requirements (in Mm^3yr^{-1})
Gashua – Damasak	56,586	1.0	1.9
Damasak – Yau	67,660	1.2	2.2
Total	124,236	2.3	4.1

Source: Polet *et al*. (1997)

Agriculture is by far the most water demanding use in the Komadugu Yobe Basin. IWACO (1985) had estimated that 80% of the water used in this area is for agricultural purposes. The water requirement for these purposes includes irrigation for both wheat and vegetables; flooded rice and residual moisture farming. The water need therefore depends on the farming calendar as summarized in Table 6.16.

Five factors have been identified as affecting the irrigation water requirements in the basin. These include the cropping pattern and cropping intensity, soil conditions, climatic conditions, irrigation conditions, climatic conditions (irrigation methods and practices) and irrigation efficiencies.

Table 6.16: Farming Calendar for Yobe River between Gashua and Mallam Fatori

Section	Flood Rice Farming	Flood Recession Farming	Irrigation Farming (Wheat)	Irrigation Farming (Vegetables)
Gashua – Geidam	July – November	October – January	September – March	August – March
Geidam – Mallam Fatori	July – December	October – February	September – December	November – February

Source: Polet *et al*. (1997)

Based on the above factors, the Borno State Ministry of Agriculture and the Chad Basin Development Authority reported that the irrigation water requirement for the area ranged between 700 $mmyr^{-1}$ and 1,400 $mmyr^{-1}$ (IWACO, 1985). NEAZDP (1995) had further given an irrigation water requirement of 1,600 $mmyr^{-1}$ having taken into consideration all the five factors and assuming a crop intensity of 100%.

Diyam (1986) and NEAZDP (1992) have identified nine irrigation users within the Komadugu Yobe Basin between Gashua and Mallam Fatori. These users under the various schemes both within Nigeria and Niger Republic have a combined potential area of 21,888 ha with a potential irrigation water requirement of 350.2 Mm^3yr^{-1} (based on 1,600 $mmyr^{-1}$). Currently, less than half of the potential area is developed with irrigation water requirement of 162.1 Mm^3yr^{-1}. It should also be noted that large areas of land along the Yobe River are flooded as a result of the overtopping of riverbanks during the wet season. This floodwater is used by farmers to grow flooded rice the magnitude of which depends on the extent, timing and depth of the flood. It has been estimated that about 1,495 $mmyr^{-1}$ is required for flooded rice and recession production. IWACO (1985) reported the existence of 44,600 ha of potential fadama along the KYB. Assuming an actual utilization at the rate of 35%, such an area requires 233.5 Mm^3yr^{-1} of water to sustain the flood rice and recession farming system. Currently, it is assumed that about half of such area is being utilized in a year with normal flooding for flooded rice and recession farming thus giving the water requirement as 116.7 Mm^3yr^{-1}.

In the dry season, when floods have receded there is usually enough residual moisture in the soil for farmers to grow a second crop. Cowpea is the most common crop but in addition sweet potato, okra, groundnut, Roselle, tomato and watermelon are also grown. The same area used for flooded rice production system is used for residual moisture farming and the calculated water requirement to sustain the flooded rice farming includes the water requirement of the recession farming system.

Livestock rearing is one of the important economic activities in the Komadugu Yobe Basin. The basin provides over 50,000 ha for grazing of animals, which principally include cattle, sheep and goats each type numbering over a million. The water requirement per animal varies from 5 litres per animal per day for sheep and goats to 30 litres per animal per day for cattle. It has been reported that the water consumption per animal increases due to the improvement in veterinary services. NEAZDP (1995) gave the water requirement for the livestock sector as presented in Table 6.17.

Table 6.17: Water Requirement for the Livestock Sector along the Yobe River

Types of Livestock	Number	Water Requirement (l/animal/day)	Total Water Requirement (in 10^6m^3)
Cattle	890,000	30	9.7
Sheep	920,000	5	1.7
Goat	1,000,000	5	1.8
Total			13.2

Fishing is another economic activity that is practiced in the Komadugu Yobe Basin. The extent of the activity is a function of the flow availability in the system. At the moment fishing is carried out on large scale in the open water bodies such as the Nguru lakes and the Marma channels and some points along the system. Fishing is a seasonal activity whose peak periods during the dry season are between October and March. It is, however, evident that river flow is highly essential for fishing activity to flourish.

Decision Support System 7

7.1 The Concept of Decision Support System

The decision support system (DSS) has a graphical user interface that shows the watershed's network representation as well as the flow pattern along the river system. A major feature of the study was the consolidation of data from a wide range of sources onto a database following groundtruthing, gap filling and quality control. Analysis focused on using water balance techniques to assess current patterns of water availability and water use.

The DSS was built on module so that the system could be modified to accommodate data as they become available. The first module is the rainfall-runoff model which simulates inflows to Tiga and Challawa Gorge reservoirs as well as the streamflow from the unregulated catchment in the Hadejia sub-basin. In addition, the model is used to estimate flow from Jama'are River. Figure 7.1 shows a schematic diagram of the KYB river system.

The model is a predictive one with capability of predicting the flow pattern along the river system on weekly time step for one year or a multiple of years (maximum of 10 years). The user is expected to either assume the climatic scenario or the monthly rainfall depth for each sub-basin. Otherwise, the user should provide the weekly rainfall depth at each sub-basin. Figure 7.2 shows the flow structure of the DSS model.

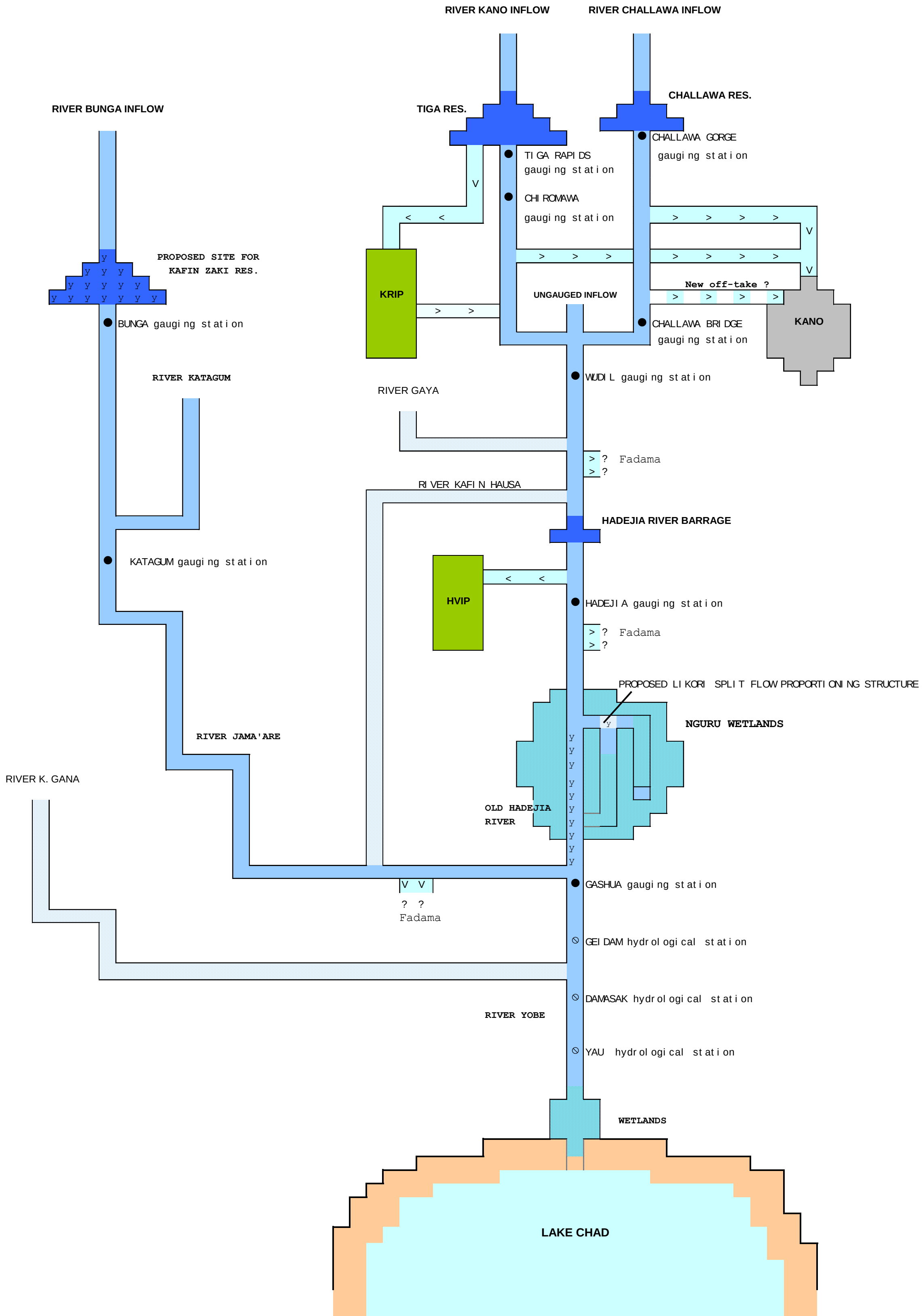
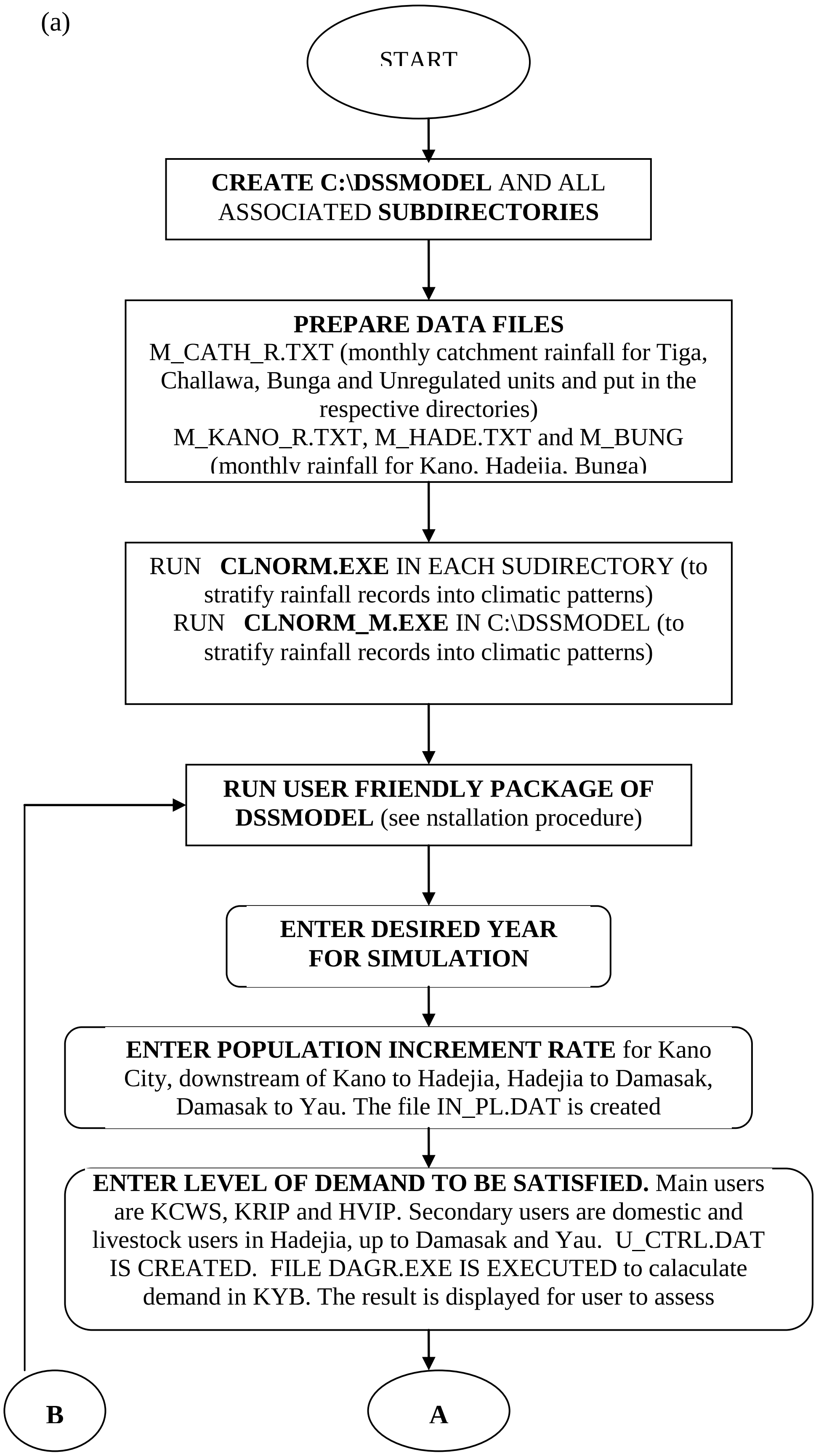


Figure 7.1: Schematic diagram of the river systems in KYB

(a)


START
CREATE C:\DSSMODEL AND ALL ASSOCIATED SUBDIRECTORIES
PREPARE DATA FILES
M_CATH_R.TXT (monthly catchment rainfall for Tiga, Challawa, Bunga and Unregulated units and put in the respective directories)
M_KANO_R.TXT, M_HADE.TXT and M_BUNG (monthly rainfall for Kano, Hadejia, Bunga)
RUN CLNORM.EXE IN EACH SUDIRECTORY (to stratify rainfall records into climatic patterns)
RUN CLNORM_M.EXE IN C:\DSSMODEL (to stratify rainfall records into climatic patterns)
RUN USER FRIENDLY PACKAGE OF DSSMODEL (see nstallation procedure)
ENTER DESIRED YEAR FOR SIMULATION
ENTER POPULATION INCREMENT RATE for Kano City, downstream of Kano to Hadejia, Hadejia to Damasak, Damasak to Yau. The file IN_PL.DAT is created
ENTER LEVEL OF DEMAND TO BE SATISFIED. Main users are KCWS, KRIP and HVIP. Secondary users are domestic and livestock users in Hadejia, up to Damasak and Yau. U_CTRL.DAT IS CREATED. FILE DAGR.EXE IS EXECUTED to calaculate demand in KYB. The result is displayed for user to assess
B
A

(b)

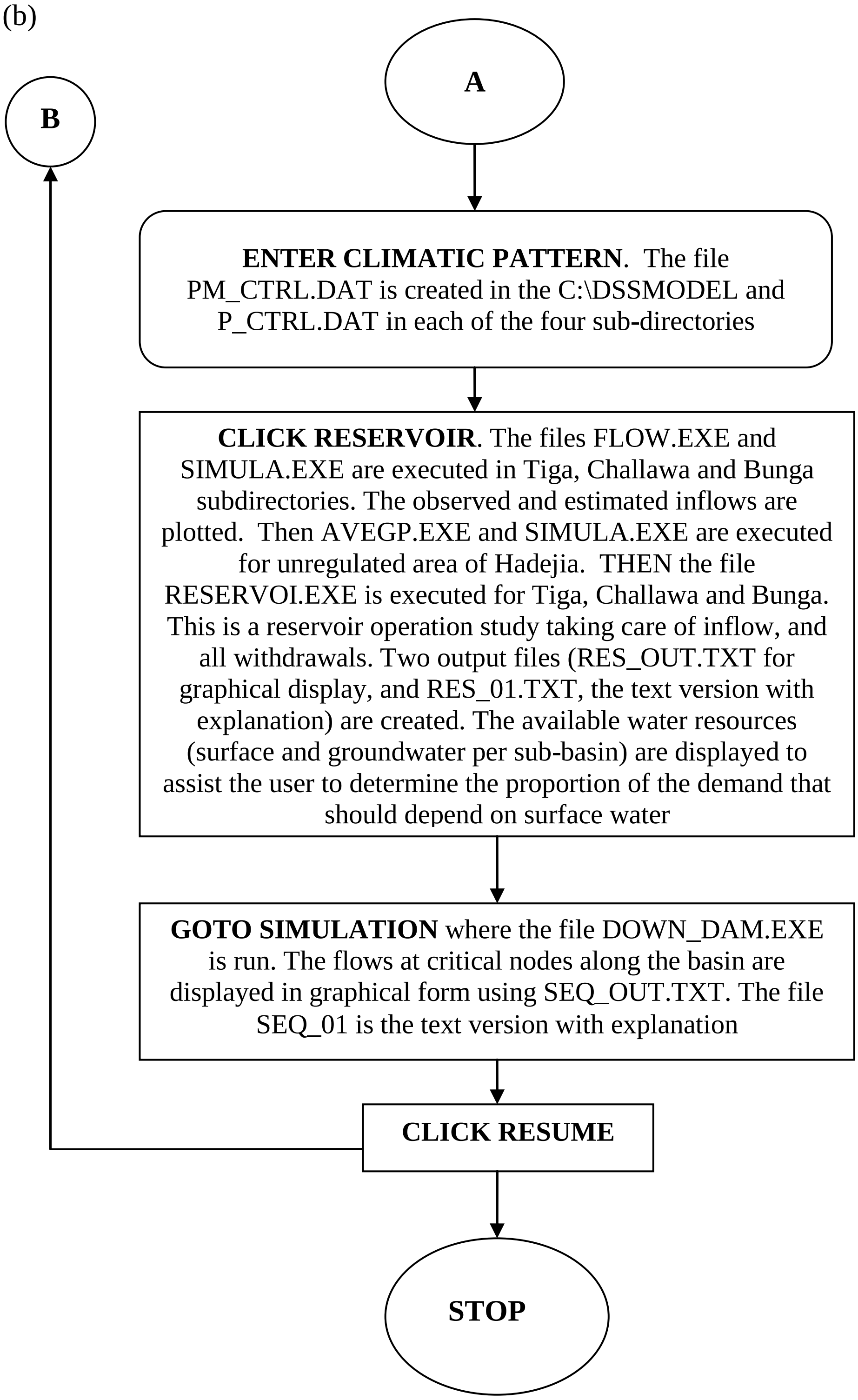


Figure 7.2: Flow Structure of the Model

7.1.1 Demand Aggregate Module

The module aggregates the primary and secondary water demands for the following nodes: Tiga, Challawa, Hadejia, Katagum, Gashua, Geidam, Damasak and Yau. The estimate is based on the current water requirement, and the level of service specified by the user.

7.1.2 Reservoir Module

The second module receives data on the inflow to the reservoir using the rainfall-runoff model and the operation principles of the reservoirs (Tiga, Challawa, Hadejia Barrage and Kafin Zaki). Based on the pre-determined ecological requirement, the module determines the possibility of meeting the requirement for domestic or irrigation needs.

7.1.3 Management Module

The third module determines in a systematic order, the water balance from upstream to the downstream end of the basin. Assumptions made in building the model are as follows:

1. The model runs on weekly time scale and was based on weekly data, where available and monthly data, otherwise.
2. Available record on reservoir operation is scanty. Simulation through the reservoir was based on available record and mathematical equation.
3. An irrigation efficiency of 50% was assumed for the irrigation scheme. The irrigation canals (secondary and tertiary) are unlined thus a minimum water level in the canal must be maintained throughout the year to reduce effect of cracking and seepage.
4. Water requirement for HNWs was estimated based in Afremedev (1999).

7.2 Climate Scenarios

Availability of water in KYB depends on rainfall, which is highly variable due to climate dynamics. Six climate scenarios were considered in the study. These include:

- Prolonged dry year
- Very dry year

- Dry year
- Normal year
- Wet year
- Very wet year

The classification of years into these groups was based on normalized annual rainfall index. The normalized annual rainfall index is defined as the ratio, expressed as percentage, of the deviation of annual rainfall from long term mean (climatic normal) and the standard deviation of the climatic normal period. The climatic normal period is from 1930 to 1960 when the series of annual rainfall in the Sudan-Sahel region of Africa do not show appreciable trend. The Palmer drought index which is a soil-moisture algorithm could not be adopted for the study due to scanty temperature data. The classification into wet and dry years based on the standardized rainfall index is summarized in Table 7.1.

Table 7.1: Degree of wetness and dryness

Scenario	Rainfall Index	Status
1	Less than -3.0	Prolonged dry
2	-3.0 to -2.0	Very dry
3	-1.99 to -1.0	Dry
4	-0.99 to 0.99	Normal
5	1.0 to 2.0	Wet
6	Greater than 2.0	Very wet

7.3 Analysis of Options

The current water uses at the upper part of KYB includes water requirements of two large irrigation projects (KRIP and HVIP) and that of KCWS. For a normal year, the regulation of the two reservoirs (Tiga and Challawa Gorge) affects the amount of water available at the downstream end of the basin. The effect of the regulation of the reservoirs on water available for the downstream end is compounded in a very dry or very wet year. There are different options available for solving such problem. The current water requirement was regarded as 100%

service level. The level of satisfaction desired is based on this level. For example, 50% service level means 50% of the current water requirement.

Current water requirement of the basin are as follows:

- Upstream section of the basin
  - 13,286 ha command area in KRIP requires to 123.62 Mm^3/year.
  - Kano City with a population of 5,855,309 requires 107.66 Mm^3/year.
  - 2,000 ha command area in HVIP requires 24.18 Mm^3/year.
- Middle section of the basin
  - 10,000 ha command area in Kawali Irrigation scheme requires 80.14 Mm^3/year.
- Downstream section of the basin
  - Ecological flow to Hadejia-Nguru Wetlands is 87.7 Mm^3/year.
  - Water supply for communities from downstream of Kano to Hadejia with a population of 984,065 requires 24.26 Mm^3/year.
  - Water supply for communities from downstream of Hadejia to Damasak requires 1.13 Mm^3/year.
  - Water supply for communities from downstream of Damasak to Yau requires 1.34 Mm^3/year.
  - Livestock requirement from Hadejia to Damasak requires 9.29 Mm^3/year.
  - Livestock requirement from Hadejia to Damasak requires 4.59 Mm^3/year.

Seven options are reported herein. The analysis focused on flooding at critical point along the Hadejia-Jama'are-Yobe River system and availability of water for meeting the stated requirements. The options are as follows:

Option 1: Current water requirements of KCWS, KRIP, HVIP and downstream section. There is no area under irrigation in Kawali Irrigation Scheme.

Option 2: Current water requirements of KCWS, KRIP, HVIP and downstream need, as well as 5,000 ha (50%) under Kawali Irrigation Scheme. This option is aimed at accessing the impact of constructing a Kafin Zaki Dam with the same reservoir characteristic as Challawa Gorge Dam.

Option 3: Current water requirements of KCWS, KRIP, HVIP and downstream need, and 10,000 ha (100%) under Kawali Irrigation Scheme. This option is aimed at accessing the impact of constructing a Kafin Zaki Dam with the same reservoir characteristic as Challawa Gorge Dam.

Option 4: Current water requirement of KCWS, 50% of current water requirements for KRIP and HVIP, and current water requirement of downstream section, and 5,000 ha (50%) under Kawali Irrigation Scheme.

Option 5: Current water requirement of KCWS, 150% of current water requirement of KRIP and current water requirements of HVIP and downstream section. There is no area under irrigation in Kawali Irrigation Scheme. This option is aimed at accessing the situation when KRIP phase 1 is completed.

Option 6: Current water requirements of KCWS and KRIP, 500% of current water requirement of HVIP and current water requirements of the downstream section. There is no area under irrigation in Kawali Irrigation Scheme. This is option is aimed at accessing the impact of irrigating 10,000 ha of HVIP when the on-going construction is completed.

Option 7: 50% of current water requirement of KCWS and current water requirements of KRIP and the downstream section. No irrigation activity in HVIP. There is no area under irrigation in Kawali Irrigation Scheme.

Table 7.2 shows the summary of the current water requirement. The demand of each sub-basin is also indicated. The current water requirement of Kano City Water Supply scheme constitutes 43.8% of KYB water requirement, while Kano

River Irrigation Project takes 25% of KYB water requirement. The current water requirement of Hadejia-Nguru Wetlands is 18% of KYB water requirement.

Table 7.2: Summary of Current Annual Demand for KYB

Sub-basin	User	Annual demand Mm^3	Proportion %
Hadejia	KCWS	215.36	43.8
	KRIP	123.50	25.2
	HVIP	24.16	4.9
	Others	24.25	4.9
	HNWs	87.73	17.9
Jama'are	Kawali Irrigation	0	0
Yobe	Others	16.17	3.3
	Total	491.26	100

Figure 7.3 shows the variation of water demand and its relationship with states in the basin. It shows that management of water resources in the basin requires proper coordination among the various agencies.

Assuming that there is no expansion activities in KRIP and HVIP, and the construction of Kafin Zaki Dam for the purpose of providing water to Kawali Irrigation Scheme did not continue, the proportion of water for KCWS will increase from 43.8% in 2005 to 57% of the total demand in 2025 (Table 7.3). Appendix 8 shows a summary of major and small dams in the basin. The potential water demand in the basin is also presented in Appendix 8. This study, however, showed that the available surface water resources are not sufficient to meet the current demand. Thus, the potential future demand canot be based on surface water resources in the basin.

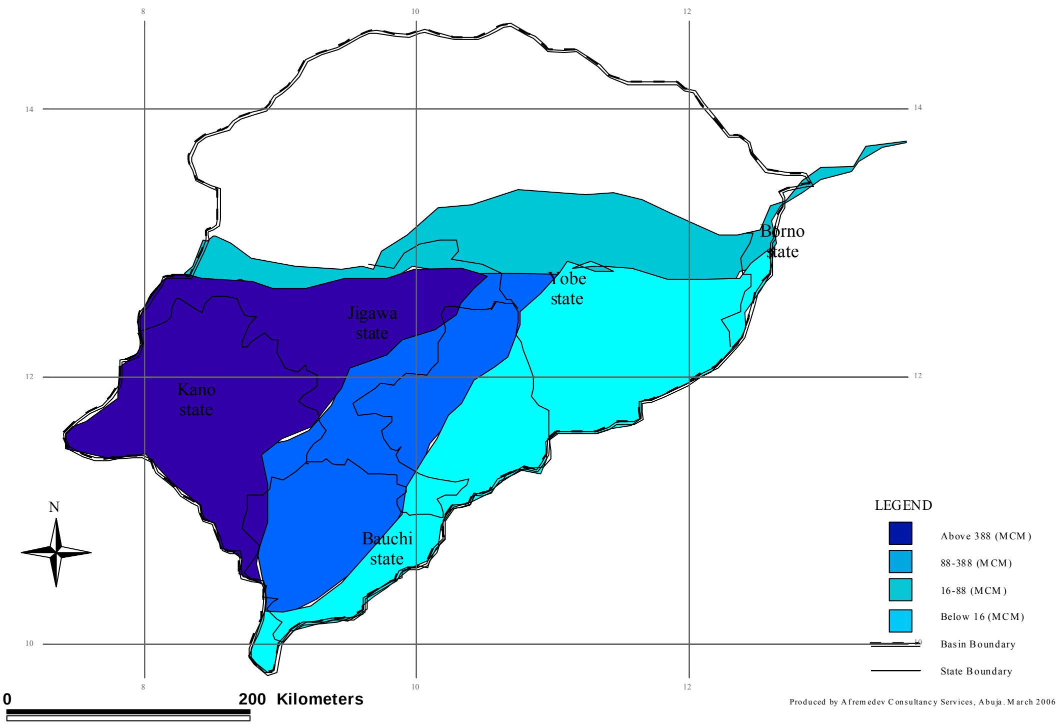


Figure 7.3: Current Water Demand in KYB

Table 7.3: Future Water Demand in KYB

	Proportion of water demand (%)		
	Current	**Year 2010***	**Year 2025***
KCWS	43.8	47.2	57.0
KRIP	25.2	23.4	18.1
HVIP	4.9	4.6	3.5
Up to Hadejia	4.9	5.2	5.8
HNWs	17.9	16.6	12.9
Kawali Irrigation	0.0	[illegible]	0.0
Up to Damasak	2.1	[illegible]	1.6
Up to Yau	1.2	1.1	1.0

* only domestic water demand is projected from current level

The analysis showed that while the current water requirement of Hadejia sub-basin, excluding the requirement of Hadejia-Nguru Wetlands, accounts for 80% of the annual demand of KYB; the sub-basin contributes 60% of water resources in KYB. This suggests that if the water requirement of KYB depends on only surface water, future expansion of KRIP and HVIP should not be carried out.

Table 7.4 shows the proportion of water demand for each unit under the various options considered. The table shows that the main users are KCWS, KRIP and HNWs. The water requirement of KCWS varies from 30% of total demand in option 7 to 43.8% of total water demand in option 1. The result of the analysis in terms of peak flow along the river system under the various climatic years is presented in Table 7.5 to Table 7.10.

Table 7.4: Proportion of Water Demand under Various Water Options

	Proportion of water demand (%)						
	Option1	**Option2**	**Option3**	**Option4**	**Option5**	**Option6**	**Option7**
KCWS	43.8	40.5	37.7	47.1	38.9	36.6	30.0
KRIP	25.2	23.3	21.6	13.5	33.5	21.0	34.4
HVIP	4.9	4.5	4.2	2.6	4.4	20.5	0.0
Up to Hadejia	4.9	4.6	4.2	5.3	4.4	4.1	6.7
HNWs	17.9	16.5	15.4	19.2	15.9	14.9	24.4
Kawali Irrigation	0.0	7.5	14.0	8.7	0.0	0.0	0.0
Up to Damasak	2.1	1.9	1.8	2.2	1.9	1.7	2.9
Up to Yau	1.2	1.1	1.0	1.3	1.1	1.0	1.6

Table 7.5: Peak flow (Mm^3/week) under normal climatic condition

Option	Wudil	Hadejia	Likori	Burum Gana	Marma Channel	Katagum	Gashua	Geidam	Yau
1	140.6	45.8	24.8	3.0	23.3	252.4	148.2	90.1	38.1
2	140.6	45.8	24.8	3.0	23.3	254.9	147.8	89.9	38.0
3	140.6	45.8	24.8	3.0	23.3	254.2	147.4	89.7	37.9
4	140.6	46.1	24.8	3.0	23.3	254.9	148.0	90.0	38.1
5	140.6	45.8	24.8	3.0	23.3	252.5	148.2	90.1	38.9
6	140.6	44.1	24.5	3.0	23.0	252.5	147.2	89.5	37.8
7	143.3	46.6	24.9	3.0	23.4	252.5	148.5	90.3	38.1

Table 7.6: Peak flow (Mm^3/week) under wet climatic condition

Option	Wudil	Hadejia	Likori	Burum Gana	Marma Channel	Katagum	Gashua	Geidam	Yau
1	316.5	66.1	27.0	3.0	24.9	331.6	195.7	119.0	50.5
2	316.5	64.8	26.9	3.0	24.8	334.2	195.3	118.8	50.3
3	316.5	64.8	26.9	3.0	24.8	333.5	195.0	118.6	50.2
4	317.5	65.3	26.9	3.0	25.2	334.2	195.4	118.8	50.3
5	315.5	64.7	26.8	3.02	24.3	331.6	195.0	119.0	50.4
6	316.5	61.3	26.6	3.0	24.4	331.6	195.0	118.6	50.2
7	318.1	65.8	26.9	3.0	25.2	331.6	195.8	119.1	50.4

Table 7.7: Peak flow (Mm³/week) under very wet climatic condition

Option	Wudil	Hadejia	Likori	Burum Gana	Marma Channel	Katagum	Gashua	Geidam	Yau
1	322.1	65.3	26.8	3.0	25.3	331.6	195.7	119.0	50.4
2	322.1	65.3	26.9	3.0	25.3	334.2	195.3	118.8	50.3
3	322.1	65.3	26.9	3.0	25.3	338.5	195.0	118.6	50.2
4	323.1	65.9	26.9	3.0	25.4	334.6	195.4	118.8	50.3
5	321.1	65.2	26.9	3.0	24.9	331.6	195.7	119.0	50.4
6	322.0	62.0	26.6	3.0	25.0	331.6	195.0	118.6	50.2
7	323.6	66.3	27.0	3.0	25.5	331.6	195.8	119.1	50.4

Table 7.8: Peak flow (Mm³/week) under dry climatic condition

Option	Wudil	Hadejia	Likori	Burum Gana	Marma Channel	Katagum	Gashua	Geidam	Yau
1	100.5	39.6	23.7	3.0	21.6	198.9	116.5	70.8	29.9
2	100.5	39.6	23.7	3.0	21.6	201.0	117.6	71.5	30.2
3	100.5	39.6	23.7	3.0	21.6	200.4	117.3	71.4	30.1
4	100.5	40.1	23.8	3.0	21.7	201.0	117.3	71.3	30.2
5	100.5	39.6	23.7	3.0	21.6	198.9	116.5	70.8	29.9
6	100.5	35.9	22.9	3.0	21.0	198.9	115.4	70.2	29.6
7	105.7	41.3	24.0	3.0	22.5	198.9	117.0	71.1	30.0

Table 7.9: Peak flow (Mm³/week) under very dry climatic condition

Option	Wudil	Hadejia	Likori	Burum Gana	Marma Channel	Katagum	Gashua	Geidam	Yau
1	77.6	36.5	23.0	3.0	21.5	177.9	104.7	63.7	26.8
2	77.6	36.5	23.0	3.0	21.5	179.6	105.7	64.2	27.1
3	77.6	36.5	23.0	3.0	21.5	179.0	105.3	64.0	27.0
4	77.6	36.8	23.1	3.0	21.6	179.6	105.9	64.3	27.1
5	77.6	36.5	23.0	3.0	21.5	177.9	104.7	63.7	26.8
6	77.6	34.0	22.4	3.0	20.9	177.9	103.3	62.8	26.5
7	77.6	37.1	23.2	3.0	21.7	177.9	105.1	63.9	26.9

Table 7.10: Peak flow (Mm³/week) under prolonged dry climatic condition

Option	Wudil	Hadejia	Likori	Burum Gana	Marma Channel	Katagum	Gashua	Geidam	Yau
1	77.6	36.5	23.0	3.02	21.5	177.9	104.7	63.7	26.6
2	77.6	36.5	23.0	3.0	21.5	179.6	105.7	64.2	27.1
3	77.6	37.5	23.3	3.0	21.8	179.0	105.3	64.0	27.0
4	77.6	37.5	23.3	3.0	21.8	179.6	105.9	64.3	27.1
5	77.6	36.5	23.1	3.0	21.5	177.9	104.7	63.7	26.8
6	77.6	34.0	22.4	3.0	20.9	177.9	103.3	62.7	26.4
7	77.6	37.1	23.2	3.0	21.7	177.9	105.1	63.9	27.0

In a wet year, the peak flow at Wudil is twice that of normal year, while that of dry year is half of the normal year. However, the peak flow obtained in a very wet year is lower than the minimum peak flow (500 Mm^3/week) obtained in a pre-dam era.

In general, there is no significant difference between the peak flows at a station under the different options considered. There is, however, a significant difference between the peak flows for the different climatic conditions. For example, peak flow in Yau ranged between 50 Mm^3 in a very wet year and 26 Mm^3. in a prolonged dry year. Flooding of communities and farmland along the KYB especially downstream of Hadejia up to Nguru has become an annual phenomenon in the last ten years as a result of weed infestation and siltation. Considering the high inter-annual variability of rainfall in the basin, flash-flood could easily occur if the river channel is blocked. The tables above show that the peak flow at either Burum Gana or Marma Channel attains the capacity of the respective channels, even for a dry year. This explains why flooding of the plains is frequent. The problem is compounded by the presence of *Typha* grass in the channel. Management of the available resources to address the inequality in time becomes important.

Figure 7.4 shows the flow at critical points on the KYB river system in a normal year under option 1. The analysis showed that the water requirement of the HNWs could not be satisfied during the first quarter of the year. Similarly, the irrigation requirement of HVIP could not be satisfied in the early part of the year. This implies that the available water resources in KYB, in a normal cliatic year, are not sufficient to sustain the proposed Sugar Project in Jigawa State. The situation in a dry year is worst (Figure 7.5). In addition, the water requirement of communities along the river system after Gashua could not be satisfied from week 1 to week 20 (January to April).

For a dry climatic pattern, the flow at the critical section is presented in Figure 7.5. The situation reflects what is experienced in a typical dry year. The effect of constructing the Kafin Zaki Dam with 10,000 ha command area under Kawali Irrigation Scheme (option 3) is illustrated in Figure 7.6 for a normal year, Figure 7.7 for very dry year and Figure 7.8 for a wet year.

The annual flow at the selected station along the KYB river system is summarized in Table 7.11.

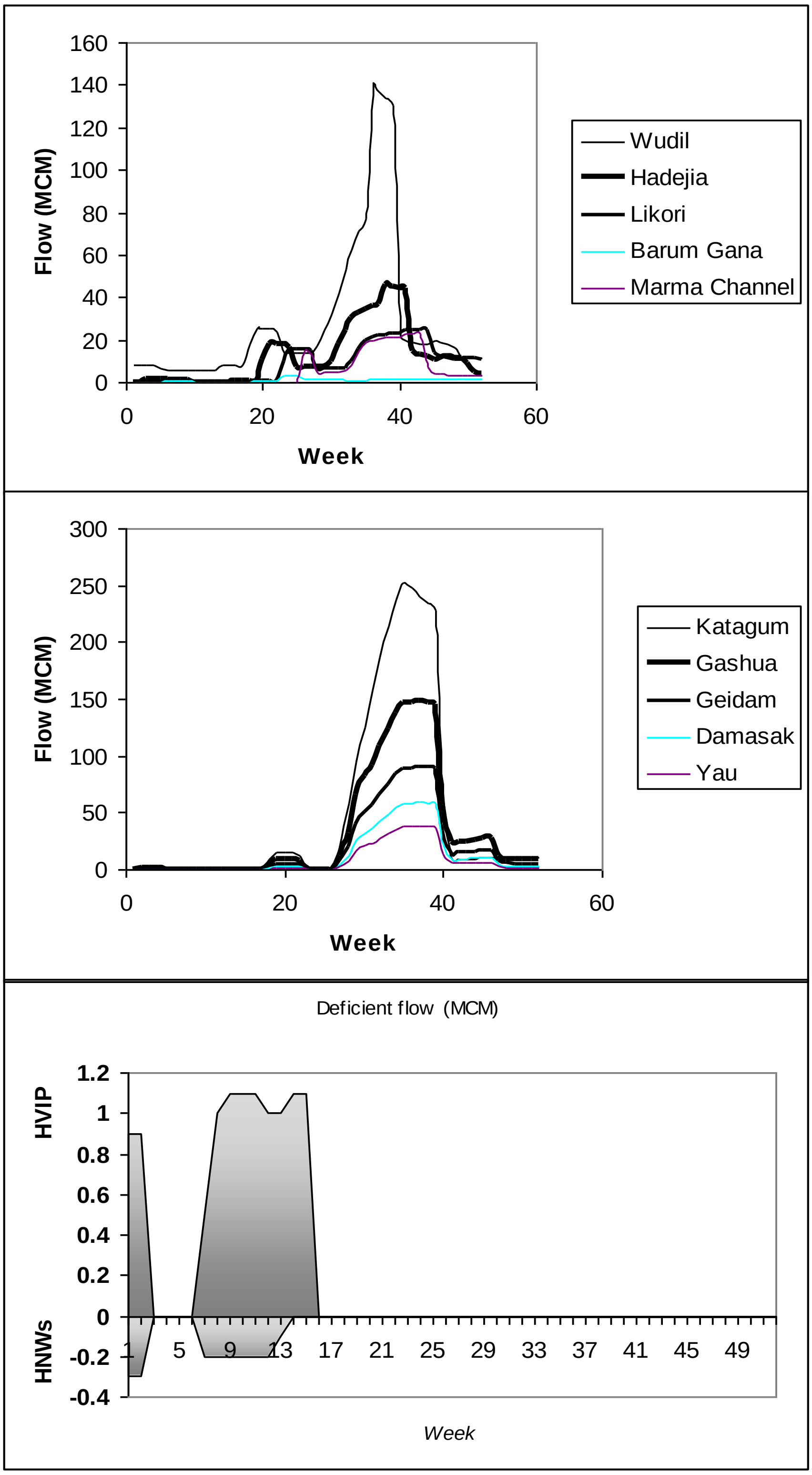


Figure 7.4: Flow along KYB in a normal year under the existing condition

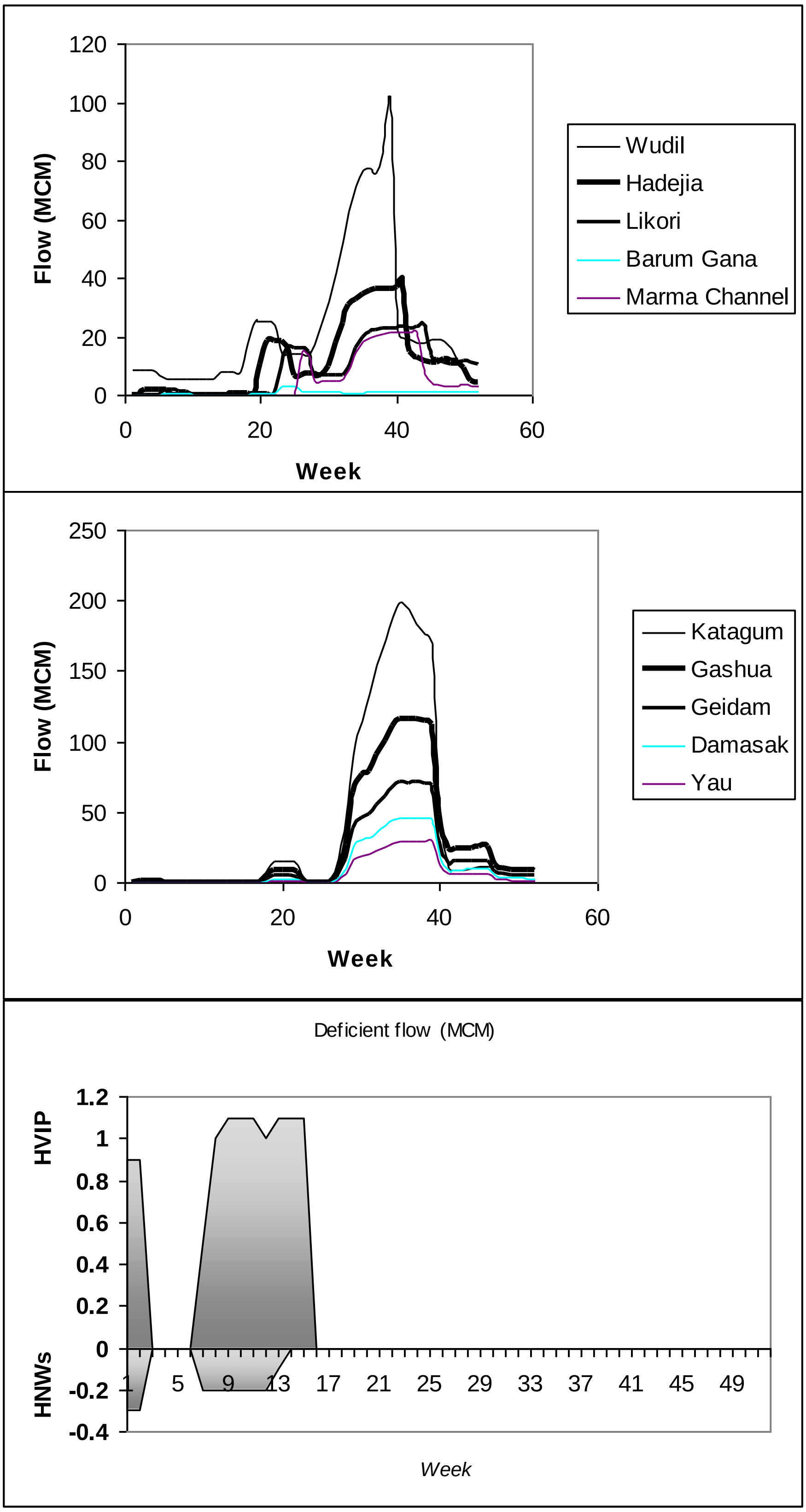


Figure 7.5: Flow along KYB in a dry year under the existing condition

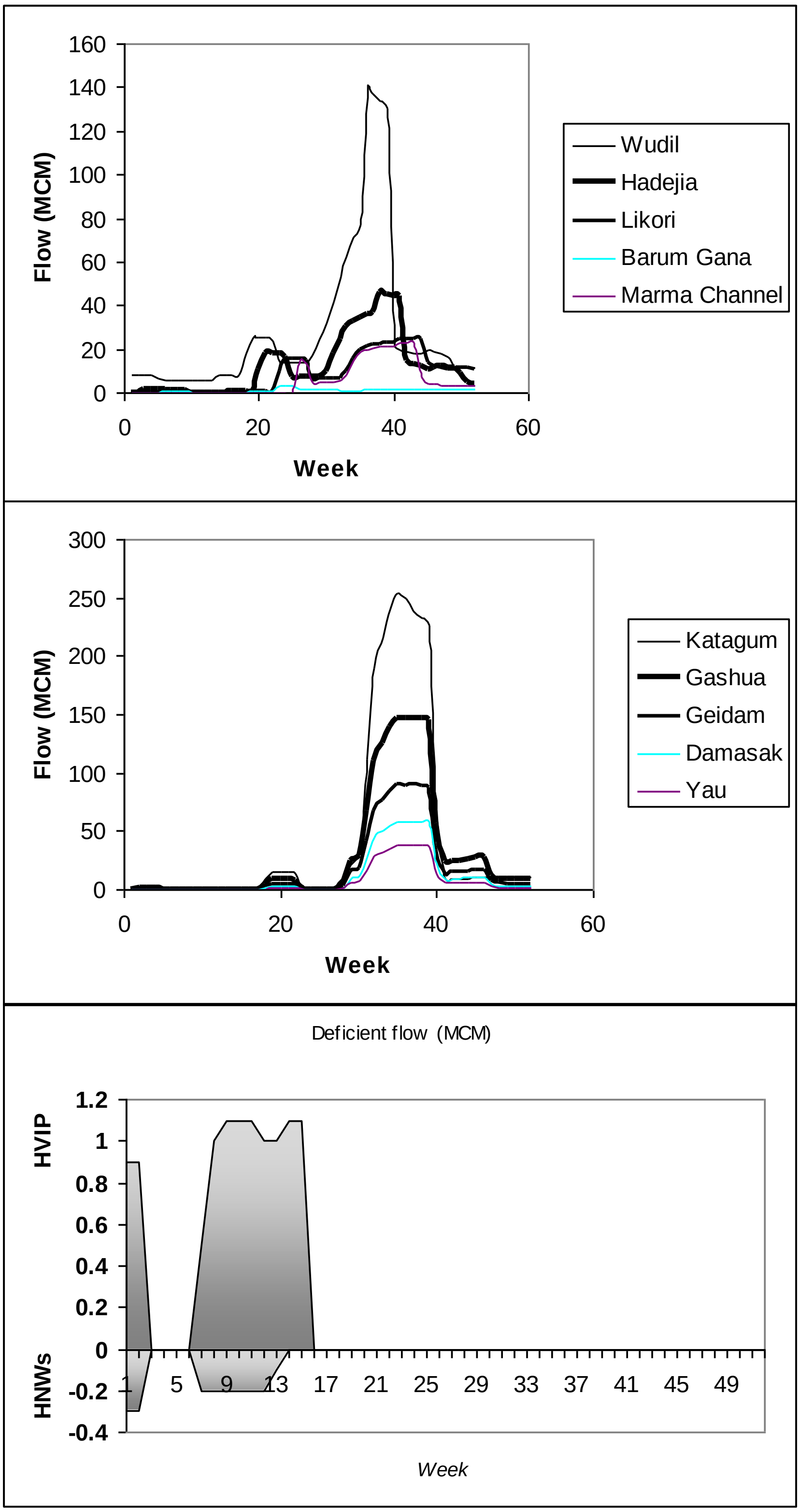


Figure 7.6: Flow along KYB in a Normal Year under Option 3

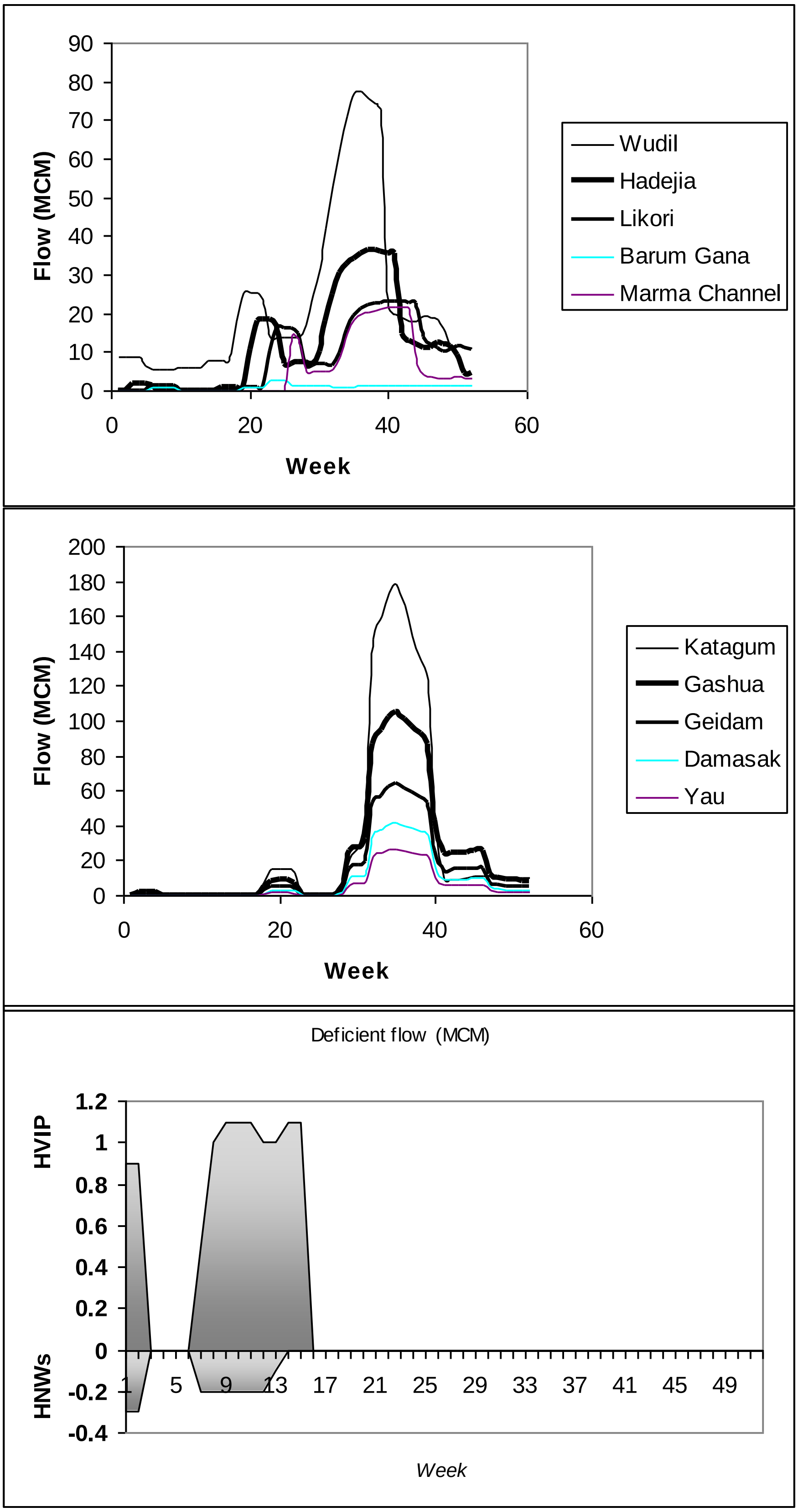


Figure 7.7: Flow along KYB in a Very Dry Year under Option 3

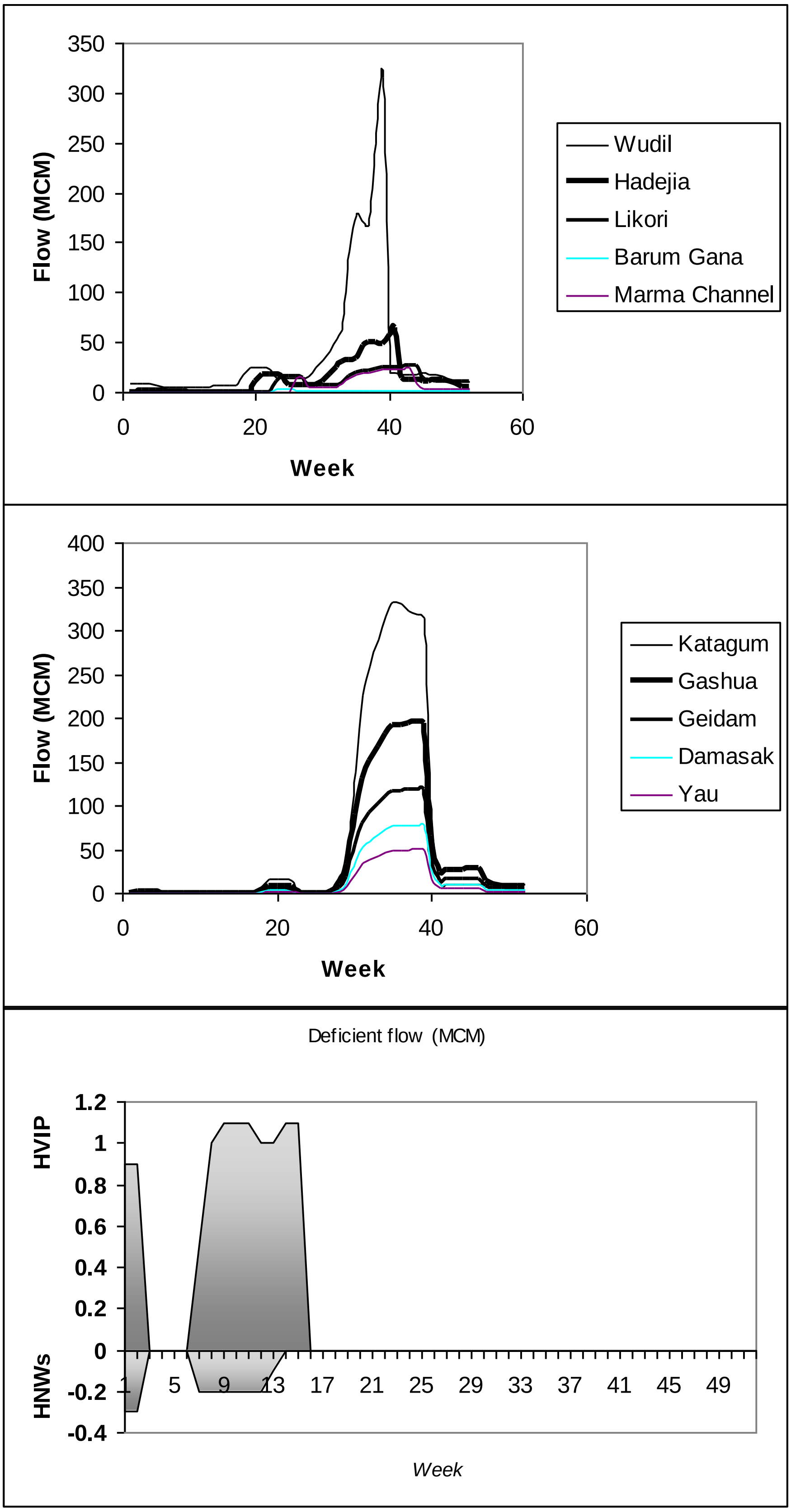


Figure 7.8: Flow along KYB in a Very Wet Year under Option 3

Table 7.11: Annual flow (Mm^3) along KYB river system

	Normal year				
Option	**Wudil**	**Hadejia**		**Gashua**	**Yau**
1	1,441.4	645.7		1,328.7	328.1
2	1,441.4	645.7		1,328.9	327.0
3	1,441.4	645.7		1,314.2	323.2
4	1,441.4	655.1		1,330.6	327.5
5	1,441.4	645.7		1,328.7	328.1
6	1,441.4	574.4		1,314.4	324.4
Pre-Tiga	2,007.9	740.6		1,536.7	
	Wet year				
Option	**Wudil**	**Hadejia**		**Gashua**	**Yau**
1	1,976.8	712.8		1,764.1	441.2
2	1,976.8	712.8		1,769.3	441.4
3	1,976.8	712.8		1,754.5	437.5
4	2,023.6	726.7		1,771.3	441.9
5	1,930.0	707.7		1,763.7	441.1
6	1,976.8	642.5		1,750.7	437.7
	Dry year				
Option	**Wudil**	**Hadejia**		**Gashua**	**Yau**
1	1,236.4	614.7		1,196.6	293.8
2	1,236.4	614.7		1,190.6	291.1
3	1,236.4	614.7		1,175.9	287.3
4	1,236.4	624.8		1,770.8	441.8
5	1,236.4	614.9		1,196.6	293.8
6	1,236.4	538.8		1,180.8	289.7

The table shows that there is a 30% reduction in flow at Wudil in a normal year due to the operation of Tiga and Challawa Gorge dams. Similarly the flow at Hadejia is reduced by 23% in a normal year. The finding confirmed earlier studies in the basin. Similar observations were made on the flow at Yobe sub-basin and contribution of Hadejia River sub-system has changed from 51% pre-dam to 2% post-dam.

Figure 7.9 shows the flow at Bagara Diffa, Niger between 1968 and 1990. Further analysis using plot of cumulative flow at Bagara Diffa (Figure 7.10) from 1968 to 1990 did not show any noticeable departure in 1974 when regulation of flow at Tiga Dam commenced. The flow in Bagara Diffa was compared with the mean rainfall in the KYB within Nigeria area (Figure 7.11) and it was found that there is a similarity between the rainfall pattern and flow. This suggests that flow regulation at Hadejia (Tiga Dam) from 1974 to 1990 did not show appreciable effect on the flow at Bagara Diffa.

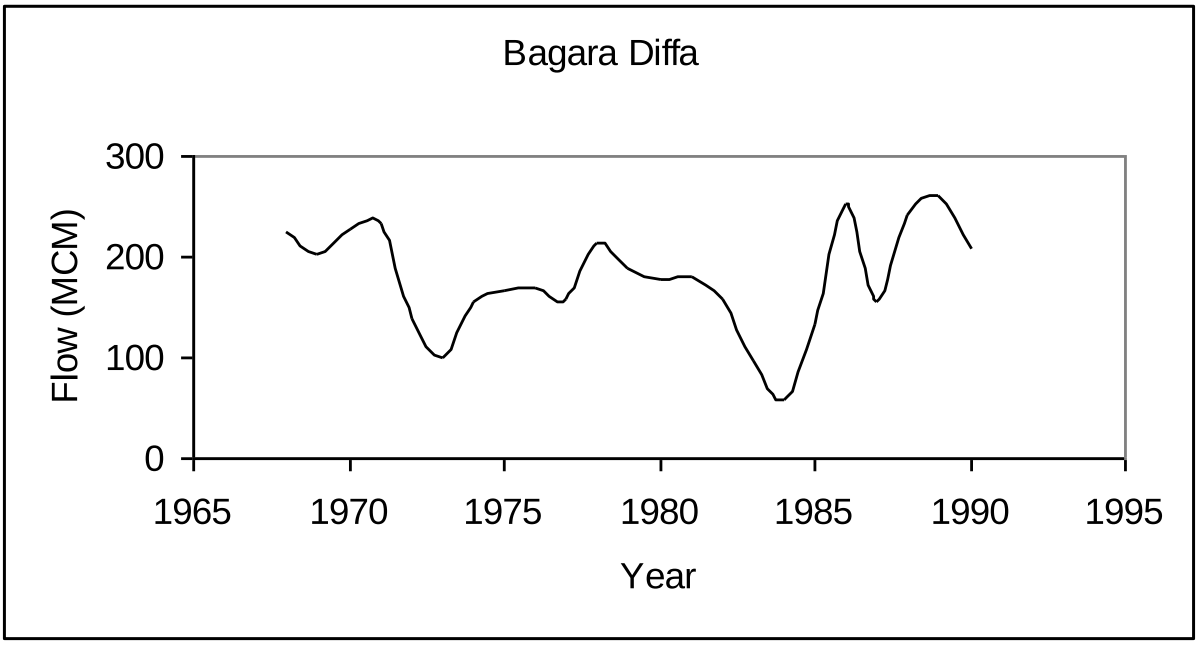


Figure 7.9: Flow at Bagara Diffa

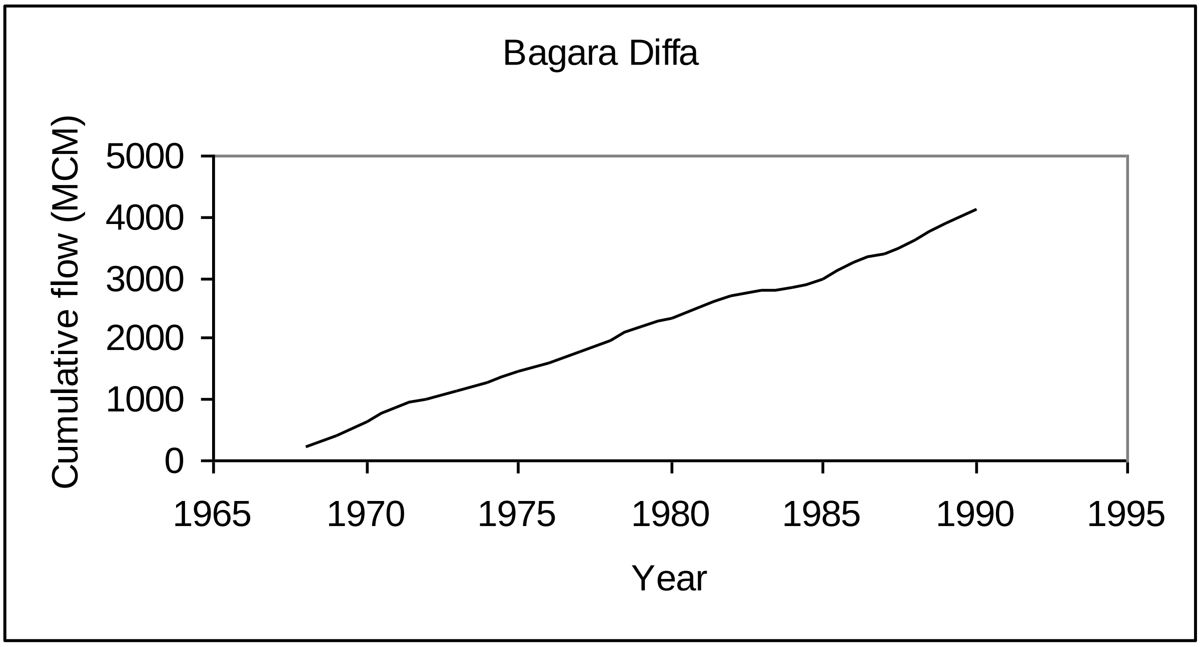


Figure 7.10: Cumulative flow at Bagara Diffa

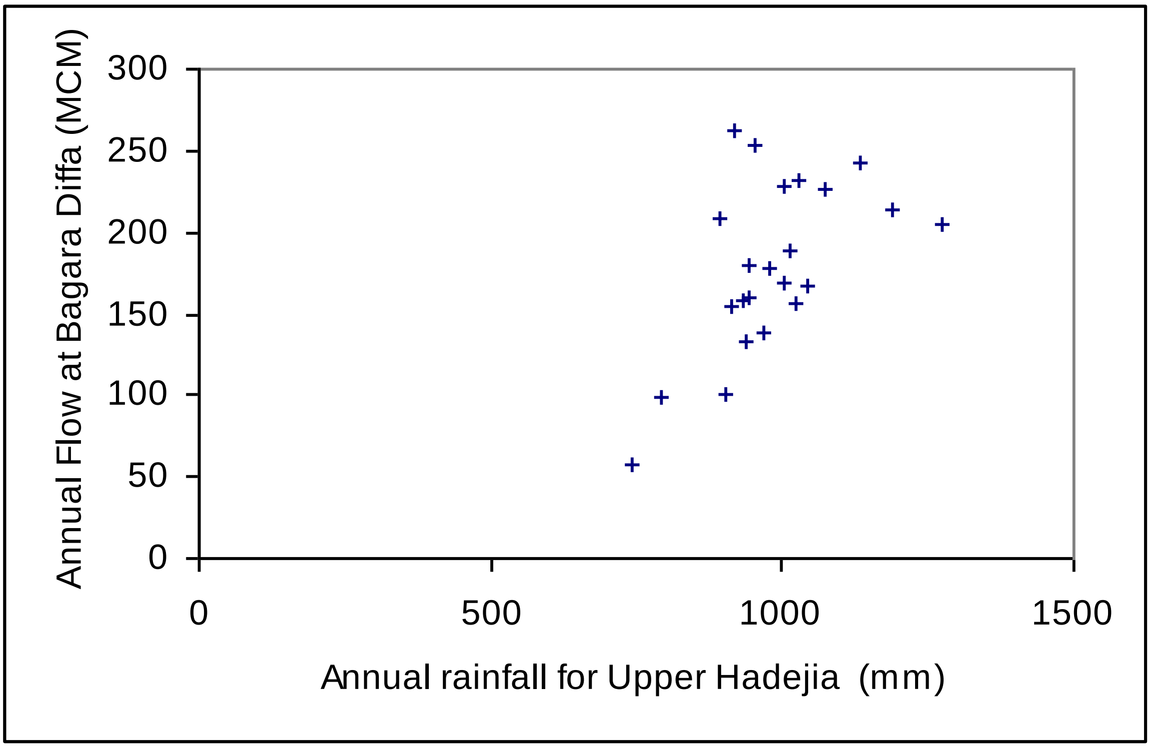


Figure 7.11: Annual rainfall for Upper Hadejia

This observation is confirmed with the finding under option 7 (i.e. operating Tiga Dam for 50% of current water supply to Kano City, with irrigation in KRIP, no Challawa Gorge Dam, no irrigation in HVIP and no irrigation in Kawali). Is this option feasible – considering the effect of meeting only 50% of Kano City demand? The economic benefit of these activities outweighs the benefit of maintaing the natural flow in bagara diffa.

However, the record of flow at Bagara Diffa from 1992 to date, when Challawa Gorge Dam had been in operation, were not available for the Consultant to assess the effect of multiple reservoirs on Hadejia on flow level in Bagara Diffa. The necessary data is urgently needed to enable the assessment of the impact of the reservoirs on the flow at Bagara Diffa to be determined.

7.4 Reservoir Operation

Earlier investigations (Afremedev, 1999 and IUCN, 1999) reported that there are on operation manuals for Tiga and Challawa Gorge dams. Record keeping at the dams is not encouraging. Figures 7.12, 7.13 and 7.14 show the simulated reservoir storage volumes in Tiga, Challawa Gorge and Kafin Zaki reservoirs. Figure 7.12 confirmed that the volume of water in Tiga Reservoir is always less than the maximum storage, even, during the peak rainy season. Thus, there is no spillage of water from the reservoir.

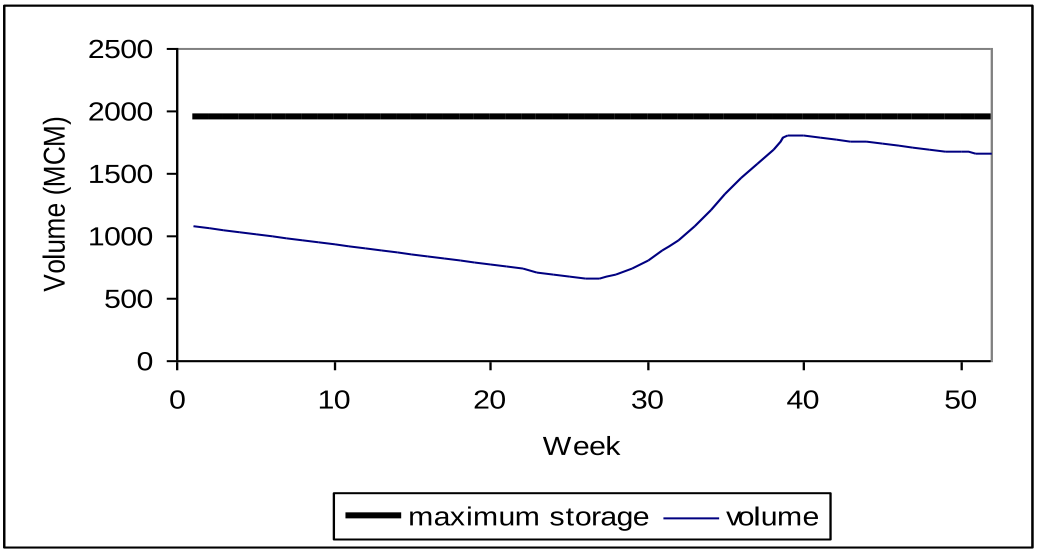


Figure 7.12: Simulated Reservoir Storage for Tiga Dam

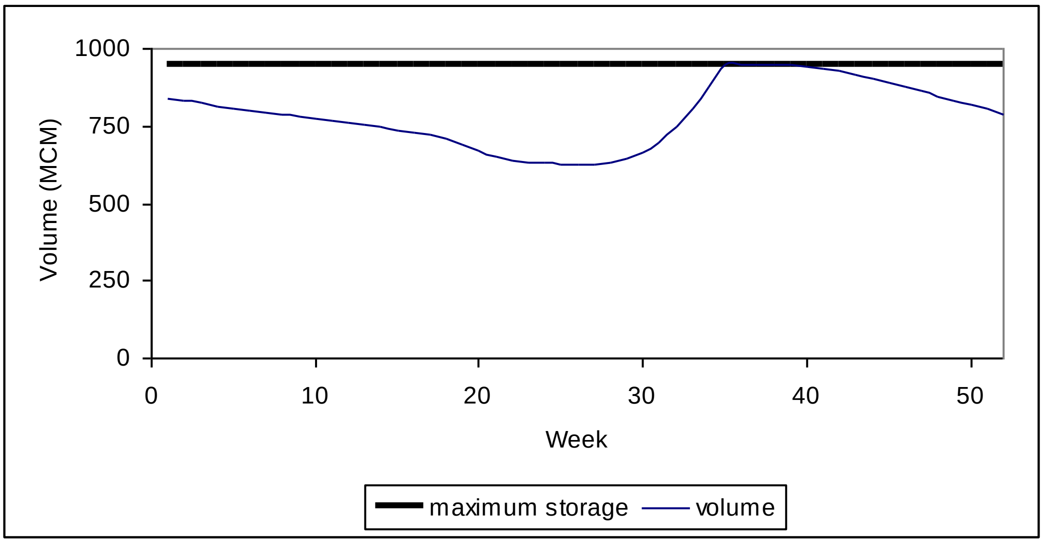


Figure 7.13: Simulated Reservoir Storage for Challawa Gorge Dam

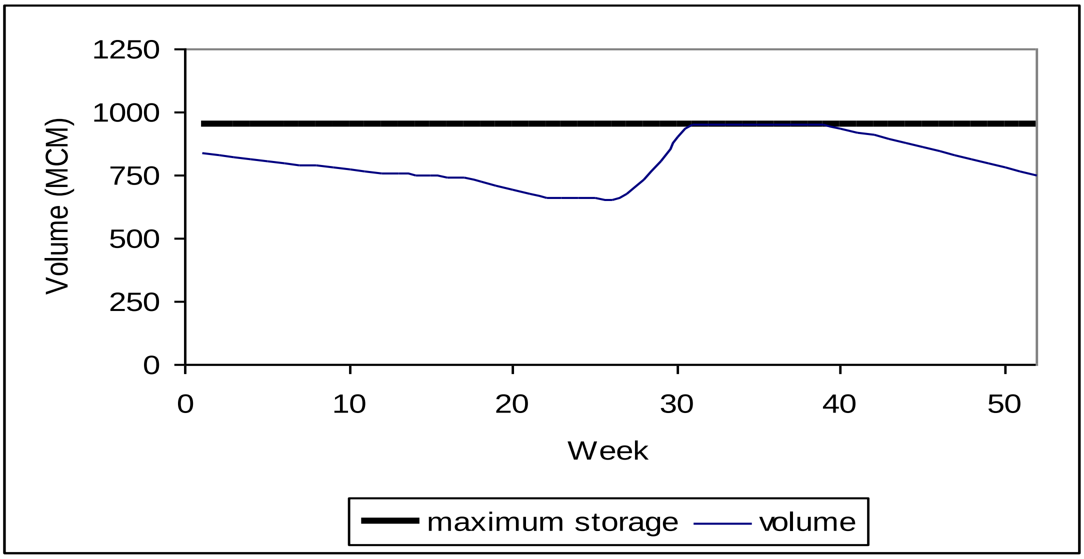


Figure 7.14: Simulated Reservoir Storage for Proposed Bunga Dam

Analysis of rainfall series in the catchment showed that the dam was designed and constructed during period of high rainfall. The rainfall after the construction of the dam has persistently been lower than the long term mean. Consequently, the storage volume of the reservoir is depleted by over 67% of the total storage capacity every year. The lowest storage volume of the reservoir is 660 Mm^3, and this occurred between week 24 and 28. It is doubtful whether the actual volume of water in the reservoir is up to 660 Mm^3 during this period due to deposition of silt in the reservoir. Unfortunately, the management agency does not monitor sediment trapped in the reservoir. For Challawa Gorge Reservoir, there is spillage of water between week 35 and 40. This dam was constructed during period of low rainfall, suggesting that both low and high rainfall records were considered in the design of the dam.

Water Constraints and Risks 8

8.1 Water-Related Constraints

Two of the broad challenges facing water management in the Komadugu Yobe Basin were noted as being: (i) how to control unsustainable water consumption; and (ii) how to enhance the water allocation mechanisms. Many of the root causes were identified, and recommendations made in the KYB-CMP. However, to successfully implement projects/policy actions aimed at alleviating these challenges, the water related constraints and risks need to be addressed as a priority.

Constraints that limit the number of resource-focused options that could and should be promoted by the CMP for KYBP and similar projects include (not in order of importance) as below.

8.1.1 Climate and Extreme Events

The climate of the Komadugu Yobe Basin is predominantly semi-arid and, consequently, rainfall is extremely variable in time and space. Hence, groundwater recharge and runoff into reservoirs would also be extremely variable, as is the productivity of rainfed arable and non-arable lands. Meanwhile, meteorological drought and floods are recurring natural phenomena that have had a relatively greater impact on the poor and vulnerable in the basin.

The GIWA (2004) assessment attributed recent climatic variability to be primarily to these long-term climatic cycles but which may have been exacerbated by recent human induced Sea Surface Temperature (SST) and land surface anomalies. It referred to anthropogenic global change and therefore it was considered as having a moderate impact. Nevertheless Birkett (2000) concluded that the seasonal fluctuations of the Lake Chad level has been primarily controlled by climate, not water management practices. However, stream diversion is still a key factor in the extent of freshwater shortage downstream of the large dam constructions and there is a concern regarding the use of what water supplies that is available in the basin during periods of low precipitation.

8.1.2 Water Resources Availability

In many sub-catchments, current usage of water resources approximates and even exceeds annual replenishment. In the absence of inter-basin transfers, the scope for augmenting water resources by developing additional ground and surface water resources is limited. The availability of freshwater is one of the most critical environmental issues of the basin and is particularly true in lower reaches that is essentially arid or semi-arid and the precipitation is highly variable. With increasing population and development we can expect that the pressures on existing water supplies in the basin and the vulnerability of the populations dependent on these resources will continue to grow (UNEP, 2004).

Despite the freshwater shortage concerns in the basin, water is still utilised inefficiently. Isiorho *et al*. (2000) estimated that in Maiduguri, 10 to 25% of water is used inefficiently. Similarly, agriculture is the largest user of water in the basin; in the Hadejia river system, irrigated agriculture accounts for approximately two-thirds of the total water requirements, and most of these irrigation projects, are utilising water resources inefficiently (Bdliya *et al*., 1999). Irrigation channels are unlined and open resulting in infiltration and evaporative losses. Although, there have been no studies that accurately quantify the level of water wasted in the sub-system, there are empirical reasons to believe that the recent trends have been exacerbated by the diversion of water by dams for irrigation projects such as the KRIP. Furthermore, the level of water use has been unsustainable in the climatic scenario of the past 40 years.

By implementing water conservation measures less water will be needed to produce a unit of crop, regrettably, even in the light of water shortages there are no clear strategies or incentives for the farmers to conserve water; farmers are not compelled to pay appropriate charges for the water, neither is the rate based on quantity of water usage, consequently by saving water they do not achieve any personal gain. Education programmes and incentives may therefore be necessary to promote water conservation.

There is also the issue of the pollution of existing water supplies, which at the moment is considered as having a slight impact due to limited industrial activity in the basin (except around Kano City). However, pollution of water supplies either directly from the industries and other non-point pollution sources such as from agricultural activities or by the increased urbanisation in the basin could increasingly become a concern in future.

Overall, the concern of freshwater shortage was considered as being severe due to its driving almost all environmental concerns in the basin. The ecological impacts on the wetlands and lake's environment have been severe. For example, since the 1960s, the Hadejia-Nguru Wetlands have been reduced by almost 50% (Barbier *et al.,* 1997) and the Lake Chad was reduced since the 1990s to just 10% of its size prior to the 1960s. Freshwater shortage has had severe economic impacts on the fisheries, flood-recession agriculture, livestock rearing and other wetland industries.

8.1.3 Demographic

Population growth: Increases in the basin's population has led to greater pressure on the natural resources of the basin most especially its water resources. The population of the basin is estimated to be 23.8 million representing over 55% of Lake Chad Basin's population. Such a concentration of population has led to extreme pressure on the diminished water resources.

Migration: There has been a large influx of immigrants from the northern fringes into the Komadugu Yobe Basin. This has been attributed to drought and desertification forcing communities to leave this increasingly arid environment. This has increased competition and aggravated conflicts between livestock-breeders who have been moving southwards and the sedentary farmers (LCBC, 2000b).

As a result of the foregoing, year by year a larger proportion of groundwater recharge and surface water storage is needed to meet rural and urban water requirements. As a consequence, the water available for other uses especially agriculture, is reducing. In addition, with increasing population and in the absence of improvements in water use productivity, there will be a decrease in the proportion of the population that can rely on landbased activities as a main source of income.

8.1.4 Poor Reservoir Management and Water Use Inefficiency

The scarcity of water in the basin has not prompted improved reservoir management to utilise resources that are available in a more efficient manner. The inefficient gravity irrigation methods are still being employed in place of more efficient methods such as drip or sprinkler irrigation systems. Irrigation channels are open and unlined, and therefore prone to infiltration and evaporation losses. There are no immediate incentives for the upstream farmers to conserve water, as they seldomly pay the token irrigation fees, which consequently has encouraged farmers to grow water intensive crops such as rice and sugar cane. It also has to be questioned whether it is appropriate for some state government to be deliberately encouraging growing such crops in a basin prone to freshwater shortages.

An international dam safety specialist recruited by the World Bank as part of the GEF project has reviewed the Tiga Dam (Hadejia River sub-basin). The main threats were identified in decreasing order of probability: internal erosion due to arching of fill material over the cut off trench, internal erosion caused by a fracture of one of the two secondary outlet pipes, and slope failure under seismic load. The probability of failure was considered high for the 8 km zoned earthfill embankment, with the main threat coming from piping i.e. water creating channels through the dam. Tens of thousands of people would be at risk from Tiga Dam. The Challawa Gorge Dam is newer and was not considered to pose an immediate threat (World Bank, 2002). Although the Tiga Reservoir has approximately twice the inflow of the Challawa Gorge Reservoir, the maximum capacity of the main Tiga Dam outlet is just a third of the maximum of the two outlets of Challawa Gorge Dam. The operation of dams remains highly uncoordinated (Bdliya *et al.*, 1999).

The Greater Kano Water Supply (GKWS) intake is located on Kano River before the confluence between the Challawa and Kano rivers. It has a sump that is easily silted, so that constant dredging is necessary. A canal had to be constructed on the Kano River to bring water to the sump. Sandbagging was also used to simulate a weir structure, but it was eroded with time, particularly with varying water releases. The Challawa intake is expected to have an even more severe problem with silting. The water at this intake is very turbid as a result of severe erosion upstream in the Watari and other tributaries. The siltation decreases the inflow by diverting water to the other bank. There are reasons to believe that inadequate sediment studies were made when situating the intakes. The discharge in the Hadejia River from the Tiga and Challawa Gorge dams towards the end of the dry season is maintained at higher than optimal levels to ensure that the sumps of Kano Water Supply are filled (Diyam, 1996 in Bdliya *et al*., 1999). The Kano State Government puts pressure on the HJRBDA to release more water in order to meet the requirements of Kano City. This consequently results in the flooding of downstream farmland (JEWEL, 2003). This is highly wasteful particularly during periods of low water availability (Bdliya *et al*., 1999).

Stream flow conveyance is hampered by the proliferation of blockages from weeds and siltation in the Hadejia river system. The blockages in the Old Hadejia River have prevented the Hadejia River from contributing to the Yobe River. These have not been cleared and have consequently continued to impede freshwater from reaching the main river channels. The water is instead restricted to the wetlands of the Hadejia-Nguru and does not reach downstream users.

8.1.5 Governance

No integrated management strategy: There is no overall water management strategy for the Komadugu Yobe sub-system (Bdliya *et al*., 1999). The Nigeria-Niger Joint Commission brokered an agreement on the equitable sharing of the water resources common to the two countries in 1989 and there are regular meetings between the two states, but there has been no capacity to promote compliance and enforce the agreement. The Commission provides an interface between the two countries that enables concerns to be discussed and conflicts to be resolved. However, this only tackles issues concerning the last 160 km stretch of the Komadugu Yobe that forms the border between Niger and Nigeria. The major water developments, which are located in the upstream States are not represented at these meetings. The Commission therefore does not enable integrated management of the entire Komadugu Yobe sub-system. The meetings are a forum to discuss problems, rather than long-term solutions for the water problems that face the entire region. The most acute obstacle in the management of water is the absence of a coordinating mechanism to harmonise the activities of the water users.

Institutional weakness: Out of the several government agencies and a couple of non-government organisations in the Komadugu Yobe Basin that have interest in the management of water resources, only two government institutions, namely; (i) the Federal Ministry of Water Resources (FMWR) and (ii) the Federal Ministry of Environment (FME), and four non-government organizations (the LCBC-GEF Project, the DFID-JWL Project, the FMWR-IUCN-NCF KYB project and the Stakeholders Consultative Forum) are concerned with the sustainable utilisation of the water resources of the basin. All the other institutions are inward-looking concerned only with meeting their water requirements, with minimal or no concern for the impacts of their activities on other users. The two River Basin Development Authorities (RBDAs), which are implementing agencies of the FMWR, are called the Hadejia-Jama'are River Basin Development Authority

(HJRBDA) and the Chad Basin Development Authority (CBDA). They both act independently of each other and their development-oriented mandates do not take responsibility for environmental protection. While the River Basin Development Authorities are required to control pollution in the projects, there is no specific provision for Health Impact Assessment (HIA), or for the mitigation and control of vector-borne diseases. Although Nigeria is known to have endemic schistosomiasis and other water-related diseases, the institutional arrangements for water resources development have not taken health issues into consideration (Ofoezie, 2002). Consequently, there is no agency that regulates and manages the water uses over the entire basin. Furthermore there are overlaps in the roles and mandates of the various governmental institutions in the basin. This scenario clearly called for a coordinating and control mechanism (Bdliya *et al.,* 1999). Consequently, the National Council on Water Resources accordingly set up the Hadejia-Jama'are- Komadugu-Yobe Basin Coordinating Committee. It however lacks statutory powers and has remained in effective.

Lack of coordination: The Nigerian water resource sector is treated as a different sector to the environment. The environment ministry is not consulted during the planning of water projects. They concentrate on managing toxic substances. When environmental problems from water resource projects did arise, the environment departments may be requested to assist. However they currently do not have expertise in water-related environmental issues. Consultants are often hired to assess the concerns, but the departments still lack the expertise to analyse the results of their studies and turn recommendations into policy. The Hadejia-Jama'are-Komadugu-Yobe Basin Coordinating Committee chaired by the Minister of Water Resources also includes representatives of the ministries of environment and health as members, but it has rarely sat. There is a lack of coordination and cooperation between riparian Nigerian States during planning and implementation of water projects (Bdliya *et al*., 1999). Water developments (e.g. the completion of the Hadejia Valley Irrigation Project) are implemented without execution of an Environmental Impact Assessment throughout the basin, which is exacerbating the inequitable water allocation and environmental damage.

Lack of water resource environmental planning: The Federal Government of Nigeria with increased revenues from oil exports during the period 1970-1980, focused on general expansion in all areas of the economy. Concerns over the food security for the rapidly expanding population resulted in agricultural policy focusing on increased production. It invested in large-scale agro-projects that included large dams for irrigation particularly in the Hadejia river system aimed at producing maximum yields in the shortest time (Neiland and Béné, 2003). The poor operation of these hydro-agricultural schemes is now posing a threat to the wetland ecosystems and downstream economies. The projects were planned with insufficient data (only those gathered during the wet periods in the 1960s), consequently, not much consideration was given to the climatic variability that has been demonstrated throughout the Lake Chad Basin's history. It was estimated by Hollis *et al*. (1993) that droughts lowered the flow at Gashua by 23% while the Tiga Dam lowered it again by a similar measurement. The consequences of reduced flows on populations in the downstream Nigerian States and Niger, whose productive systems are highly dependent on the river flow, was not sufficiently taken into account. Meanwhile, the governments of the riparian State Governments have continued to demonstrate insufficient political commitment, especially at the leadership level, with no long-term goals and objectives to solve freshwater shortage concerns.

Lack of stakeholder participation: The upstream dam developments had minimal stakeholder involvement. Decision-making and consultations were only made at the state and federal levels in Nigeria. Lobbying from communities and state officials for large dams have continued at the Federal Government level as capital required to finance the projects often exceed state financial capacity. Niger, which is located downstream of the basin was not consulted or considered during planning. There was no involvement of the public in the planning or implementation stages including the communities of the Hadejia-Nguru wetlands. At the Nigerian national level, the National Council on Water Resources, which is comprised of the state water authorities under the chairmanship of the FMWR, is responsible for coordinating water use (Bdliya *et al*., 1999). There have been concerns that only limited stakeholders are represented in the technical committees who make recommendations at these forums. The water authorities (RBDAs) control the dams and provide water services, thus they are both service providers and regulators at the same time. Additionally, the Federal authorities dominate the decision making process at the Nigeria-Niger Joint Commission and Lake Chad Basin Commission with little interaction with, and involvement of the State governments or local populations.

Government policy: Currently, there are few incentives or disincentives to encourage individuals or groups of water users to maximise water use efficiency and/or productivity. This is despite there being an active debate on this topic.

Legal Framework: Although Nigeria has some legislation related to water resources management, it does not promote integrated basin management. The text of Federal Government of Nigeria Water Resources Act, cap W2 of 2004 (Decree 101 of 1993 of Federal Government of Nigeria (1993)), predate the 1992 Dublin Conference which set the stage for IWRM. Furthermore, its provisions are yet to be implemented or enforced as the regulations and rules for administration and enforcement have not been published. In addition pollution studies will be required to monitor the impact on water availability and distribution of these in the environment, and to assist in the formulation of regulations regarding pollution, which are lacking in the current legislative framework.

Although, there is a policy of the National Water Resources Council, which stipulates releases of water from the Federal Government/River Basin Authority dams at a prescribed charge per m^3 to State Water Agencies downstream, the charges are neither paid nor even demanded by the RBDAs. For example, releases from the Tiga and Challawa Gorge dams to Kano State Water Corporation. There is however no water allocation law between Nigerian States or between Nigeria and Niger. The inadequate water for the downstream states has fuelled disputes between the downstream states of Borno and Yobe about who has the right to this diminishing resource. With no water allocation law for the entire basin, the uncertainty over water rights also transcends national boundaries. It has been argued that since Nigeria uses a large share of Lake Chad's water for irrigation, they have special responsibility in insuring the long-term sustainability of water use for all riparian countries (Isiorho *et al*., 2000).

It is also significant to note that prior to Decree No. 101 of 1993 (National Water Resources Act, cap w2 of 2004), water users in Northern Nigeria have had customary rights, which had the force of law, permitting anyone to make use of water where available for his personal needs and for his livestock and agriculture.

8.1.6 Capacity

Specialist knowledge: Although specialist knowledge and experience exist, there are not always readily available to, or used by, communities and the implementors of watershed development or rural water supply programmes. Careful targeting of interventions to particular physical, social and institutional settings is rarely practiced. Consequently, the tendency is to fund and implement the same interventions everywhere, regardless of the setting or priority needs.

Capacity to promote compliance and enforce agreements and policies: The LCBC lacks the capacity to enforce issues under its mandate. Earlier agreements in the Komadugu Yobe sub-system had guaranteed that certain amounts of flow from the Hadejia river system would be released for downstream communities. For instance, the Bagauda Agreement which emerged after the construction of Tiga Dam in 1974 stipulated the long-term average annual flow at Gashua as minimum guaranteed flow at Gashua. This has not been implemented (IUCN, 2003a).

8.1.7 Knowledge

Public awareness: Information is only disseminated amongst the scientific community and to governmental departments and agencies. This information seldom filters down to the communities such as those in the Hadejia-Nguru wetlands, partially due to poor communication infrastructure and a lack of consideration by policy makers of local management systems. The Water Audit has also shown that, in general, there is a lack of awareness at all levels, of the severity and complexity of water resource problems in the basin.

Poor quality information: Much water-related decision-making are based on official statistics that are incorrect and/or out of date.

Information sharing: There is weak information sharing networks between the Federal agencies and the State governments as well as between the two riparian countries. The Nigeria-Niger Joint Commission has meetings where some information is exchanged verbally; however these meetings primarily resolve disputes it does not have a clear information dissemination mechanism. Environmental and hydrological data are rarely widely dispersed among various Federal ministries and their agencies, and thus they are difficult to access (Lemoalle, 1997). For instance, the water resources Master Plan was scantily disseminated and is rarely used nor has it been updated since it was produced in 1995.

An insufficient knowledge of water resources and the functioning of aquatic ecosystem: Although the basin is the most studied region of the Lake Chad Basin yet it still lacks a comprehensive model that is able to predict the hydrodynamic reactions of proposed water projects. The current models could be significantly improved with the provision of and up-to-date application of remote sensing and GIS. There is a lack of hydro-meteorological information to support decision-making in the region and monitoring networks have not been operating since the late 1970s (IUCN, 2003a). Information networks on river flows and sediment loads are particularly weak. There is presently a lack of knowledge regarding future climate changes and its impact on water infrastructure, ecology and socio-economic status of the basin.

Scientific resources: Nigeria and Niger authorities place inadequate importance on scientific and technical research, which can be partly blamed on financial difficulties. The region lacks adequate professional human resources and monitoring and evaluation facilities. The Federal Ministries do not disseminate or coordinate research efforts.

8.1.8 Miscellaneous Socio-Economic Issues

Irregular Energy supplies: Frequent shortage of petrol encourages farmers to over-irrigate when petrol is available. Frequent and prolonged power cuts, particularly during summer months, as well as power surges that often damage transformers and, thereby, causing disruption of water utilities operation leading to shortages of treated water for domestic use.

Short-termism: There is a belief, generated in part by watershed development propaganda, that there are quick fixes to the water-related challenges facing communities in the downstream communities: simply stop all further water resources development works upstream but do so without regards to the others further downstream.

Water-related myths: A number of water-related myths have become accepted wisdom at the policy level in Nigeria, the most damaging being that by ignoring the matter it would go away or by stopping all water resources development the situation would be improved or that government must do all things. Subscription to these myths has led to poor decision-making, ineffective policies and wastage of financial and human resources.

Small and fragmented land holdings: In general, farmers have holdings that are becoming increasingly fragmented. This makes good land husbandry and good water management difficult.

8.2 Water-Related Risks

Experience in the basin has shown that there are a number of water-related risks associated with watershed management and with the resource protection measures implemented as part of improving water governance programmes. These include the below.

8.2.1 Unsustainable Use of Deep Aquifers

The issue of changes in water table although regarded as having a moderate impact due to the reduction in the wetlands and lake and therefore their aquifer recharge function, the indiscriminate sinking of boreholes that are often uncapped and free flowing is considered to be unsustainable. There is however a lack of adequate information on groundwater reserves and the full impacts of abstraction are not fully known.

Increased borehole drilling by individuals: In most cases, the prime motivation of such individual is to become self sufficient in potable water supply, but it is also encourage profligacy in water use. At the watershed scale, this is justified only if the resources that are being "harvested" do not have a higher value if they are put to other uses.

Deterioration in some village water supplies: There is a high risk that some project interventions will reduce runoff into wetlands or other structures that are important sources of recharge of the aquifers that meet rural water requirements. Some project interventions have also led directly or indirectly to increased pumping of groundwater for irrigation in urban and peri-urban areas, thereby, increasing the risk of failure of village water supplies during the summer months. Finally, some of such project interventions are leading to increased consumption of water: per household, by livestock, by horticulture within the village and by land and non-land-based activities.

8.2.2 Exploitation of Shallow Aquifers

Increased tubewell and washbore construction and increased irrigation by "poor" landowners: Successful water development projects often improve the financial status of relatively poor farmers. Consequently, the National Fadama Development Project has been providing loans for constructing tubewells and washbores and installing pumps. This is fine as long as the water they "harvest" is renewable i.e. does not exceed the annual recharge rate and have no alternative higher-value uses (e.g. as a source of domestic water supply).

8.2.3 Conflict Between and Within Communities

Large dam developments in the upstream of the basin have had potentials to cause conflicts due to downstream users receiving insufficient amounts of water to meet their requirements. There has also been significant migration from the north of the basin as "environmental refugees" have fled drought, increasing the pressure on natural resources and inciting social tensions.

Some interventions, that involve changing land use or patterns of water availability and use, result in distinct winners and losers. If there is a risk of this happening, conflicts should be managed by ensuring that losers are compensated in some way. As above, decisions on whether an intervention should take place should be based on economic and social value.

Reduction in net productivity: There is a risk that promotion of interventions with a high social value will lead to reductions in net productivity at the village or watershed scale. For example, use of water for irrigation on marginal lands (usually owned by poorer farmers) will tend to be less productive than use of the same water on better quality land (usually owned by relatively richer farmers). Ultimately, determining the balance between acceptable social and economic value is a political decision.

8.2.4 Environmental Degradation

It is generally assumed that an increase in forestry equates to environmental improvement in watersheds and that this is sufficient in terms of meeting environmental sustainability targets. In many cases, increased forestry will lead to significant improvements in biodiversity, particularly if indigenous tree species are planted. There are risks, however, that changing patterns of land and water use and, hence, the hydrology of watersheds will lead to reduction in biodiversity in areas other than forested areas (e.g. in wetland areas, in ephemeral streams, in and around reservoirs). There is also a risk that some project interventions will adversely affect water quality (e.g. pollution resulting from: increased use of agro chemicals).

Lack of incentives promoting environmentally sound practices: There is an absence of economic instruments, incentive measures, and specific programmes to promote and support local initiatives (World Bank, 2002). For example farmers have no incentive to conserve water, as they do not pay economic quantitative rate for the resource. This has encouraged farmers to grow crops such as rice, which fetch high market prices, yet are water intensive.

Inadequate valuation of environmental goods and services: Water diversion as part of the Komadugu Yobe irrigation projects e.g. the Kano River Irrigation Project supplied by the Tiga Dam, did not take into account the essential income and nutrition benefits in the form of agriculture, grazing resources, non-timber forest products, fuel wood and fishing provided for local communities around the Hadejia-Nguru wetlands. The wetlands also serve other wider regional economic purposes, such as providing dry-season grazing for semi-nomadic pastoralists, agricultural surpluses for neighbouring states, groundwater recharge of the Chad Formation aquifer and 'insurance' resources in times of drought (Barbier *et al*., 1997).

According to the Ramsar Convention on Wetlands the present value of the aggregate stream of agricultural, fishing and fuel wood benefits were estimated to be around 34 to 51 USD per ha (1989/90 prices based on the maximum flood inputs) (Barbier *et al*., 1997). The Hadejia-Nguru wetlands have declined by 210,000 to 230,000 ha. It is therefore estimated that decline in this wetland has had an economic cost of between 7.1 million and 11.7 million USD. However, it must be noted that this has been a result of both upstream water developments and climatic variability.

8.2.5 Deepening of Poverty

Endemic poverty faced by the population of the basin is a catalyst for environmental degradation. For their short-term survival the communities exploit natural resources at an unsustainable level. The people suffer greatly from the effects of freshwater shortage that has prevailed over the past 40 years. The prevalence of poverty in the basin requires special attention regarding water allocation. There has consequently been severe food insecurity in some part of the region and a proliferation of diseases.

In the basin, the rural population is highly differentiated and the poor, critically, do not have access to fishing and farming resources (Bene *et al*., 2002). This can be attributed to the predominance of traditional management systems at a local level (83% of Nigerian villages) and the absence of strong modern systems, which results in the majority of the benefits from water resources, such as the fisheries, being retained by a powerful elite minority, including local leaders, their extended families, and other prominent people and their associates (Neiland and Béné 2003).

Causal Chain Analysis, Policy Options and Recommendations

9

9.1 Preamble

The Causal Chain Analysis (CCA) is intended to support the decision support system to identify priority policy options and recommendations that were considered in CMP. Decision support system is primarily a simulation of natural environment, and by identify the root causes of the environmental and socio-economic impacts resulting from those issues and concerns that were prioritised, namely water shortages, irregularity in stream river flows, equity of allocation of water among others, stakeholders would be better placed to develop and select appropriate policy options and interventions.

CCA is based on procedures employed in the UNEP/GEF Global International Waters Assessment (GIWA) and involves the development of an analytical model based on identified local information. On the basis of the causal chain analysis feasible policy options that target the key component problems in order to minimise future impacts on the environment were recommended. The key criteria used in selecting recommended interventions from a wide range of potential policy options proposed by stakeholders, key political actors and experts were capacity to implement, institutional appropriateness, as well as political and social acceptability. The policy options and recommended interventions presented in the report have been further analysed in the preparation of Catchment Management Plan (CMP). The recommendations are therefore intended as broad contribution to policy processes and general debate among stakeholders in the basin.

For each area of concern, commencing with matrices showing the linkages between critical problems, a causal chain model was formulated. The causal elements cited in the matrices were considered and the relationships among them determined, starting with the establishment of the primary, secondary, tertiary and root causes. To facilitate the analysis the following guidelines, based on the perception of the nature of the causes were employed as the broad criterion:

- Primary causes are those of a technical nature,
- Secondary causes are those of an economic nature;
- Tertiary causes are those of an institutional nature; and
- Root causes are those of a socio-political nature.

A graphic representation was also chosen that facilitates easier identification of the causal elements and their attributes. Moving always from the right to left, from the root causes towards the problem, the causal-effect relationships are represented by means of connecting lines with their attributes, in terms of priority and trends. Furthermore, values were assigned to each one of the elements and their attributes, in order to facilitate the final analysis of recommended strategic actions required to be implemented, based on the problems identified.

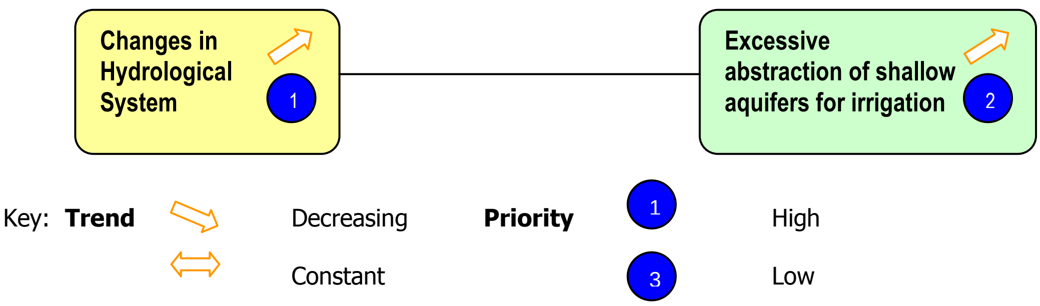


Figure 9.1: Typical representation of connections in causal chain analysis

In particular, attention was focused on those issues that relate to socio-economic losses associated with water constraints, institutional constraints and potential conflicts over water use, since the primary concern of the water audit is to address the water allocation.

9.2 Identification of Critical Themes and Priorities for Action

The preparation of the Causal Chain was the bridge linking the water audit and preparation of catchment management plan. Although the analysis used the outcome of various stakeholder discussions as the primary baseline, it nonetheless was the outcome of a professional multidisciplinary consultant work, that took into account biodiversity, water resources, agriculture, teaching and research as well as the regional and inter-institutional cultures of governance.

The Causal Chain Analysis was based on information from the outcome of stakeholder discussions, several knowledge-based studies, the assessment from the water audit study and subsequent discussions at the state levels with senior government officers, line department specialists, senior researchers, NGO staff and KYBP staff led to the identification of the principal critical problems. The field interviews with stakeholders also made it possible to identify the causes of critical problems, and served as inputs for establishing their causal chains. In assembling the causal chain, the causes of each critical problem were analyzed by a team of consultants, so as to analyze the information and to ensure that it is consistent with the outcome of the decision support system.

From the preliminary analysis, the principal problems identified were those related to three main themes: those associated with changes in hydrological system, those related to socio-political organization and those associated with human activities. Each of these themes was further subdivided into associated critical problems as detailed below:

Problems associated with the hydrological system

- Emerging potential conflicts over water use;
- Economic and social losses including those associated to critical events (droughts and floods)

Problems associated with socio-political organization

- Political and institutional weaknesses and Poor utilization of IWRM best practices and instruments

Problems associated with human activities

- Land degradation and water pollution
- Loss of biodiversity

These major concerns were analysed to determine the degree of relative importance (priority assessment) for each cause, during which a value of between 1 for the most important causes, to 2 for moderately important causes and 3 for the least important causes. Consideration was given to information on major projects underway in the basin including the synergy between the three partner projects of FMWR-IUCN-NCF KYB, LCBC-GEF and DFID-JWL. Cross-referencing was made between the causes, under each critical theme and its characteristics, ranging from technical, economic, and institutional/socio-political. Furthermore, the status of the evolving trends of the causes under each critical theme were assessed and categorized as increasing, decreasing or constant. Accordingly, each block contains a trend assessment and a priority assessment. These indicators are to serve as a basis for determining priority actions under each critical problem and in future will serve as a basis for operation of the decision support system.

The causal chain flow charts for each critical problem, with the root causes, tertiary, secondary and primary causes represented by blocks and lines that shows the logical relationships between them are as shown in Figures 9.2 to 9.6. For ease of referencing, each block has been assigned identification codes: R for root causes, T for tertiary causes, S for secondary causes and P for primary causes. Each of the critical problems identified would be elaborated below.

9.2.1 Emerging Potential Conflicts over Water Use

Freshwater shortage has been considered by GIWA assessment study and indeed all knowledge based studies to be the most critical concern in the Lake Chad Basin. The Komadugu Yobe Basin remains one of the hotspot. The considerable decline witnessed recently in the basin potential water resources can be attributed to both natural and anthropogenic factors. Emerging potential for conflicts over water use in the basin can be ascribed to the absence of integrated water resources management in the basin. The lack of IWRM policies, institutions and management instruments to lay the foundation for articulate and proactive management of the scarce water resources, has been compounded by insufficient quality information. Furthermore, absence of a forum for all stakeholders to participate actively in decision making have all combined to create potential for conflicts among users, the great majority of whom are not aware of the conflict resolution and participative instruments foreseen by the formation of HJKYBCC.

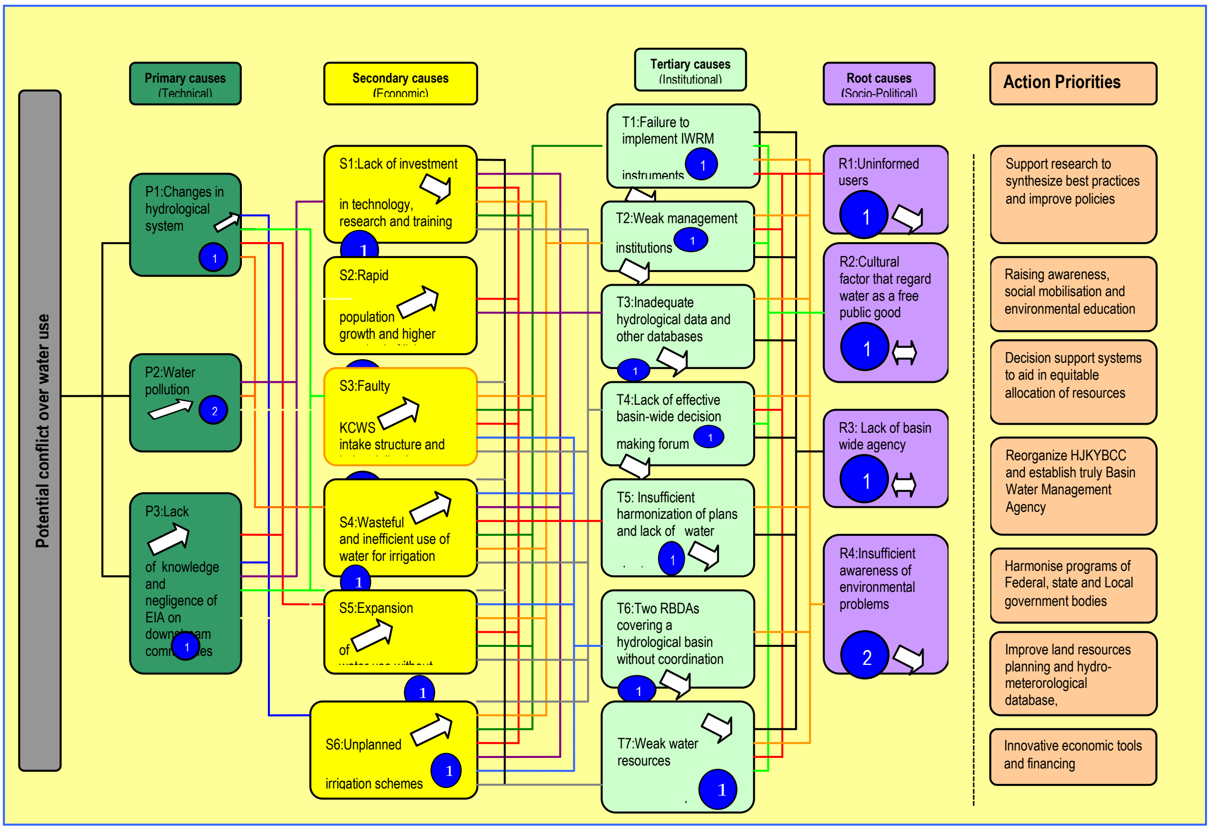


Figure 9.2: Causal Chain – A1 Emerging Potentials for Conflicts over Water Use

There has been a substantial increase in population and high water consumptive economic activities in the basin. In particular, there has been significant increase in irrigated agriculture, livestock rearing, mining and tourism. As a consequence, the demands for water for irrigation, watering livestock, domestic and industrial water supply have increased significantly. At the same time, the equally significant deterioration in water quality arises from ineffective quality control and as direct consequences of increased demand from industries and none point pollution from agricultural chemicals arising from run-off from the farmlands, animal and human wastes and poor disposal of waste water.

The field interview revealed that few stakeholders and water users in the basin perceive water as being a public good, with economic value. This is a reflection of awareness and sensitization of the local population as has been confirmed by the socio-economic and environmental study. Likewise, institutional weaknesses of the organizations responsible for environmental and water resources management as reflected by limited capacities among the stakeholders, planners and managers as well as the inertia in implementing proven IWRM instruments remain a source of concern. Poor hydro-meteorological and cartographic databases are also contributing to exacerbate potentials for conflicts between water users by making logical decision tenuous.

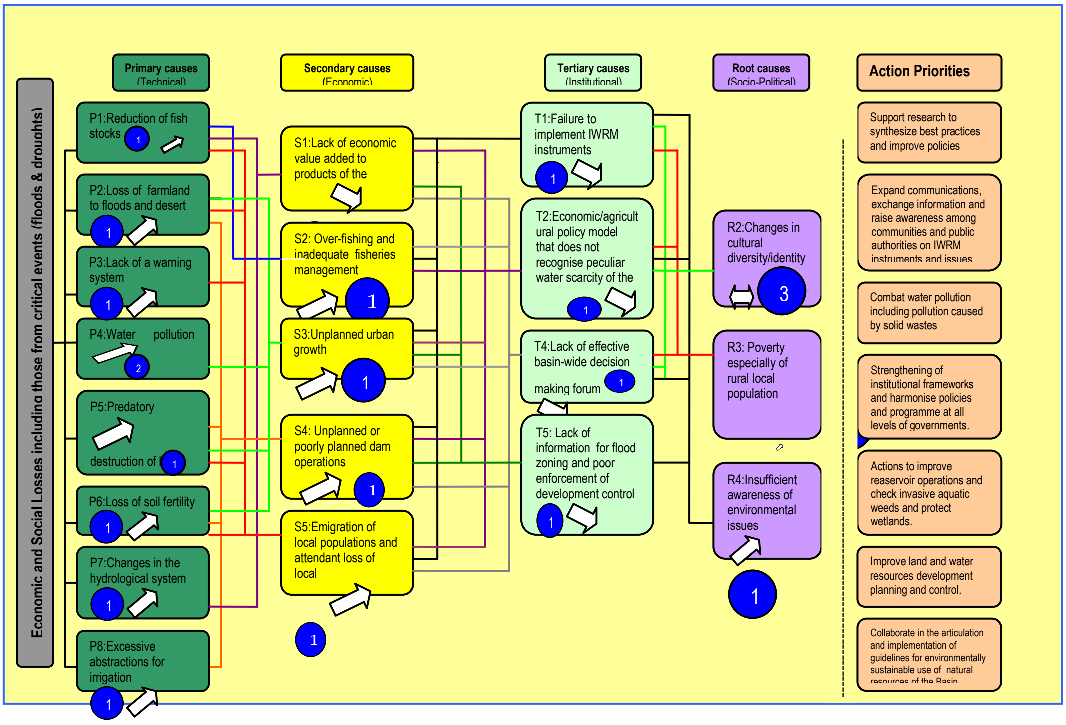


Figure 9.3: Causal Chain – A2 Economic and Social Losses including those associated to critical events (droughts and floods)

9.2.2 Economic and Social Losses including those associated to Critical Events (Droughts and Floods)

The theme of economic and social losses was included principally in recognition of the problem of uncontrolled flooding consequent upon the massive infestation of aquatic weeds that have led to siltation and blockage of the river channels. To address the problem of this flooding, and to mitigate the scope of flood damage, basic measures are required that include mapping and risk assessments of areas most vulnerable to flooding, clearing of blocked channel, improved reservoir operations among others. Furthermore, the gentle gradients of the river channel in the floodplain, the low carrying capacities of the riverbeds and the flatness of the landscape has contributed to seasonal phenomenon of flooding, the situation which was often worsened by poor reservoir operations. While, the nature of the floods would not warrant engineering works as a defense, it is nevertheless appropriate to implement non-structural measures, such as flood mapping, zoning of areas, real-time early-warning systems based on adequate hydrological monitoring of rainfall and river gauging.

The floodplains and the Hadejia-Nguru wetlands support a significant proportion of the basin's population, providing them with source of income and nutrition in the form of agriculture, grazing lands, fishing, non-timber products, fuel wood, drought fall back security and tourism potential. Ramsar estimated between 34 to 51 USD per ha as the economic value of the wetlands (Barbier *et al*., 1997) following which Schujit (2002) estimated the total economic value of the Hadejia-Nguru wetlands to be 15.9 million USD (see Table 9.1).

Table 9.1 Economic values of the Hadejia-Nguru Wetlands, valued using market pricing

Wetland goods or services	Economic value per annum converted to 2002 (million USD)
Agriculture	10.7
Fishing	3.5
Fuel wood	1.6
Doum palm	0.1
Potash	<0.1
Total economic value	**15.9**

(Source: Schuijt, 2002)

The problems of unplanned urban and rural growth, coupled with migration towards the upper reaches of the basin in pursuit of better opportunities are another set of socio-economic issues. The rural to urban migration as well as the rapid demographic growth are stretching the basic infrastructure in the urban centers. Meanwhile, those migrating to urban center are predominantly the able bodied young men, this is depriving agriculture their services and putting additional stress on food production system.

The floodplains and wetlands have been intensively cultivated and frequented by domestic animals, especially during the dry season, when the nomadic pastoral groups migrate southwards in search of grazing areas. In particular, the Hadejia-Nguru wetlands host approximately 120,000 cattle in the wet season which increases to about 320,000 cattle in the dry season, 370,000 goats and 375,000 sheep (using aerial reconnaissance). The North East Arid Zone Development Programme (NEAZDP) estimated that there could be twice as many in the dry season and that is beside intensified agricultural production, areas claimed for human settlements and as bases for fishing. These anthropogenic activities have had significant impacts on the wetlands.

The fisheries are largely dictated by the intra-annual flood regime. The largest fish market in the Lake Chad Basin is Baga-Kawa on the lake shore in Borno State of Nigeria. The majority of fish caught in the Lake Chad Basin regardless of country of origin is directed into Nigeria. Like the communities on the shore of Lake Chad, fishing is also a critical activity of the floodplains and is practiced strictly within a seasonal matrix of various activities. Over-fishing has resulted in the decline in fishstocks, especially of the most commercially attractive species, and has caused a consequent sharp decline in income among riverine communities. Among the commercially attractive fish species before the 1972-1974 Sahelian drought were *Lates, Hydrocunus, Labeo, Citharinus* and *Distichodus* (Neiland and Béné, 2003). There are six key livelihoods associated with the fisheries, namely: fishermen, fish processors, fish wholesalers, fish retailers, fish gear dealers and boat builders.

Lack of coordination among the agencies, responsible for executing public programs and more specifically poverty alleviation program, has exacerbated these problems. Furthermore, unplanned agricultural activities based on high water consuming crop in complete disregard to the water scarcity situation in the basin not only deplete the resource but makes it difficult to attract investments in adequate infrastructure. It also makes it difficult to produce the kind of performance that produce good returns on investment while creating flashpoint for conflicts. Besides all of the foregoing, further economic losses stemming from loss of soil fertility, water pollution, and decline in biodiversity have been recorded. What is even more disturbing is the fact that the effects of these environmental changes are generally very expensive to reverse. Meanwhile, due to the ineffectiveness of the environmental agencies, such effects have simply been ignored, thus compounding the problems even the more.

To avoid further deterioration of the basin's environmental quality, while attending to the developmental needs of current and future generations, public policies are needed that would stimulate local enterprises that conserve water, strengthen the earning capacity of local communities and promote agricultural policies that would optimize the use of scarce water resources and at the same time ensure better control and enforcement of environmental standards.

9.2.3 Political and Institutional Weaknesses and Poor Utilization of IWRM Best Practices and Instruments

The critical theme of political and institutional weakness and poor utilization of IWRM instruments raises special concerns, because it is at the heart of KYBP. Its strategic importance in addressing other critical issues affecting the basin is not in doubt, as it holds the key to unlocking the interventions to address the other problems. The constraints arising from institutional weaknesses have for long been recognized by both the decision-makers and other stakeholders. The consensus has been that they require strong political will and motivation to produce the institutional reforms and actions needed to ensure environmental protection and foster basin-wide prosperity. The major constraints arising from institutional weaknesses can be classified in terms of their socio-political or root causes, namely:

- Insufficient knowledge and appreciation on the part of decision-makers with regard to environmental problems, IWRM policies, best natural resources management practices and instruments;
- The communities are ill prepared to participate effectively in common resources management, nor have they been assisted to acquire the required capacity to do so;
- Insufficient political will, absence grassroot advocacy group and low levels of citizen participation at all levels.

Insufficient knowledge and appreciation on the part of decision-makers with respect to the desired water resources policies for IWRM has been the most critical factor in the emergence and exacerbation of numerous governance problems in the basin. Such problems tend to generate others that all culminate in hampering actions required to institute IWRM for the basin. To a great extent, the problems of political and institutional weaknesses and the failure to deploy IWRM instruments derive from structural flaws in the current decision-making process. There are currently two RBDAs supervising the basin, with no coordination except through HJKYBCC, which is neither a statutory body nor does it have any direct influence on the activities of the two RBDAs. Meanwhile, there is also fragmentation of ill-defined and often conflicting responsibilities among many players engaged in water resources and environmental management in the basin. Their programmes are not harmonized nor coordinated. Furthermore, these problems, in turn reflect upon the lack of capacity on the part of the communities to participate effectively in basin management. Such unpreparedness has tended to accentuate existing problems, with members of local communities being reluctant to assume the role of agents for change, by shunning responsibilities and adopting a narrow mind-set that makes them opposed to all attempts at instituting sustainable management practices in the basin.

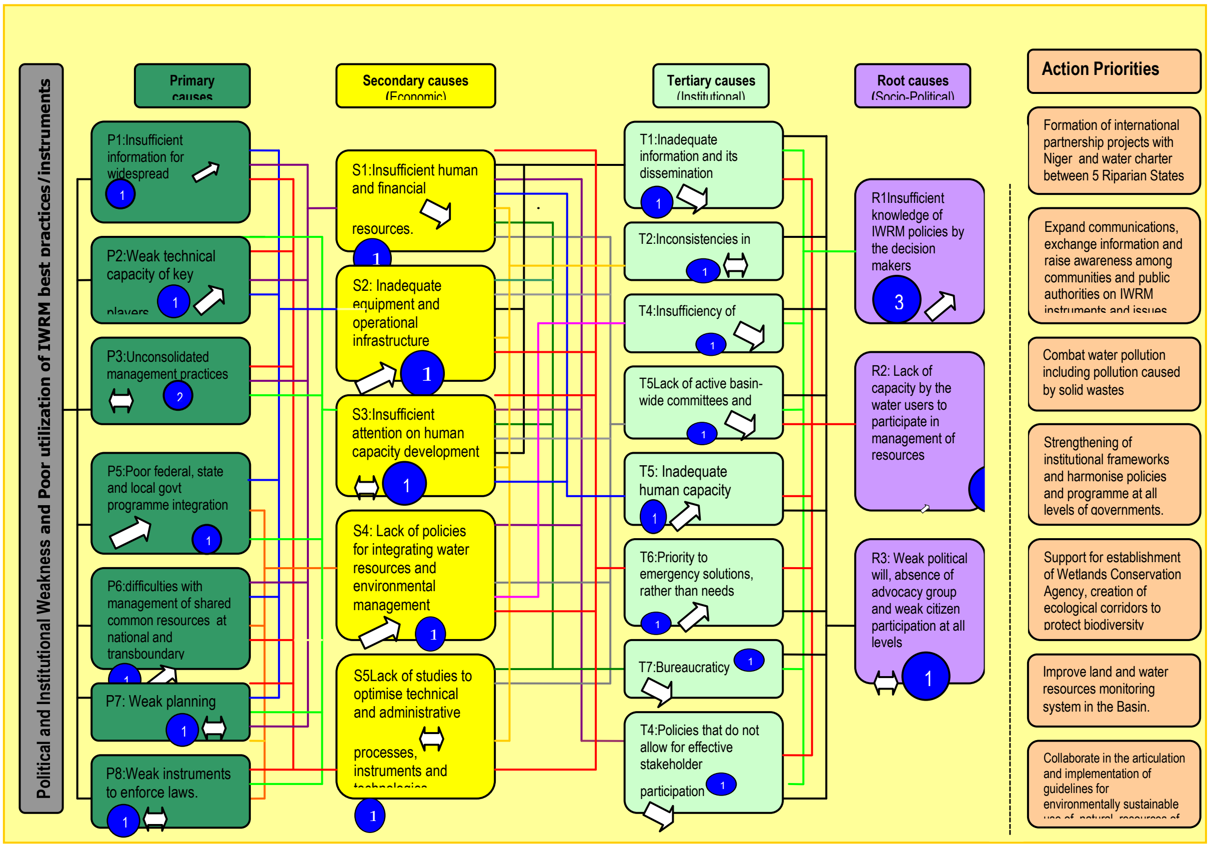


Figure 9.4: Causal Chain – B1 Political and Institutional Weakness and Poor Utilization of IWRM Best Practices/Instruments

Among the many undesirable consequences of the institutional weaknesses are:

- The failure to establish basin-wide water management agency and RBDAs inability to constitute their advisory committee as provided in their enabling legislation;
- Scarcity of adequately trained personnel and dwindling financial resources made available to the RBDAs to meet demands and priorities, as well as inadequacies in terms of operational equipment and infrastructure required to conserve and regulate water allocation and utilization;
- Limited understanding of and compliance with EIA laws, even on the parts of those responsible for deploying IWRM instruments, along with a lack of systematic process for mobilizing the society, applying water-use charges, and in enforcing environmental and water resources regulations; and

- Reluctance in exchanging information on water resources management issues.

Weak political will and motivation, public apathy at all levels would need to be reversed, to facilitate measures necessary for strengthening environmental and water resources management institutions in the basin.

9.2.4 Land Degradation and Water Pollution

The principal causes of land degradation in the basin are associated with endemic poverty faced by the population, overexploitation of natural resources, poor agricultural practices and overgrazing. Increased population has further led to greater pressure on the natural resources of the basin. The concentration of population of the basin, which is estimated to be between 20-25 million (GIWA, 2004) has led to extreme pressure on the fertile floodplain. These changes have been accompanied by flooding and erosion that has resulted in considerable loss of soil nutrient.

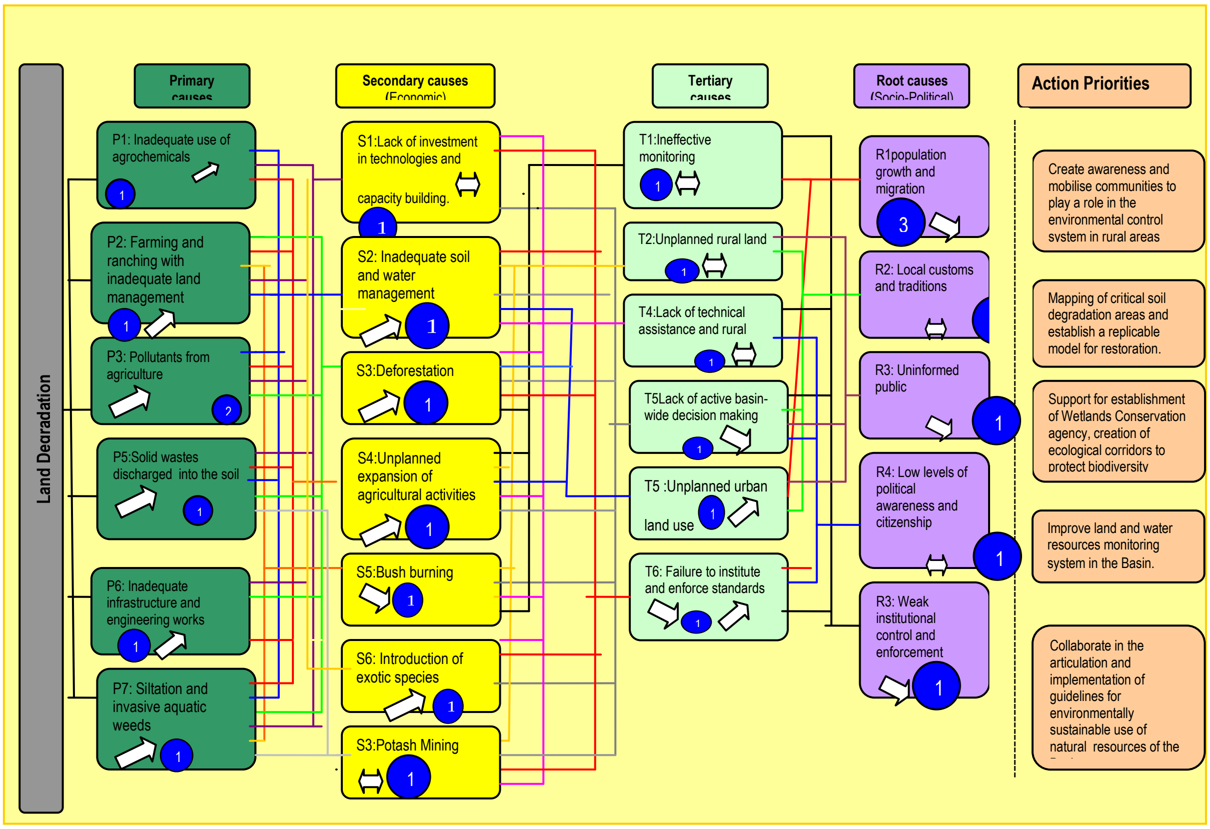


Figure 9.5: Causal Chain – C1 Land Degradation

The legislation though not adequate in respect of land degradation and loss of biodiversity, yet even the inadequate provision is seldom implemented owing to weak enforcement and low level of environmental awareness. Erosion and related problems, especially from the headwater areas of the fast flowing streams that run down to the floodplain of Chad formation has aggravated problems of siltation, transport of agrochemical and interference in migratory patterns of fish in the basin.

There are other various causes of land degradation that stem from other human activities in the floodplain and Nguru-Hadejia Wetlands. Recent studies have shown that considerable deforestation, overgrazing and other land impacting activities are taking place in the wetlands, which have resulted in modification of vegetation cover. The spread of *Typha* weeds and the constant trampling of the floodplains by cattle have affected the structure of the soil.

Overgrazing and overcultivation are considered to be the most significant causes of desertification in the basin, as grazing removes the little vegetation cover and expose the soil to processes of wind and soil erosion while overcultivation leads to unsustainable consumption of soil nutrients. The lands are now being replanted without sufficient fallow time. Large areas have thus been rendered useless for future regenerations because substantial quantities of soils and nutrients were removed by these processes thus limiting its future productivity. Nigeria estimates that it losses up to 5.1 billion USD annually from environmental degradation, out of which desertification (and soil erosion) accounts for close to 73% (FGN, 2002). It has been estimated that between 50% and 75% of Bauchi, Borno, Jigawa, Kano and Yobe States in Nigeria are affected by desertification. Overall, the country is estimated to be losing close to 350,000 ha of its landmass annually to desert-like conditions, thus desertification has been advancing southwards at a rate of about 0.6 km per year (FGN, 2002).

Land degradation is being exacerbated by increase in human populations, with the result that in many areas in the basin the sustainable yield threshold of the vegetation and soils is being breached. Furthermore, increasing population pressure on the limited and fragile natural resources has been aggravating continuous overexploitation of the marginal lands resulting in further degradation even during years of normal rainfall. The steady deterioration in the Northern States of Nigeria has continued largely ineffectively challenged for several years (FGN, 2002).

Presently there is insufficient information on water pollution. There is relatively little industrial and mining activities in the basin, except around Kano and the potash mining around Gashua. Effluents discharge directly into the river particularly in Kano City from tanneries and textile production have led to localized fish kills. Untreated domestic wastes are also being discharged into the rivers of the basin with negative effects on quality. Agro chemicals washed away from the farmlands as well as reduced stream flows have caused the proliferation of weeds, mainly *Kachalla* grass (*Typha sp.*) that have encroached into reservoirs and clogged channels near Madachi, Kirikisama and Nguru and hampered freshwater use. It has also been reported that water quality in the Hadejia River has been declining, with increased salinity (World Bank, 2002a).

9.2.5 Loss of Biodiversity

The upstream of the basin is estimated to contribute a total long-term natural yield of about 7 km^3/year. This has however been significantly changed in part by human stream diversion and in part by impact of drought. The proportion of the influence and the role of these factors remain to be fully studied and ascertained. The drought of the 1970s and 1980s severely affected the basin most especially the eastern half of the basin. This drought prompted massive construction of dams on the Hadejia River system has negatively affected the hydrology of the Yobe River.

The largest irrigation scheme in the basin – Kano River Irrigation Project (KRIP) is located upstream. It is fed by Tiga Dam that was completed in 1974 and has an active reservoir capacity of 1,400 million m^3. In 1992, the spillway level was lowered the preserve the structural stability of the dam, this resulted in a 31% reduction in its storage capacity. The dam also provides water to Kano City. It is reported that before the construction of Tiga Dam, Hadejia River system use to have relatively strong stream flow during the months of June to October and accounted for 98-99% of annual flow of Yobe (UNEP, 2004). This study however revealed otherwise, the contribution of Jama'are River system is certainly more that 2% of the Komadugu Yobe system.

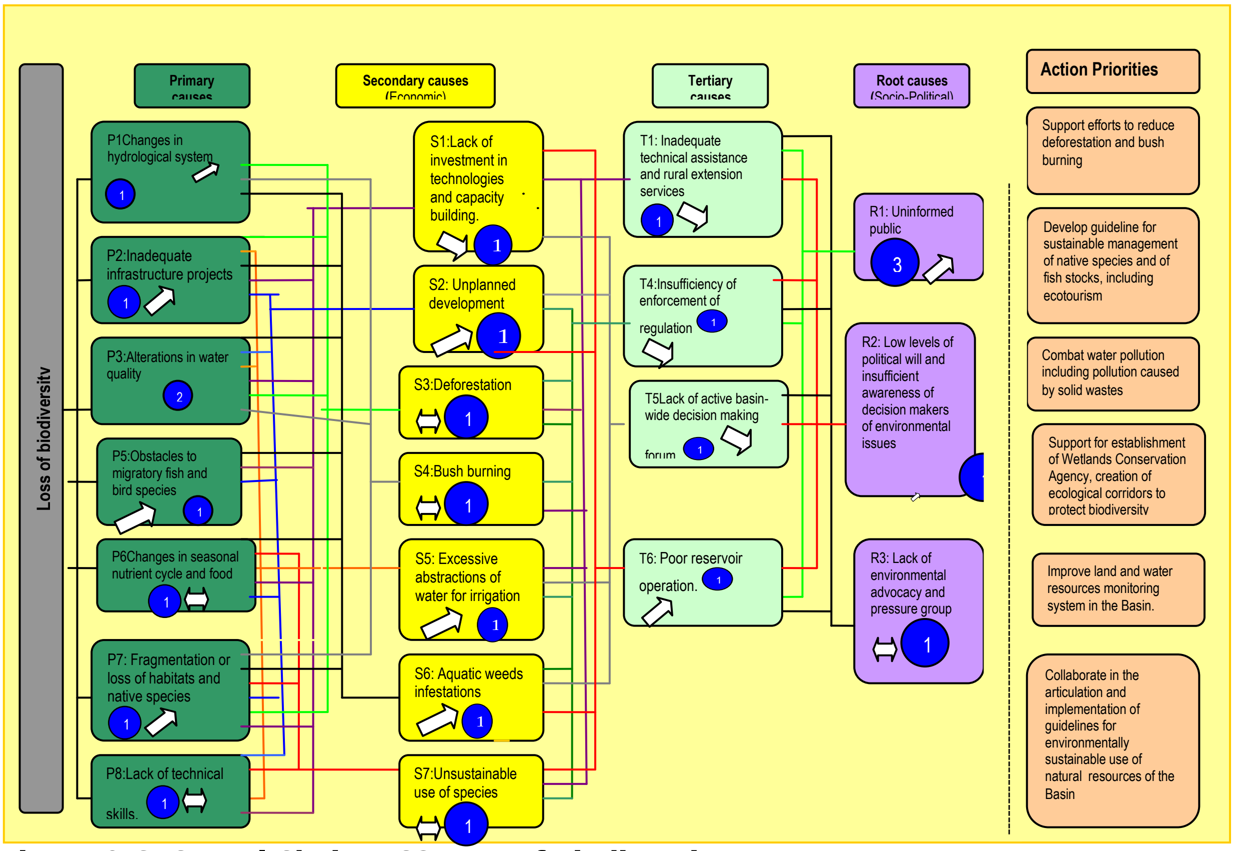


Figure 9.6: Causal Chain – C2 Loss of Biodiversity

The Challawa Gorge Dam on Challawa River a tributary of Hadejia River has a reservoir capacity of 972 million m^3. It was commissioned in 1992 and provides water to supplement releases from Tiga Dam to Kano City and into Hadejia River for subsequent storage in the Hadejia barrage to supply the Hadejia Valley Irrigation Project. If all the 20 dams on the Hadejia River system were to operate at their design capacity the total reduction of flow at Gashua would be in the order of 76million m3. Meanwhile, since the 1974, dry-season water releases from the dams upstream have modified the dry-season flow from hitherto zero flows to almost a perennial regime. These are in part responsible for the invasive aquatic weeds infestation and other negative impacts on the ecological systems downstream of Gashua (Oyebande, 2001). The absence of an articulate integrated river basin management strategy has allowed the uncoordinated operations of the dams to persist which have aggravated growth of invasive weeds and silt blockages along the old Hadejia Rive channel that have prevented its contribution to the Komadugu Yobe. This in turn has impacted drastically on the ecology of the basin, such as decline in wetlands extent which has proportionately decreased the fish abundance in the wetlands and taken out more than five species in the foodplain among other losses (Oyebande, 2001).

The predominant vegetation of the basin is woodland with an understory of long grasses, shrubs and herbs. The northern east portion hosts mainly grasslands that are dominated by numerous short grasses. Shrubland that is scattered in patches can be witnessed throughout the basin. Riparian forests occur along many of the waterways and small areas of adaphic vegetation such as grassy floodplains or *fadamas* are found in the basin (UNEP, 2004). There are significant differences between the vegetation found on the higher reaches of the basin towards the Jos plateau and that found in the wetlands where seasonal flooding is a dominant factor, as well as the fringes of Lake Chad that is characterized by drought.

The gentle slope of the floodplain from south-west to north-east, the effects of seasonal flooding and the gradual ebb of its water create a complex of luxuriant natural habitat that shelter a relatively rich fauna, including a number of endemic species. Common large animals are vervet monkey (*Chrolocebus aethiops*), baboon (*Papio hamadryas papio and Papio hamadryas anubis*), bushbuck *(Tragelaphus scriptus),* warthog (*Phacochoerus africanus*), and savannah monitor lizard (*Varanus exathematicus*). Most large mammals have been heavily poached with most surviving species found sparsely in the National Park. World Bank study (2002a) estimated that irrigation developments and decreased precipitation have caused a significant shrinkage of Hadejia-Nguru Wetlands from between 250,000 and 300,000 ha in the 1960s and 1970s to the more recent 70,000 to 100,000 ha. The pronounced dry season which corresponds with winter in the higher latitudes signals migration of fauna within and without the region; including the annual passage of migrant birds on the Afrotropical-Palaeartic flyway (UNEP, 2004). The number of birds in the Hadejia-Nguru Wetlands is correlated with the extent of the wetlands. Consequently, abundance of birdlife has been reduced.

Firewood is the predominant source of fuel for basin's population. Furthermore, there has been expansion of agricultural land to meet the rapidly increasing population demand of the basin. Unsustainable forestry and agricultural practices to meet increased demand for firewood and food has resulted in the over-harvesting of the basin's woodland resources, habitat modification and acceleration of destruction of wildlife habitat on the remaining non-cultivated areas. Although, a number of forest reserves were developed in the basin, especially areas that are being heavily exploited by commercial firewood harvesters for large urban centers, not much has been done to protect or expand these forest reserves in the recent. Neiland and Verinumbe (1990) estimated that the demand for wood in Nigerian sector of the Lake Chad (which KYB constitutes the majority) probably exceeds the available supply as shown in the Table 8.2. However, the relationship between supply and demand for wood can be complicated by several factors.

Table 9.2: Wood supply and demand in the Lake Chad Basin (Nigerian sector) for 1989

Total area of Lake Chad Basin – Nigerian sector (km^2)	136,000
Human population	22 million
Annual domestic wood demand (tonnes)	7.5 million
Annual sustainable wood extraction (savannah) (tones/km^2)	50
Area required to meet present demand (km^2)	150,000

Note: Figures based on best reliable estimates of wood supply and demand (Source: Neiland and Verinumbe 1990)

9.3 Policy Options and Recommendations

The study confirms that freshwater scarcity is severe and remains the priority concern of the basin and that governance issues are the most critical weakness responsible for the situation. Although other concerns have been expressed such as significant modification of habitats, losses of fish production, invasive aquatic weed infestation and even pollution, yet a close look as revealed above shows that all these are a function of and closely linked with fresh water shortage and inability to effectively manage the available resources that is at the heart of the problems. The wetlands and sensitive ecosystems have decreased primarily due to changes in the seasonal timing and extent of flooding (Oyebande, 2001). Freshwater scarcity arising from anthropogenic fresh water shortage issues such as unsustainable flow modification, weed infestation, irrational use of water, uncoordinated reservoir operations can be substantially addressed through greater political will, improved capacity building and utilization as well as effective use of integrated water resources management instrument.

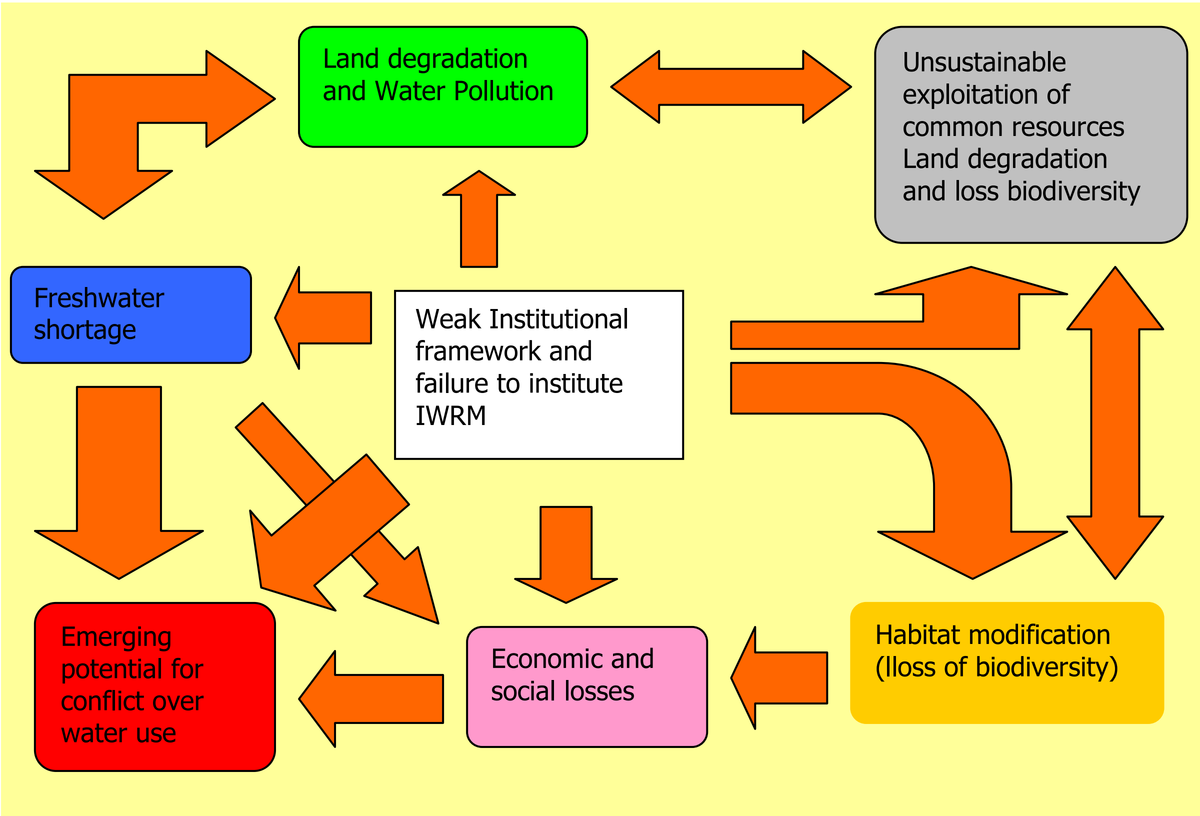


Figure 9.7: A model showing centrality of governance issues and of interlinkages and synergies of the five assessed concerns of the KYB and freshwater shortage

From the foregoing the obvious policy options are two: Implementation of Integrated Basin Management System and Instruments; and Sustainable Use of Water Resources and Environmental Restoration. These policy options would be examined further in the process of preparing a CMP. Meanwhile, some broad recommendations are proffered.

9.3.1 Summary of Main Recommendations

Recommendation 1: The following assessed concerns should be further assessed in the process of catchment management plan to identify activities that would promote a wider range of options/interventions and, in particular, options/interventions aimed at: protecting drinking water supplies, improving the access of poor households to water for productive purposes and reducing the impacts of flood and droughts on rural livelihoods.

Recommendation 2: Projects involving water governance activities should target and match interventions to the specific physical, social and institutional settings.

Recommendation 3: State-level water related participatory planning should take place within a wider *economic planning framework*.

Recommendation 4: There should be a much greater emphasis on water resource management and a shift of emphasis from supply to demand management of water resources.

Recommendation 5: A major effort is needed to update and improve the quality of the water-related information that is being used to underpin decision making at all levels. Effort should also be directed towards making information more accessible to potential users, particularly at the community level.

Recommendation 6: The CMP should be vigorously implemented, regularly monitored and evaluated (at least biannually) and the water audit should be updated and improved upon at interval of not more than five years so that information and DSS that is being used to underpin decision making are correct and reflect current situation on the ground.

The recommendations listed above should be viewed within the overall recommendation that the CMP should adopt. These are aimed primarily at building capacity at all levels in adaptive and integrated water resources management principles and methodologies.

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APPENDICES

Appendix 1: Study Objectives and Terms of Reference

The Coordinating Committee of Hadejia-Jama'are-Komadugu-Yobe Basin responded to the increasing evidence of deterioration of the basin's water situation and the river system, as well as the growing community concern by ordering the conduct of a Water Audit. The Water Audit is expected to serve as the foundation for comprehensive assessment of surface and groundwater availability, as well as the nature and magnitude of water demands. For a general outlook, a comprehensive water audit would involve the following:

- The assessment of water resources monitoring network in the basin
- The review and assessment of water availability and demand, taking into account traditional water-dependent activities and their related water requirements
- Limited analysis of water quality indices
- An assessment of the overall water balance including analysis of projected water demands for the future
- Creation of computerized Decision Support System (DSS) to aid policy-makers in the basin
- Preparation of a Catchment Management Plan (CMP).

In order to achieve the stated objectives, the activities of the assignment shall consist of:

a) Assembling all relevant hydrological, meteorological and water use data from all identified sources beginning with the FMWR-IUCN-NCF KYB Project database with particular attention to
    - Data on water uses, river flow, groundwater and meteorology for Nigeria and, where possible, Niger republic.
    - Digital daily river flow database submitted with Diyam (1996) report as well as monthly data on CD available at the FMWR-IUCN-NCF KYB Project office.
    - Published and unpublished Water Resources and Engineering Construction Agency (WRECA) data on river flow stations on the Komadugu River and the Yobe River downstream of Gashua.

- Information on inflow and outflow rates from the two large dams (Tiga and Challawa Gorge) as well as the Hadejia Barrage.
- The data from the well monitoring networks in the basin (Bauchi, Yobe, Borno, Kano and Jigawa States).
- Evaporation and rainfall data for the reservoirs.
- Rainfall data for the basement complex area and recent rainfall data for Nguru.

b) Constructing rating curves and calculating daily discharge data for the sites with only water level data and recent gauging; filling data gaps in runoff series.

c) Carrying out data quality checks with special attention to river flow data that have not undergone elaborate quality checks in the past, notably, the data from 1999 to date; as well as critical quality check and review of the following:

- data on size of irrigated areas and crop yields,
- proportion of drilled boreholes that are active and their abstraction rates,
- meteorological stations which provided and are providing reliable data with relatively few interruptions, and
- the monitoring wells which provided and are providing reliable data.

d) Interpreting all the relevant meteorological data collected by the FMWR-IUCN-NCF KYB project. This assignment covers:

- GIS maps showing all reservoirs in the basin, and isolines for rainfall and evaporation (long-term mean and mean for the past five years).
- Tables with measured or estimated current and long-term monthly evaporation and rainfall rates (based on the closest meteorological stations) for all the reservoirs in the basin.
- Work done on the rainfall-runoff relations for the basement complex area on the three main rivers.

e) Determining the environmental river flow requirements of the HNWs, Lake Chad and other ecologically valuable areas.

f) Analysing the shallow groundwater data (first aquifer) in the basin. The components of the analysis include:
   - interpreting the data from the identified monitoring well networks in the basin on long-term trends in water level,
   - preparing a GIS map that contains the monitoring wells with the identified long-term trends, the shallow groundwater abstraction points (with abstraction rates) and areas where the number of wells tapping the first aquifer will increase significantly,
   - comparing, per sub-section, the estimated annual recharge of the shallow aquifer (river bed, floodplain and rain-fed) with the present and projected shallow groundwater abstraction,
   - identifying, based on the prepared map, critical areas where over-abstraction from the first aquifer may occur, and
   - proposing locations and depths of wells that need to be included in the existing monitoring networks.

g) Determining the weekly surface water availability (very-dry year, dry year, normal year, wet year and very-wet year) for all the water audit sections in the basin on the basis of the statistical analysis of the river flow data.

h) Estimation of the annual shallow groundwater availability or recharge rates for the water audit sections under the different scenarios (very dry year, dry year, normal year, wet year and very wet year).

i) Quantification of, on monthly basis, the present water uses for all water audit sections in the basin (surface water and groundwater in the first aquifer); this involves estimating future water uses for the water audit sections for three future years (2010, 2020, 2030) for the different scenarios. Rank the future water-use scenarios on the basis of their likelihood, noting the following factors:
   - The rainfall distribution over the basin; e.g., areas that have a low potential for rain-fed agriculture are more dependent on river flow than areas with a high potential for rain-fed agriculture.
   - High annual variability in available water resources due to climate change.

- The cultural practices of the farmers in the floodplains (flood and flood recession agriculture).
- The environmental flow requirements in HNW and Lake Chad.

j) Building a Decision Support System (DSS) that calculates water balances on weekly, monthly and annual basis for all the water audit sections in the basin and all the combinations of the above mentioned present and future water uses and water availabilities. Create the possibility in the DSS for non-technical users to prepare their own scenarios. The DSS is expected to be in a format that is easily accessible to all the relevant organisations in the basin. The DSS should include graphical presentations of the data and scenarios in the form of graphs and GIS based maps. The chosen software for DSS should be approved by the FMWR-IUCN-NCF KYB Project. The suitability of the following software should be evaluated in developing the water management scenarios:
   - WEAP (Water Evaluation And Planning software from Stockholm Environment Institute). The software is based on monthly data and communicates well with GIS.
   - MS-Excel in combination with GIS. The advantage is that MS-Excel is widely used as a result of it flexibility. The disadvantage is that it does not have a nice graphical interface and that may require quite a lot of programming.

k) Developing a Catchment Management Plan (CMP) for the basin.

Appendix 2: Database of Rainfall Record

Table A2.1: Rainfall at Zaria

ZARIA	1	2	3	4	5	6	7	8	9	10	11	12
1943	0	0	21	1	165	121	130	447	255	0	0	0
1944	0	0	60	3	64	170	150	461	128	16	0	0
1945	0	0	0	21	82	92	267	410	224	49	0	0
1946	0	0	11	37	111	148	245	278	265	94	0	0
1947	0	0	0	0	140	110	165	349	181	46	0	0
1948	0	0	4	118	132	154	192	221	218	0	0	0
1949	0	0	2	5	133	186	198	398	148	4	0	0
1950	0	0	0	38	93	90	201	313	196	14	0	0
1951	0	0	0	0	0	129	285	329	320	63	0	0
1952	0	0	1	0	147	165	324	168	222	63	0	0
1953	0	6	22	0	193	91	257	203	187	23	0	0
1954	0	18	51	110	224	116	171	347	283	22	29	0
1955	0	0	19	36	101	227	268	298	350	84	0	0
1956	0	0	31	35	19	111	216	207	232	71	0	0
1957	0	0	0	45	156	161	260	338	299	100	0	0
1958	0	0	10	74	83	140	136	206	269	27	0	0
1959	0	0	16	19	163	136	190	292	241	17	0	0
1960	0	0	0	96	29	188	242	247	338	17	0	0
1961	1	0	0	36	68	238	153	100	176	0	0	0
1962	0	0	4	65	35	237	193	403	407	65	23	0
1963	0	0	0	53	105	252	189	275	132	147	0	0
1964	0	0	0	25	78	151	303	269	234	0	0	0
1965	0	6	0	43	38	348	196	233	134	41	0	0
1966	0	0	0	122	0	152	193	284	347	0	0	0
1967	0	0	1	40	33	158	312	107	259	0	0	0
1968	0	0	4	104	116	147	260	248	120	2	0	0
1969	0	0	0	50	45	185	350	210	140	55	0	0
1970	0	13	15	1	136	85	162	290	170	8	0	0
1971	0	0	2	0	95	40	219	350	188	12	0	0
1972	0	0	0	16	216	100	145	300	150	50	0	0
1973	0	0	0	5	32	165	250	220	200	0	0	0
1974	0	0	11.2	30	33.8	144.3	253	329	247	67.6	0	0
1975	0	0	0.3	85.8	130.3	135.5	303.7	113.4	210.7	8.4	0	0
1976	0	0	0	86.2	135.5	206.9	226.4	188.1	191	162	0	0
1977	0	0	0	0	78.3	101.7	59	302.7	199.5	4.3	0	0
1978	0	0	1.3	77.7	193.9	164.7	145.3	324.9	207.2	33.9	0	0
1979	0	0	10.4	19.8	86.3	220.2	373.8	299.8	142.8	30.8	9.8	0
1980	0	0	0	3.7	154.4	116.4	268.9	215.8	71.9	16.3	0	0
1981	0	0	0	100.7	90.7	159	214.8	280.6	133.3	0	0	0
1982	0	0	0	59.7	72.1	113.9	168.7	190.7	117.6	45.8	0	0
1983	0	0	0	0	73.3	74.3	107.5	259.7	93.4	0	0	0
1984	0	0	0	0	98.9	55.4	173.8	158.1	189	177.5	0	0
1985	0	0	64.3	0	120.6	87.2	348.8	250.8	190.9	5.8	0	0
1986	0	0	0	6.5	42.4	69.3	265.6	298.9	149.7	1.7	0	0
1987	0	0	1	0	91.1	149.1	247.4	356.1	93.8	35	0	0
1988	0	3.7	0	23.8	136	157.9	177.8	398.7	209.3	11.4	0	0
1989	0	0	0	21.5	110.1	89.3	146.4	286.1	68.1	64.9	0	0

ZARIA	1	2	3	4	5	6	7	8	9	10	11	12
1990	0	0	0	2.3	163.2	152.6	197.3	192.9	156.9	3	0	2.7
1991	0	0	42.2	75.5	323.1	100.3	255.9	366.5	75.9	30.7	0	0
1992	0	0	0	36.6	115.3	81.4	274.8	216.7	242.4	6.2	2.4	0
1993	0	0	1	39	84	88	244	282	200	19	0	0
1994	0	0	0	34	79	103	126	352	205	167	0	0

Table A2.2: Rainfall at Kano

KANO	1	2	3	4	5	6	7	8	9	10	11	12
1905	0	0	0	0	104.6	265.7	136.9	288.8	118.6	17.3	0	0
1906	0	0	0	0.3	84.8	117.6	214.6	396.5	118.4	28.4	0	0
1907	0	0	0	2.5	45	149.4	108.2	254.8	88.1	0.3	0	0
1908	0	0	13.7	5.8	29.5	104.6	260.1	344.4	115.1	0.5	0	0
1909	0	0	2.3	44.5	221	94.2	228.9	450.1	173.5	19.6	0	11.4
1910	0	0	0	0.5	24.9	104.6	205.7	227.8	117.3	0	0	0
1911	5.1	0	11.4	26.7	118.4	136.9	262.1	236.5	191.8	27.2	0	0
1912	0	0	0	33	8.1	51.1	124.7	317.2	201.4	6.1	0	0
1913	0	0	0	0	63.5	72.9	137.4	136.1	68.8	5.1	0	0
1914	0	0	0.8	0	13	94	201.2	254.5	114.3	7.1	0	0
1915	0	0	0	0	17	152.1	285.5	244.9	109.5	4.6	0	0
1916	0	0	0	31.8	127.3	110	217.9	283.7	215.9	2	0	0
1917	0	0	0	6.4	99.1	72.9	236.5	304	144.5	0	0	0
1918	0	0	0.3	41.4	8.4	222	158	451.9	151.9	1	0	0
1919	0	0	0	0	66	83.6	294.4	207.8	171.5	0	0	0
1920	0	0	0	0	99.8	111.5	326.9	387.4	168.7	3	0	0
1921	0	0	2	0	46.2	73.4	158.2	461.4	100.9	27	0	0
1922	0	0	0	0.3	6.4	65.2	213.9	388.6	208.1	29.2	0	0
1923	0	0	0	1	44.2	76.5	96.3	393.1	187.1	7.9	0	0
1924	0	0	0	0	11.2	88.3	270.1	316.7	109	16	0	0
1925	0	0	17.3	54.9	96.2	66.5	204.2	305.4	136.8	18.4	0	0
1926	0	0	0	0.3	32.8	176.8	191.3	246.4	51.6	1.3	0	0
1927	0	0	0	1	52.3	110.5	159.3	299	147.1	1	0	0
1928	1.5	0	1.3	11.7	83.5	93.2	197.9	286.5	132.6	42.4	0	0
1929	0	0	0	0	62	131.3	194.3	331	102.6	12.7	0	0
1930	0	0	0	0.3	83.1	93.7	308.6	326.6	159	24.1	0	0
1931	0	0	0	19.8	43.7	137.2	369.1	384.6	111.5	2.3	0	0
1932	0	3.6	0	2.3	11.7	126.5	240.5	270.5	236	114.6	0	0
1933	0	0	0.8	2.3	70.6	238	116.8	308.6	111	0	0	0
1934	0	0	0	61	76.7	145.8	172	264.6	99.1	1.8	0	0
1935	0	0	1.3	0	36.3	140	191.5	499.1	24.1	1	0	0
1936	0	0	4.1	9.7	122.2	122.7	301.5	279.4	140.2	0	0	0
1937	0	0	0	0	40.1	101.9	257.8	204	132.1	0	0	0
1938	0	0	0	2	47	103.6	257.8	403.7	276.1	22.9	0	0
1939	0	6.4	0	4.3	71.1	82	143.3	260.1	128	0	0	0
1940	0	0	0	0	113.5	150.1	180.6	244.1	93	30.5	0	0
1941	0	0	0	0	179.6	149.6	143.8	257	106.4	0	0	0
1942	0	0	0	0	84.6	93.5	76.5	254.3	111.3	0	0	0
1943	0	0		0.5	96.8	40.6	187.2	336.3	91.9	5.6	0	0
1944	0	0	0	0	11.7	70.4	39.1	295.9	52.8	14.2	0	0
1945	0	0	0	20.1	128.5	76.5	224.5	387.6	125.7	28.7	0	0

KANO	1	2	3	4	5	6	7	8	9	10	11	12
1946	0	0	0	7.9	70.9	112.5	207	215.9	173.7	13.2	0	0
1947	0	0	0	0	27.2	151.1	193.8	241.3	182.6	1.3	0	0
1948	0	0	0	7.4	23.6	93.5	217.7	299.7	58.7	0	0	0
1949	0	0	0	29.2	25.7	58.7	133.6	306.6	30.5	0	0	0
1950	0	0	0	3	17.8	84.8	261.9	406.1	138.9	9.7	0	0
1951	0	0	0	0	51	113	209	158	267	12	0	0
1952	0	0	2	0	224	109	187	339	150	24	0	0
1953	0	0	0	0	55	143	172	258	85	2	0	0
1954	0	1	0	28	164	112	355	287	118	34	4	0
1955	0	0	0	2	58	171	215	456	138	33	0	0
1956	0	0	2	0	1	76	292	315	63	10	0	0
1957	0	0	0	3	151	168	234	256	185	12	0	0
1958	1	0	0	14	26	248	217	258	63	0	0	0
1959	0	0	0	6	75	93	181	409	255	2	0	0
1960	0	0	0	31	30	73	293	252	77	1	0	0
1961	1	0	0	0	20	70	220	340	120	0	0	0
1962	0	0		0	80	280	190	330	200	40	0	0
1963	0	0	5	3	40	80	130	360	80	0	0	0
1964	0	0	1	1	60	60	206	260	71	0	2	0
1965	0	0	0	0	43	246	269	272	101	13	0	0
1966	0	0	0	15	112	94	97	305	155	2	0	0
1967	0	0	0	0	58	154	251	230	96	0	0	0
1968	0	0	0	105	75	147	113	123	47	0	0	0
1969	0	0	0	9	19	191	237	220	109	70	0	0
1970	0	0	0	0	22	55	315	283	235	3	0	0
1971	0	0	0	3	69	24	174	223	204	1	0	0
1972	0	0	0	3	100	128	71	239	45.5	5	0	0
1973	0	0	0	0	2.5	38	166	169	34.5	0	0	0
1974	0	0	0	0	41.6	42.4	261.6	198.1	109.2	5.6	0	0
1975	0	0	0	18.2	39.6	128	125	224	178	0	0	0
1976	0	2.3	0	0	42	99	132	123	66	60	0	0
1977	0	0	0	0	7	198	33	439	106	4	0	0
1978	0	0	0	35	74	198	309	258	30	29	0	0
1979	0	0	0	0	32	111	192	257	111	20	0	0
1980	0	0	0	0	94	123	283	311	68	35	0	0
1981	0	0	0	20	36	62	143	203	109	0	0	0
1982	0	0	0	18.6	66.2	62.3	157.9	261.3	70.5	1.3	0	0
1983	0	0	0	0	27.2	47.4	91.4	266.1	67	0	0	0
1984	0	0	0	0.3	52.7	81.7	157.5	50.5	118.7	17.3	0	0
1985	0	0	21.5	0	27.4	164.6	169.8	162.2	110.1	0	0	0
1986	0	0	0	2.1	9.8	136.6	259.2	175.2	105.8	4.2	0	0
1987	0	0	0	0	82.2	68.9	164.5	110.1	65.5	14.8	0	0
1988	0	8.1	0	32.8	1.6	149.2	213.6	458.5	154.1	0	0	0
1989	0	0	0	0	10.4	36	142.4	382.1	84	45.3	0	0
1990	0	0	0	0	40.1	54.8	233.1	142.4	89.2	0	0	0
1991	0	0	1.7	63	104.8	148.6	287.3	455.1	26.9	0	0	0
1992	0	0	0	37.4	122.1	45.1	191.4	324.8	205.5	0	0	0
1993	0	0	0	0	48	222	175	107	67	1	0	0
1994	0	0	0	17	63	94	149	325	157	0	0	0

Table A2.3: Rainfall at Jos

JOS	1	2	3	4	5	6	7	8	9	10	11	12
1922	0	0	0	70	79	228	276	143	204	68	0	0
1923	0	0	59	95	139	279	557	391	166	43	0	0
1924	0	0	0	132	88	263	233	206	251	23	0	1
1925	0	0	61	41	154	216	235	379	119	100	0	0
1926	0	2	39	78	220	296	230	380	322	20	0	0
1927	22	0	0	71	300	200	396	262	173	42	0	18
1928	0	0	109	21	264	126	398	262	236	35	0	0
1929	0	0	19	63	183	179	323	276	152	97	0	0
1930	0	0	10	81	269	180	287	327	173	31	0	0
1931	0	0	0	87	141	382	250	245	198	15	6	0
1932	0	9	11	69	154	250	235	282	294	37	0	0
1933	38	0	40	147	205	152	288	352	194	0	0	2
1934	0	0	52	131	309	187	254	293	157	27	0	0
1935	12	0	14	85	237	335	291	418	190	16	0	0
1936	0	0	39	136	305	159	385	175	328	63	0	0
1937	0	0	59	32	158	325	207	226	208	27	0	0
1938	0	0	8	104	186	235	199	263	274	41	0	0
1939	0	0	13	139	225	169	444	215	306	86	0	33
1940	0	0	0	77	234	258	406	313	83	44	3	0
1941	0	0	7	167	212	227	270	381	130	0	27	0
1942	0	0	33	107	243	178	406	300	118	43	0	0
1943	0	0	8	73	248	240	243	491	223	29	2	0
1944	0	0	73	95	34	233	407	295	251	28	0	0
1945	4	0	0	45	90	252	433	277	244	32	0	0
1946	0	0	1	39	167	268	329	287	228	94	0	0
1947	0	0	0	68	243	103	438	252	216	61	0	0
1948	0	0	77	152	146	280	461	279	302	1	0	0
1949	0	0	9	25	293	118	284	235	182	21	0	0
1950	0	0	0	81	160	261	209	168	169	17	0	0
1951	0	0	4	41	249	155	255	392	181	85	1	0
1952	5	0	28	61	255	220	408	122	260	28	0	0
1953	0	15	36	36	328	191	185	263	184	21	0	0
1954	0	2	42	109	351	159	367	208	230	47	33	0
1955	2	0	0	76	146	258	337	249	234	87	0	0
1956	0	13	113	66	82	240	227	184	286	25	1	14
1957	0	0	2	90	221	209	427	276	319	139	14	0
1958	10	2	1	178	143	294	189	232	297	35	0	0
1959	0	0	36	97	267	209	349	282	316	10	0	0
1960	0	0	2	196	159	261	276	299	267	5	0	0
1961	10	0	0	0	90	140	300	200	160	20	0	0
1962	0	0	0	130	100	210	260	180	320	50	0	0
1963	0	3	60	170	120	200	420	320	140	140	0	0
1964	0	0	1	95	180	210	323	323	185	28	3	0
1965	0	38	3	100	99	257	251	300	193	10	0	0
1966	0	0	8	117	165	262	358	312	250	50	0	0
1967	0	0	5	112	150	195	350	287	211	38	5	0
1968	0	0	0	211	183	271	384	323	152	20	0	0
1969	0	0	0	204	144	198	426	388	232	118	13	0
1970	0	0	9	71	161	118	242	256	249	16	0	0

JOS	1	2	3	4	5	6	7	8	9	10	11	12
1971	0	0	10	42	247	192	337	311	267	24	0	0
1972	0	0	39	49	235	181	248	408	198	6	0	10
1973	0	0	12	174	121	153	372	341	169.2	14.5	0	0
1974	0	0	0	71.6	87	188	368.8	296.2	308	18	0	0
1975	0	0	0	78	116	155	332	366.3	341	12	0	4
1976	3	9.4	19	101	177	192	344	305	236	0	0	0
1977	0	0	13.3	5.8	232.9	162.3	307.3	262.1	159.4	33.8	0	0
1978	0	0	17.5	115.6	103.7	236.1	297.1	366.2	222.7	110.6	0	0
1979	0	0	9.3	81.4	179.2	204.6	254.2	309.2	156.4	15.1	6.7	0
1980	0	18.1	14.2	11.3	238.4	166.3	239.5	237.3	113.6	69.7	0	0
1981	0	0	0	99.5	191.3	205.8	249.4	294.6	190.7	41.2	0	0
1982	0	0	8.4	204.7	144.2	169.2	381.5	252.8	135.5	34.1	0	0
1983	0	0	20.7	0	150	250.2	317	356.4	80.8	0	0	0
1984	0	0	54.9	98.4	168.2	124.5	162.4	220.3	317.3	9.1	0	0
1985	0.6	0	97.9	5.2	194.6	244.5	248.5	208.8	145.5	16.1	0	0
1986	0	44.3	4.4	76.2	172.9	172.7	351.1	202.2	160.5	16.2	0	0
1987	0	0	60.2	18.6	66.6	256	296.9	349.8	164.6	76.4	0	0
1988	0	0	33.9	173.6	196.3	182	215.1	160.2	223.7	52.9	0	0
1989	0	0	0.3	118.3	96	237.8	244.5	321.6	131.1	62.4	0	11
1990	0	0	0	39.3	294	199.2	217.9	256.1	206.1	18.2	0	0
1991	0	0.7	29.5	128.2	203.6	246.7	303.2	245.4	108.8	42.4	0	0
1992	0	5.3	73.1	155.3	182.8	270.4	270.4	261.9	157.5	67	4.5	0

Table A2.4: Rainfall at Balle

BALLE	1	2	3	4	5	6	7	8	9	10	11	12
1992	0	0	0	0	0	18	85	166	46	0	0	0
1993	0	0	0	0	0	18	85	233	69	0	0	0
1994	0	0	0	0	16	27	185.5	298.5	126	12	0	0
1995	0	0	0	0	2.2	22.1	112.1	167.7	121.8	0	0	0
1996	0	0	0	0	16	27	185.5	298.5	126	12	0	0
1997	0	0	0	0	0	16	73	113	12	0	0	0
1998	0	0	0	0	0	0	72	117	61	0	0	0
1999	0	0	0	0	0	42	98	226	102	6	0	0
2000	0	0	0	0	0	16	72	129	31	0	0	0
2001	0	0	0	0	0	52	59	103	46	2	0	0
2002	0	0	0	0	0	12	52	103	31	0	0	0
2003	0	0	0	0	0	6	50	259	85	12	0	0
2004	0	0	0	0	0	2	30	69	42	3	0	0

Table A2.5: Rainfall at Samaru

SAMARU	1	2	3	4	5	6	7	8	9	10	11	12
1928	0.5	0	52.5	56.1	182.1	245.4	235.7	233.2	217.3	39.4	0	0
1929	0	0	12.7	1.5	210.7	110.8	285	356	257.7	49.2	0	0
1930	0	0	0	33.8	115.5	89.5	228.3	417.1	158	2.1	0	0
1931	0	0	0	63	148.8	210.3	289.9	243.4	236.2	4.6	1.5	0
1932	0	10.7	0	64.7	226.6	252.3	138.8	223.8	223	58.2	0	0
1933	0.3	0	0	24.7	99.1	233.3	329.5	351.2	270.9	0	3	0
1934	0	0	0	73.4	180.2	141.5	181.2	339.3	106.4	54.6	0	0
1935	0	0	8.9	9.4	106.6	232	136.8	354.4	145.4	2.5	0	0
1936	0	0.8	0.8	64.5	151.4	111.5	265.8	207.9	315.1	28.7	0	4.1

SAMARU	1	2	3	4	5	6	7	8	9	10	11	12
1937	0	0	0	21.8	110.7	128.4	203.7	277.2	240.2	1	0	0
1938	0	0	0.8	67.6	135.6	179.6	138.9	239.7	213.5	11.9	0	0
1939	0	6.1	15	12.2	159.7	133.6	156.5	288.3	265.6	92	0	0
1940	0	0	0	26.7	73.7	139.9	217	210.7	203.2	39.7	0	0
1941	0	0	0	40.4	155.1	148.7	187.4	261.1	235.6	0	5.8	0
1942	0	8.6	0	52.8	245.3	112.4	167.1	202	92.7	55	0	0
1943	0	0	21.4	1.3	167.1	132.9	164.8	539.5	244.5	1.8	0	0
1944	0	0	23.8	2.8	43.2	155.6	192.5	367.1	133.3	10.4	0	0
1945	0	0	0	15.3	41.7	160.4	213	272.1	217.6	63.5	0	0
1946	0	0	13.7	0	163.6	190.7	307	420.9	255.8	73.5	0	0
1947	0	0	0.3	0.3	137.6	214.5	255.1	297.2	215.3	29.5	0	0
1948	0	0	4.8	89.6	79.3	128.3	134.9	211.9	248	0	0	0
1949	0	0	9.9	2.8	126.5	132.9	140.2	416.3	158	2.3	0	0
1950	0	0	0	21.6	79	119.8	251.4	216.3	193.3	16.7	0.5	0
1951	0	0	2.5	27.9	140.6	104.9	221.5	280.7	285.9	95.4	0.3	0
1952	0	0	3.6	3.3	129.2	159.4	330.8	204.2	228.9	46.2	0	0
1953	0	8.3	0	0	255.8	141.4	293.7	222.1	226.6	7.6	0	0
1954	0	12.2	79	64.8	219.8	156.7	168.1	417.1	298.5	47	19.3	0
1955	0	0	0.8	37.3	75.7	182.7	316.4	333.1	331.3	68	0	0
1956	0	7.1	33.5	44.7	43.9	100.6	194.3	193.7	218.7	90.1	0	0
1957	0	0	0	51.9	266.4	151.8	255	315	263.4	91.3	0	0
1958	1.1	0	0	33	88.1	189.1	129.7	168.4	257.2	22.1	0	0
1959	0	0	6.9	47.5	118.4	168.9	158.2	275.4	287.4	0.8	0	0
1960	0	0	0	53.1	55.1	183.2	209.5	245.6	339	6.5	0	0
1961	7.1	0	5.8	37.4	57.6	208.1	144.6	122.2	241.8	0	0	0
1962	0	0	0	49.8	57.1	186.1	227.5	317.9	380.7	63.8	19.5	0
1963	0	0	0	28.9	73	219.4	147	270.9	214.6	138	0	0
1964	0	0	4.8	33.6	37.5	174.6	292.3	251.7	260.7	0	0	0
1965	0	0	0.3	20.8	20.8	296.3	227.9	248	148.8	15	0	0
1966	0	0	0.5	98	129.1	137.3	216	379.6	297.3	74.3	0	0
1967	0	0	6.6	47.3	83.7	182.7	248.4	96.5	299.8	3.3	0	0
1968	0	0	0.3	85.8	143.5	124.9	257.4	302.2	139.2	6.4	0	0
1969	0	0.3	0	43.2	116.7	184.5	445.1	233.9	89.9	104.5	0	0
1970	0	0	6.9	1.8	131.4	104.9	259.1	262.8	174.8	6.6	0	0
1971	0	0	3.6	0	116.8	31.4	230.9	298.7	195	7.6	0	0
1972	0	0	0.3	51.3	152.9	95.7	172.5	325.3	85.2	24.2	0	0
1973	0	0	0.5	21.6	46.9	191.7	191.8	227.5	292.6	1.5	0	0
1974	0	0	11.2	30	33.8	144.3	253.1	328.6	246.9	67.5	0	0
1975	0	0	0.3	85.7	130.3	135.4	303.5	113.4	210.6	8.4	0	0
1976	0	0	0	86.2	135.5	206.7	226.4	202.3	203	129.3	0	0
1977	0	0	0	0	78.3	103.7	59	300.7	199.5	4.3	0	0
1978	0	0	1.3	77.7	193.9	165.7	145.3	324.9	207.2	33.9	0	0
1979	0	0	0	19.8	86.3	220.2	373.8	299.8	142.8	30.8	9.8	0
1980	0	0	0	3.7	154.4	116.4	268.9	215.8	71.9	16.3	0	0
1981	0	0	0	100.7	90.7	159	254.8	280.6	133.3	0	0	0
1982	0	0	0	59.7	72.1	113.9	166.7	190.7	117.6	45.8	0	0
1983	0	0	0	0	73.3	74.3	107.5	259.7	93.4	0	0	0
1984	0	0	5.2	30.1	0	55.4	173.8	0	0	177.5	0	0
1985	0	0	32.9	0	140.7	142.2	313.1	256.3	163.3	3.3	0	0
1986	0	0	0	5.8	59.1	82	293.6	322.1	205.7	0	0	0
1987	0	0	0	0	135.7	146.8	276.7	268.3	102.1	42.6	0	0
1988	0	3.5	0	34.6	94.4	133.2	181.5	402.5	192.3	114.7	0	0
1989	0	0	0	15	113	124.4	154.6	170.4	118.3	52.9	0	0
1990	0	0	0	0	123.3	155.7	221.8	255.3	131.5	0	0	5
1991	0	0	44.7	47.8	243	87	189.6	329	51.2	28.7	0	0
1992	0	0	0	32.3	73.1	112.4	243.6	287.3	229.7	39.9	2.6	0

SAMARU	1	2	3	4	5	6	7	8	9	10	11	12
1993	0	0	0	8.3	113.6	155.8	269	292.6	181.7	0	0	0
1994	0	0	0	20.4	120.1	232.2	169.8	215.9	78.2	69.2	0	0
1995	0	0	0	90.5	45.3	125.4	165.6	258.6	159.1	32.5	0	0
1996	0	0	0	158.7	143.3	156.7	171.1	136.2	51.2	0	0	0
1997	0	0	0	47.6	86.4	155.2	213.8	284.2	182.6	81.4	0	0
1998	0	0	0	110	92.8	129.7	196.4	473.9	221	41.6	0	0
1999	0	0	0	7.9	23.4	238.3	285.5	155.1	204.1	38.4	0	0

Table A2.6: Rainfall at Bauchi

BAUCHI	1	2	3	4	5	6	7	8	9	10	11	12
1906	0	0	0	6	114	123	251	311	138	109	0	0
1907	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	999.9
1908	0	0	9	36	49	193	321	479	59	48	0	0
1909	0	0	0	99	63	141	269	279	218	10	0	0
1910	0	0	0	24	82	118	303	224	189	28	0	0
1911	0	0	12	40	225	204	109	343	181	28	0	0
1912	0	0	0	20	51	121	225	307	153	16	0	0
1913	0	0	0	25	91	85	225	222	184	12	0	0
1914	0	0	0	41	29	128	313	409	189	18	0	0
1915	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	999.9
1916	0	0	0	37	98	143	354	384	196	65	0	0
1917	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	999.9
1918	0	0	0	0	80	202	187	361	157	36	0	0
1919	0	0	1	5	161	80	250	270	204	2	0	0
1920	0	0	0	25	106	145	167	282	216	3	0	0
1921	0	0	0	77	126	157	209	351	163	0	0	0
1922	0	0	0	46	55	112	234	237	280	134	0	0
1923	0	0	50	37	44	107	295	457	238	44	0	0
1924	0	0	0	25	19	168	427	367	262	42	0	0
1925	0	0	34	40	72	137	232	290	113	16	0	0
1926	0	0	0	45	84	262	191	222	181	9	0	0
1927	0	0	0	18	123	86	231	314	140	57	0	3
1928	0	0	0	2	94	168	122	305	194	36	0	0
1929	0	0	0	15	114	234	400	217	75	40	0	0
1930	0	0	17	24	24	109	369	288	108	18	0	0
1931	0	0	0	58	107	144	104	172	160	28	0	0
1932	0	0	0	27	116	180	357	483	180	85	0	0
1933	0	0	26	55	115	254	66	483	175	0	0	0
1934	0	0	0	121	146	68	152	276	131	75	0	0
1935	0	0	0	3	68	145	221	555	161	18	0	0
1936	0	0	3	96	152	123	162	445	266	18	0	0
1937	0	0	1	5	38	141	234	263	215	35	0	0
1938	0	0	0	100	32	149	229	500	188	21	0	0
1939	0	0	12	18	145	111	187	328	241	55	0	4
1940	0	0	0	36	95	136	217	406	106	39	0	0
1941	0	0	0	89	48	170	313	214	67	9	15	0
1942	0	0	22	26	92	160	178	437	148	45	0	0
1943	0	0	0	9	129	121	234	475	312	29	10	0
1944	0	0	20	77	31	76	334	317	163	45	0	0
1945	0	0	0	11	46	141	174	464	191	48	0	0

BAUCHI	1	2	3	4	5	6	7	8	9	10	11	12
1946	0	0	0	48	49	113	466	447	283	62	0	0
1947	0	0	0	9	68	146	210	321	176	55	8	0
1948	0	0	4	48	53	279	143	460	109	23	0	0
1949	0	0	0	12	143	106	187	245	99	7	0	0
1950	0	0	0	11	108	136	263	425	126	24	0	0
1951	0	0	0	0	190	89	203	270	216	22	3	0
1952	0	14	2	18	182	117	227	234	225	32	0	0
1953	0	7	1	33	169	122	309	221	187	10	0	0
1954	0	0	7	51	97	176	459	348	203	62	0	0
1955	0	0	0	28	77	128	193	282	263	96	0	0
1956	0	0	34	18	23	116	309	291	102	28	0	0
1957	0	0	0	28	91	221	415	289	125	25	0	0
1958	0	0	0	58	88	115	300	346	201	15	0	0
1959	0	0	9	0	145	145	128	207	248	9	0	0
1960	0	0	0	37	83	165	268	337	167	0	0	0
1961	0	0	0	1	17	170	346	290	123	9	0	0
1962	0	0	16	26	32	134	228	316	250	89	0	0
1963	0	0	0	55	69	171	248	282	138	78	0	0
1964	0	0	0	19	46	208	154	512	242	34	0	0
1965	0	0	0	13	51	135	307	344	131	13	0	0
1966	0	0	0	103	116	208	106	156	200	37	0	0
1967	0	0	0	40	70	130	270	320	170	40	5	0
1968	0	0	1	70	90	160	290	340	88	36	0	0
1969	0	0	9	19	69	130	240	320	263	67	3	0
1970	0	0	0	0	58	139	214	296	182	27	0	0
1971	0	0	0	0	115	87	418	207	247	3	0	0
1972	0	0	0	55	139	67	245	329	53	37	0	0
1973	0	0	0	22	33	118	210	168	161	4	0	0
1974	0	0	0	17.6	131.1	171.8	318.7	310.2	183.8	38	0	0
1975	0	0	0	13.7	77.3	114.4	354.5	306.3	224	55.4	0	0
1976	0	48.3	0	73.3	106	125.1	230.7	363.4	211.5	90.7	0	0
1977	0	0	0	0	27.3	142.3	181.2	330.4	117.4	16.4	0	0
1978	0	0	0	20.2	74.8	212.8	299.6	367.2	133.2	42.8	0	0
1979	0	0	0	37.2	75.1	83.5	329.4	258.7	165.7	41.7	0	0
1980	0	0	0	0.5	11.6	121.3	314.1	317.9	82.5	40.3	0	0
1981	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	999.9
1982	0	0	0	43.8	38.4	164.9	233.2	237.1	186	31.6	0	0
1983	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	-999.9	999.9
1984	0	0	0	19.3	148.7	77.8	239	227.8	164	10.3	0	0
1985	0	0	33.2	0	122.3	108.4	152.2	162.2	145.6	1.7	0	0
1986	0	0	5.6	8	40	129.5	342.8	171.9	228.9	20.3	0	0
1987	0	0	0	0	56.3	219.3	151.1	240.4	31.2	46.3	0	0
1988	0	0.5	1.8	66.6	90.9	143.3	173.3	276.1	159	9.2	0	0
1989	0	0	0	26.6	100	77.6	182.3	324.7	140.8	57.4	0	0
1990	0	0	0	5.9	108.7	100.5	284.7	262.3	87.8	29.7	0	0
1991	0	0	28.5	85.9	149.1	103.3	283.1	244.7	35.9	19.1	0	0
1992	0	0	2.4	49.4	51.2	177.5	328	357.6	233.5	28.1	2.7	0

Table A2.7: Rainfall at Bula Nguwa

BULA NGUWA	1	2	3	4	5	6	7	8	9	10	11	12
1992	0	0	0	0	0	60	102	178	29	0	0	0
1993	0	0	0	0	0	16	72	193	22	19	0	0
1994	0	0	0	0	0	62	104	261	33	16	0	0
1995	0	0	0	0	4.2	8.6	128	212	63	16	0	0
1996	0	0	0	0	0	40	178	262	92	14	0	0
1997	0	0	0	0	130	24.5	115.3	133.4	65.5	12.5	0	0
1998	0	0	0	0	0	76	129	131	53	0	0	0
1999	0	0	0	0	0	0	57	192	81	0	0	0
2000	0	0	0	0	0	24	79	141	33	0	0	0
2001	0	0	0	0	0	59	41	152	52	0	0	0
2002	0	0	0	0	0	20	73	182	28	0	0	0
2003	0	0	0	0	8.2	20	16	213	52	6	0	0
2004	0	0	0	0	0	12	31	82	6.8	0	0	0

Appendix 3: Rating Curve Equation for KYB

Site	Period of Applicability	Stage range [m]	Section 1	Stage range [m]	Section 2
Bunga Bridge	1993/4-1994/5	0.50-4.50	3.37(H-0.5)^2.25	>4.5	1.55(H-0.5)^2.98 #
	1995/6-1998/9	0.50-6.92	4(H-0.5)^2.5	>7.7	1.55(H-0.5)^2.98 #
Katagum Bridge	1993/4-1997/8	>1.00	47.1(H-1)^1.677		
	1998/9	> 1.00	47.1(H-1)^1.73		
Gashua Bridge	1993/4	0.70-4.00	8.7(H-0.7)^1.87	>4.00	4.57(H-0.7)^2.4
	1994/5	>0.50	7.17(H-0.5)^2.015		
	1995/6	0.50-4.50	7.17(H-0.5)^2.015	>4.50	0.7(H-0.5)3.7
	1996/7	0.50-4.60	7.17(H-0.5)^2.015	>4.60	0.7(H-0.5)^3.65
	1997-1998 *	-0.31-3.79	7.17(H+0.31)^2.015	>3.79	0.7(H+0.31)^3.65
Hadejia Bridge	1991/2-1993/4	0.15-3.15	10.48(H-0.15)^1.206	>3.15	0.948(H-0.15)^3.58
	1994/5-1995/6	0.15-3.78	10.48(H-0.15)^1.206	>3.78	0.0676(H-0.15)^5.12
	1996/7-1997/8	0.15-3.85	10.48(H-0.15)^1.28	>3.85	0.0676(H-0.15)^5.12
	1998/9	0.15-3.95	10.48(H-0.15)^1.35	>3.95	0.0676(H-0.15)^5.12
Likori Bridge	1991/2-1994/5	>2.00	16.5(H-2)^2.5		
Marma Channel	1995/6-1997/8	>2.30	19.3(H-2.3)^3.3		
	1998/9	2.30-3.33	19.3(H-2.3)^3.3	>3.33	19.3(H-2.3)^2.2
Kasaga Bridge	1995/6	> 0.35	12.5(H-0.35)^2		
	1996/7-1998/9**	> 0	12.5(H)^2		
Dapchi Bridge	1996/7-1997/8	> 1	10(H-1)^1.2		

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* new stage board (= old stage - 0.81m)

** new stage board (= old stage - 0.35)

Appendix 4: Mathematical Basis of the Rainfall-Runoff Model

The rainfall-runoff consists of four linear reservoirs:

Surface Storage: This unit is augmented by rainfall and artificial inflow (if any), and depleted by evapotranspiration loss and infiltration to the soil moisture zone. Channel inflow will occur when the storage in the unit exceeds a threshold value, and a simple budget yields the amount of the channel inflow. The average monthly evapotranspiration loss was computed by the Blaney-Morin-Nigeria model. The Blaney-Morin-Nigeria model accepts daily temperature, relative humidity and ratio of maximum possible radiation to the annual maximum radiation as inputs to give the average daily/monthly evapotranspiration.

The average monthly evapotranspiration is given by the model as:

$$E_{tp} = nr_f(0.45\,T + 8)(520 - R^{1.31})/100 \qquad \text{.......................... (A4-1)}$$

where E_{tp} is the average monthly potential evapotranspiration in mm, n is the number of days in the month, T is the mean monthly temperature in ^{O}C, R is the average monthly relative humidity (%) and r_f is the ratio of maximum possible radiation to the annual maximum.

The rate of infiltration which depends on the type and intensity of rainfall, and the present state of soil moisture was evaluated by the following equation given as:

$$f_i = f_o e^{-kt} \qquad \text{.......................... (A4-2)}$$

where f_i is the potential infiltration rate in mm. f_o is the maximum infiltration rate in mm. k is the infiltration coefficient and t is the time unit

Channel Storage: The channel storage is augmented by channel inflow and depleted by surface runoff. The surface runoff is conceived as a linear function of the storage. The constant of proportionality depends on the soil type and cover.

The Soil Moisture Storage: The movement of water into the unit is controlled by infiltration and capillary rise. Evapotranspiration and deep percolation control the movement of water out of the unit. Deep percolation occurs when the soil moisture storage exceeds a threshold value. Capillary rise will cease whenever there is deep percolation. Both capillary rise and deep percolation depend on the storage level of the moisture and groundwater storage.

Groundwater storage: This is augmented by deep percolation, and depleted by capillary rise and flow. When the ground water storage exceeds the threshold value, the soil moisture storage is capillary rise and deep percolation will cease to occur, while evapotranspiration loss will act directly on the groundwater.

Appendix 5: Catchment rainfall for the sub-basins

Table A5.1: Catchment Rainfall for Tiga

1928	1994											
TIGA	1	2	3	4	5	6	7	8	9	10	11	12
1928	0.7	0	54.6	24.3	175.4	136.8	285.5	266	190.9	38.8	0	0
1929	0	0	10.1	25.5	140.1	146.3	263.9	314	153.4	53.7	0	0
1930	0	0	4	39.3	163.9	127.4	283.9	344.9	164.4	22.5	0	0
1931	0	0	0	55.3	103.6	249.7	305.6	300.5	171	7.8	2.7	0
1932	0	7.2	4.4	41.5	111.6	201.1	218	265.8	256.6	72.3	0	0
1933	15.3	0	16.3	64.7	130.1	202.7	227.8	334.5	176.2	0	0.6	0.8
1934	0	0	20.8	91.5	190.3	161.4	206.6	290.9	123.7	22.4	0	0
1935	4.8	0	7.9	35.9	130.6	236.4	220.4	437.7	114.7	7.3	0	0
1936	0	0.2	17.4	71.2	201.2	135	327.8	223.3	250.3	30.9	0	0.8
1937	0	0	23.6	17.2	101.4	196.4	226.7	227.4	184.1	11	0	0
1938	0	0	3.4	55.9	120.3	171.4	210.5	314.6	262.7	27.9	0	0
1939	0	3.8	8.2	59.8	150.4	127.1	266.2	247.7	226.7	52.8	0	13.2
1940	0	0	0	36.1	153.7	191.2	278	265	111	37.7	1.2	0
1941	0	0	2.8	74.9	187.7	180.4	203	307.4	141.7	0	12	0
1942	0	1.7	13.2	53.4	180.1	131.1	226.4	262.1	110.3	28.2	0	0
1943	0	0	7.5	29.7	171.3	138.8	205	438.8	174.9	14.2	0.8	0
1944	0	0	34	38.6	26.9	152.5	216.9	309.8	148.2	19	0	0
1945	1.6	0	0	29.1	95.7	163.5	305.6	320.3	191.4	37	0	0
1946	0	0	3.1	18.8	127.9	190.3	275.8	285.3	211.8	57.6	0	0
1947	0	0	0.1	27.3	135.6	144.5	303.7	256.8	202.5	30.8	0	0
1948	0	0	31.8	81.7	83.7	175.1	298.5	273.9	193.9	0.4	0	0
1949	0	0	5.6	22.2	152.8	97.3	195.1	299.9	116.6	8.9	0	0
1950	0	0	0	37.9	86.9	162.3	238.6	272.9	161.8	14	0.1	0
1951	0	0	2.1	22	148.1	128.2	229.9	276.1	236.4	57.9	0.5	0
1952	2	0	12.7	25.1	217.4	163.5	304.2	225.2	209.8	30	0	0
1953	0	7.7	14.4	14.4	204.4	161.9	201.5	252.8	152.9	10.7	0	0
1954	0	3.6	32.6	67.8	250	139.7	322.4	281.4	198.9	41.8	18.7	0
1955	0.8	0	0.2	38.7	96.7	208.1	284.1	348.6	215.1	61.6	0	0
1956	0	6.6	52.7	35.3	42	146.5	246.5	238.3	183.3	32	0.4	5.6
1957	0	0	0.8	47.6	202.1	181.2	315.4	275.8	254.3	78.7	5.6	0
1958	4.6	0.8	0.4	83.4	85.2	254.6	188.3	229.7	195.4	18.4	0	0
1959	0	0	15.8	50.7	160.5	154.6	243.6	331.5	285.9	5	0	0
1960	0	0	0.8	101.4	86.6	170.2	269.5	269.5	205.4	3.7	0	0
1961	5.8	0	1.2	7.5	55.5	125.6	236.9	240.4	160.4	8	0	0
1962	0	0	0	62	83.4	233.2	225.5	267.6	284.1	48.8	3.9	0
1963	0	1.2	26	75	78.6	155.9	249.4	326.2	130.9	83.6	0	0
1964	0	0	1.8	45.1	103.5	142.9	270.1	283.5	154.5	11.2	2	0
1965	0	15.2	1.3	44.2	61	260.5	253.6	278.4	147.4	12.2	0	0
1966	0	0	3.3	72.4	136.6	169.9	225.2	322.7	221.5	35.7	0	0
1967	0	0	3.3	54.3	99.9	176.1	290.1	226.1	182.8	15.9	2	0
1968	0	0	0.1	143.6	131.9	192.2	250.3	238.8	107.4	9.3	0	0
1969	0	0.1	0	93.8	88.5	192.5	354.2	290	154.4	96.1	5.2	0
1970	0	0	5	28.8	99.5	90.2	274.6	268.2	228.6	8.9	0	0
1971	0	0	4.7	18	149.8	92.7	250.6	273.3	227.4	11.5	0	0
1972	0	0	15.7	31.1	164.6	142.7	162.1	323.9	114.4	9.2	0	4
1973	0	0	4.9	73.9	58.8	114.7	253.6	249.5	140	6.1	0	0
1974	0	0	2.2	34.6	58.2	121	302.8	263.4	216.3	22.9	0	0

1928	1994											
TIGA	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1975	0	0	0.1	55.6	88.3	140.3	243.5	258.8	249.7	6.5	0	1.6
1976	1.2	4.7	7.6	57.6	114.7	157.7	235.7	211.7	161.4	49.9	0	0
1977	0	0	5.3	2.3	111.6	164.9	147.9	340.6	146.1	16	0	0
1978	0	0	7.3	75.8	109.9	206.8	271.5	314.7	142.5	62.6	0	0
1979	0	0	3.7	36.5	101.7	170.3	253.2	286.4	135.5	20.2	4.6	0
1980	0	7.2	5.7	5.3	163.8	139	262.8	262.5	87	45.1	0	0
1981	0	0	0	67.9	109.1	138.9	207.9	255.2	146.5	16.5	0	0
1982	0	0	3.4	101.3	98.6	115.4	249.1	243.8	105.9	23.3	0	0
1983	0	0	8.3	0	85.5	133.9	184.9	300.9	77.8	0	0	0
1984	0	0	23	45.5	88.4	93.6	162.7	108.3	174.4	46.1	0	0
1985	0.2	0	54.3	2.1	116.9	192.1	229.9	199.7	134.9	7.1	0	0
1986	0	17.7	1.8	32.5	84.9	140.1	302.8	215.4	147.7	8.2	0	0
1987	0	0	24.1	7.4	86.7	159.3	239.9	237.6	112.5	45	0	0
1988	0	3.9	13.6	89.5	98	159.1	207.8	328	189.6	44.1	0	0
1989	0	0	0.1	50.3	65.2	134.4	185.7	315.6	109.7	53.7	0	4.4
1990	0	0	0	15.7	158.3	132.7	224.8	210.5	144.4	7.3	0	1
1991	0	0.3	21.4	86	172	175.5	274.1	346	64.5	22.7	0	0
1992	0	2.1	29.2	83.5	136.6	148.7	233.4	292.1	191.1	34.8	2.3	0
1993	0	0	0	1.7	61.1	208.8	193.8	144.1	89.9	0.8	0	0
1994	0	0	0	17.7	74.4	121.6	153.2	303.2	141.2	13.8	0	0

Table A5.2: Catchment Rainfall for Challawa Gorge

1928	2001											
CHALLAWA GORGE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1928	1	0	26.9	33.9	132.8	169.3	216.8	259.9	175	40.9	0	0
1929	0	0	6.4	0.8	136.4	121.1	239.7	343.5	180.2	31	0	0
1930	0	0	0	17.1	99.3	91.6	268.5	371.9	158.5	13.1	0	0
1931	0	0	0	41.4	96.3	173.8	329.5	314	173.9	3.5	0.8	0
1932	0	7.2	0	33.5	119.2	189.4	189.7	247.2	229.5	86.4	0	0
1933	0.2	0	0.4	13.5	84.9	235.7	223.2	329.9	191	0	1.5	0
1934	0	0	0	67.2	128.5	143.7	176.6	302	102.8	28.2	0	0
1935	0	0	5.1	4.7	71.5	186	164.2	426.8	84.8	1.8	0	0
1936	0	0.4	2.5	37.1	136.8	117.1	283.7	243.7	227.7	14.4	0	2.1
1937	0	0	0	10.9	75.4	115.2	230.8	240.6	186.2	0.5	0	0
1938	0	0	0.4	34.8	91.3	141.6	198.4	321.7	244.8	17.4	0	0
1939	0	6.3	7.5	8.3	115.4	107.8	149.9	274.2	196.8	46	0	0
1940	0	0	0	13.4	93.6	145	198.8	227.4	148.1	35.1	0	0
1941	0	0	0	20.2	167.4	149.2	165.6	259.1	171	0	2.9	0
1942	0	4.3	0	26.4	165	103	121.8	228.2	102	27.5	0	0
1943	0	0	14.1	0.9	143	98.2	160.7	440.9	197.1	2.5	0	0
1944	0	0	27.9	1.9	39.6	132	127.2	374.7	104.7	13.5	0	0
1945	0	0	0	18.8	84.1	109.6	234.8	356.6	189.1	47.1	0	0
1946	0	0	8.2	15	115.2	150.4	253	304.9	231.5	60.2	0	0
1947	0	0	0.1	0.1	101.6	158.5	204.6	295.8	193	25.6	0	0
1948	0	0	2.9	71.7	78.3	125.3	181.5	244.2	174.9	0	0	0
1949	0	0	4	12.3	95.1	125.9	157.3	373.6	112.2	2.1	0	0
1950	0	0	0	20.9	63.3	98.2	238.1	311.8	176.1	13.5	0.2	0
1951	0	0	0.8	9.3	63.9	115.6	238.5	255.9	291	56.8	0.1	0
1952	0	0	2.2	1.1	166.7	144.5	280.6	237.1	200.3	44.4	0	0
1953	0	4.8	7.3	0	167.9	125.1	240.9	227.7	166.2	10.9	0	0

	1928	2001											
CHALLAWA GORGE		1	2	3	4	5	6	7	8	9	10	11	12
	1954	0	10.4	43.3	67.6	202.6	128.2	231.4	350.4	233.2	34.3	17.4	0
	1955	0	0	6.6	25.1	78.2	193.6	266.5	362.4	273.1	61.7	0	0
	1956	0	2.4	22.2	26.6	21.3	95.9	234.1	238.6	171.2	57	0	0
	1957	0	0	0	33.3	191.1	160.3	249.7	303	249.1	67.8	0	0
	1958	0.7	0	3.3	40.3	65.7	192.4	160.9	210.8	196.4	16.4	0	0
	1959	0	0	7.6	24.2	118.8	132.6	176.4	325.5	261.1	6.6	0	0
	1960	0	0	0	60	38	148.1	248.2	248.2	251.3	8.2	0	0
	1961	3	0	1.9	24.5	48.5	172	172.5	187.4	179.3	0	0	0
	1962	0	0	1.3	38.3	57.4	234.4	203.5	350.3	329.2	56.3	14.2	0
	1963	0	0	1.7	28.3	72.7	183.8	155.3	302	142.2	95	0	0
	1964	0	0	1.9	19.9	58.5	128.5	267.1	260.2	188.6	0	0.7	0
	1965	0	2	0.1	21.3	33.9	296.8	231	251	127.9	23	0	0
	1966	0	0	0.2	78.3	80.4	127.8	168.7	322.9	266.4	25.4	0	0
	1967	0	0	2.5	29.1	58.2	164.9	270.5	144.5	218.3	1.1	0	0
	1968	0	0	1.4	98.3	111.5	139.6	210.1	224.4	102.1	2.8	0	0
	1969	0	0.1	0	34.1	60.2	186.8	344	221.3	113	76.5	0	0
	1970	0	4.3	7.3	0.9	96.5	81.6	245.4	278.6	193.3	5.9	0	0
	1971	0	0	1.9	1	93.6	31.8	208	290.6	195.7	6.9	0	0
	1972	0	0	0.1	23.4	156.3	107.9	129.5	288.1	93.6	26.4	0	0
	1973	0	0	0.2	8.9	27.1	131.6	202.6	205.5	175.7	0.5	0	0
	1974	0	0	6.1	15	39	92.9	254	275.5	155.5	36.8	0	0
	1975	0	0	0.2	49.8	78.6	117.9	221	172.1	173.1	5.5	0	0
	1976	0	0.6	0	43.1	87.8	154.3	179	182.7	138.6	108.7	0	0
	1977	0	0	0	0	48.7	134.5	48.6	367.1	145.7	8.4	0	0
	1978	0	0	0.7	62.4	133.2	165	206.1	296.5	129.9	26.1	0	0
	1979	0	0	2.6	10	53.9	153.1	275.1	279.4	119.1	21.8	4.9	0
	1980	0	0	0	1.9	104.7	126.6	256.3	255.5	62.7	26.4	0	0
	1981	0	0	0	57.4	68.4	117.4	197.3	229.3	113.2	0	0	0
	1982	0	0	0	35.6	76.4	95	153.9	227.4	90.2	24.3	0	0
	1983	0	0	0	0	49.1	58.2	93.7	253.1	82.7	0	0	0
	1984	0	0	1.3	10.4	46.6	71.4	176.1	66	105.4	93.1	0	0
	1985	0	0	35.3	0.1	84.7	137.3	256.5	216.7	160.1	2.3	0	0
	1986	0	0	0	4.1	30.5	96.9	243.7	250	147.7	2.5	0	0
	1987	0	0	0.3	0	89.4	109.5	210.5	211.9	85.4	25.2	0	0
	1988	0	4	0	33.2	60.1	140.8	183.9	435.5	177.5	32.2	0	0
	1989	0	0	0	9.1	63.9	73.6	141.6	276.1	96.7	47.4	0	0
	1990	0	0	0	0.6	84.8	96.9	219.9	194.9	114.6	2.4	0	1.9
	1991	0	0	24.1	55.2	186	119.1	235.4	394.2	41	15.9	0	0
	1992	0	0	0	31.7	93.9	70.4	234.2	308.3	209.1	11.5	1.4	0
	1993	0	0	0.3	11.8	68.9	169.9	207.3	170.9	197.9	23.5	0	0
	1994	0	0	0	22.7	61.5	175.3	167.5	225.5	120.7	69.1	0	0
	1995	0	0	0	45.3	24.2	104.4	151.8	209.1	162	19.6	0	0
	1996	24.1	0	0	0	104.2	129.6	197.2	173.1	146.4	41.4	0	0
	1997	0	0	0	25.5	85.4	127.6	171	243.8	152.9	51.5	0	0
	1998	0	0	0	57.2	99.9	138.7	250	446.3	240	25.5	0	0
	1999	0	0	0	4	42.5	147.7	276.9	236.1	139	25.9	0	0
	2000	0	0	0	0	31.1	127.9	203.2	172.4	85	23.2	0	0
	2001	0	0	0	0.5	83.1	170.8	314.1	278.6	134.2	0.7	0	0

Table A5.3: Catchment Rainfall for Bunga

1922	1992											
BUNGA	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1922	0	0	0	60.4	69.4	181.6	259.2	180.6	234.4	94.4	0	0
1923	0	0	55.4	71.8	101	210.2	452.2	417.4	194.8	43.4	0	0
1924	0	0	0	89.2	60.4	225	310.6	270.4	255.4	30.6	0	0.6
1925	0	0	50.2	40.6	121.2	184.4	233.8	343.4	116.6	66.4	0	0
1926	0	1.2	23.4	64.8	165.6	282.4	214.4	316.8	265.6	15.6	0	0
1927	13.2	0	0	49.8	229.2	154.4	330	282.8	159.8	48	0	12
1928	0	0	65.4	13.4	196	142.8	287.6	279.2	219.2	35.4	0	0
1929	0	0	11.4	43.8	155.4	201	353.8	252.4	121.2	74.2	0	0
1930	0	0	12.8	58.2	171	151.6	319.8	311.4	147	25.8	0	0
1931	0	0	0.2	75.88	128.08	287.92	192.28	217.2	184.12	20.68	3.6	0
1932	0	5.4	6.6	52.56	139.84	223.36	286.08	365.8	249.64	56.84	0	0
1933	22.8	0	34.68	110.76	169.84	194.52	199.64	407.6	187.84	0	0	1.2
1934	0	0	31.2	127.76	244.92	140.16	214.16	288.16	147.64	46.88	0	0
1935	7.2	0	8.4	52.52	169.92	260.24	264.4	476.56	179.44	17	0	0
1936	0	0	24.92	120.6	245.08	145.4	296.92	285.96	305	45.32	0	0
1937	0	0	36	21.24	110.24	252.52	219.28	242.6	212.36	30.64	0	0
1938	0	0	4.8	103.36	124.6	201.56	212.68	361.12	241	33.24	0	0
1939	0	0	12.68	91.04	194.24	146.6	342.6	262.52	281.84	74.24	0	21.52
1940	0	0	0	61.04	179.2	210.36	331.8	353	93.2	42.56	1.8	0
1941	0	0	4.2	136.36	147	205.6	289.52	315.88	105.32	3.88	22.48	0
1942	0	0	28.84	75.08	183.48	172.12	316.16	357.8	131.04	52.2	0	0
1943	0	0	4.8	47.56	201.32	193.16	241	487.64	260.6	29.2	5.28	0
1944	0	0	52.24	88.28	33	170.88	380.04	305.92	217.04	35.4	0	0
1945	2.4	0	0	31.68	72.88	208.72	330.72	354.96	224.32	38.72	0	0
1946	0	0	0.6	42.92	120.12	206.84	387	353.96	251.92	81.6	0	0
1947	0	0	0	44.44	173.44	121.44	348.44	281.84	201.44	59.04	3.36	0
1948	0	0.32	47.92	111	109.36	281.28	344.96	354.64	225.48	10.24	0	0
1949	0	0	5.4	20.08	234.12	109	246.48	240.88	149.72	15.76	0	0
1950	0	0	0	53.28	140	212.16	232.4	273.64	152.72	20.04	0	0
1951	0	0	2.4	24.6	226.8	129.48	235.6	345.04	196.4	60.24	2.04	0
1952	3	5.88	17.72	44.12	227.16	179.76	337.24	168.6	247.76	29.8	0	0
1953	0	12.16	22.12	35	265.6	164.4	246.72	247.92	186.6	16.88	0	0
1954	0	1.2	28.24	86.24	250.24	167.24	406.84	266.24	220.72	53.72	19.8	0
1955	1.2	0	0	57.2	119.2	206.92	280.64	220.52	198.84	91.4	0	0
1956	0	7.8	81.6	47.12	58.84	191.24	261.76	228.76	222.52	26.6	0.6	8.4
1957	0	0	1.2	65.68	169.68	215.32	425.04	283.16	242.4	93.56	8.4	0
1958	6	1.2	0.6	130.36	121.88	223.44	244.56	279.92	262.32	27.28	0	0
1959	0	0	25.36	58.52	219.12	184.32	261.64	253.52	290.68	9.64	0	0
1960	0	0	1.2	132.84	129.32	223.64	274.72	316.36	228.08	3	0	0
1961	6	0	0	0.4	61.2	153.28	320.8	238.16	146	15.64	0	0
1962	0	0	6.52	88.88	73.12	180.56	248.68	236.72	293.92	66.28	0	0
1963	0	1.8	36	124.56	100.24	189.6	343.96	306.88	140.4	115.68	0	0
1964	0	0	0.6	64.92	126.68	210.64	255.76	402.08	209.36	30.72	1.8	0
1965	0	22.8	1.8	65.48	80.24	209.16	275.36	320.12	169.36	11.28	0	0
1966	0	0	4.8	112.36	146.24	241.92	258.08	250.6	214.84	129.96	0	0
1967	0	0	3	87.24	134.08	144.64	285.84	290.8	182.6	119.68	3	0
1968	0	0	0	133	157.84	225.08	336.4	314.08	126.96	27.04	0	0
1969	0	0	3.96	130.32	114.64	172.64	353.12	363.16	246.28	98.04	9	0

1922	1992											
BUNGA	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1970	0	0	5.4	42.6	120.36	127.28	232.68	274.08	223.68	20.68	0	0
1971	0	0	6.52	25.2	196.76	150.56	372.16	271.04	246.44	15.72	0	0
1972	0	0	23.4	52.04	176.36	135.32	248.48	376.68	141.16	9.88	0	6
1973	0	0	7.2	117.08	86.32	139.56	308.76	272.88	165.44	20.5	0	0
1974	0	0	0	52.52	104.64	181.88	348.68	302.16	258.36	26.04	0	0
1975	0	0	0	52.28	100.48	138.72	322.84	344.94	204.6	29.36	0	2.4
1976	1.8	24.96	11.4	89.88	147.04	165.2	298.64	325.84	226.24	36.28	0	0
1977	0	0	7.98	3.48	152.14	154.3	256.86	289.42	142.6	26.84	0	0
1978	0	0	10.5	77.6	92.14	226.78	298.1	366.6	186.9	83.48	0	0
1979	0	0	5.58	63.72	137.56	156.16	284.28	289	160.12	25.74	4.02	0
1980	0	10.86	8.52	6.98	187.68	148.3	269.34	269.54	101.16	57.94	0	0
1981	0	0	0	99.5	191.3	205.8	249.4	294.6	190.7	41.2	0	0
1982	0	0	5.04	140.34	101.88	167.48	322.18	247.32	139.7	33.1	0	0
1983	0	0	17.62	0	128	199.52	281.04	287.52	100.68	0	0	0
1984	0	0	35.66	66.76	160.4	105.82	193.04	223.3	255.98	9.58	0	0
1985	0.36	0	72.02	3.12	165.68	190.06	209.98	190.16	145.54	10.34	0	0
1986	0	26.58	4.88	48.92	119.74	155.42	347.78	189.72	187.86	17.84	0	0
1987	0	0	36.12	11.16	62.48	241.32	240.98	306.04	111.24	64.36	0	0
1988	0	0	21.06	130.8	154.14	166.52	198.38	206.56	197.82	35.42	0	0
1989	0	0	0.18	81.62	97.6	173.72	219.62	322.84	134.98	60.4	0	6.6
1990	0	0	0	25.94	219.88	159.72	244.62	258.58	158.78	22.8	0	0
1991	0	0.42	29.1	111.28	181.8	189.34	295.16	245.12	79.64	33.08	0	0
1992	0	3.18	44.82	112.94	130.16	233.24	293.44	300.18	187.9	51.44	3.78	0

Appendix 6: Monthly stream flow for Chiromawa, Challawa Gorge and Bunga

Table A6.1: Monthly runoff in the Kano at Chiromawa in million cubic metres

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1964	0	0	0	0	6.2	22.2	173	638.9	559	59.4	8.2	2
1965	0.5	1.4	0.1	0.1	0.9	186.5	150.9	338.3	518.4	25.3	3.8	0.9
1966	0.2	0	0	0	56.3	59.2	30.4	524.9	723.3	104.6	11.5	2.7
1967	0.8	0.2	0	0	2.8	20.6	114.9	357.6	319.7	56	8	2.1
1968	0.4	0	0	29	53.6	76.7	308.5	343	137.9	18.7	2.1	0.1
1969	0	0	0	0.3	6.6	92.7	257.7	375.5	368.8	82.7	15.9	2.9
1970	0.5	0.1	0	0	17.4	23.1	125	651	541.7	30.3	4.6	1.8
1971	0.3	0.6	1.3	1.1	13.5	18.1	101.3	505.3	372.1	22.3	2.8	0.6
1972	0.7	0.6	0.6	0	19.5	31.7	60.1	399	112.2	19.3	1.8	1
1973	0.8	1.1	1.7	32.5	1.9	17.3	72.5	198.8	68.5	8.4	2.7	3.2
1974	3.1	2.9	4.9	7.5	8.4	15.8	13.2	99.8	16	12.3	3.9	2.9
1975	3.3	3	4	4.1	6.3	6.4	16.4	17.6	18.5	6.1	6.9	7.8
1976	10.2	7.8	11.6	9.7	9.5	13.2	10.1	18.3	10.6	13	17.4	16.7
1977	13.8	13.7	18.7	16.5	18.6	20.4	20.9	113.5	286.9	63.6	31.7	38.7
1978	31.6	39.2	49.3	50.4	62	61.9	76.8	84.3	66.8	28.3	22.9	23.3
1979	30.7	24	26.3	19.3	28.9	50.9	56.5	46.5	164.9	99.5	26.4	23.8
1980	33.5	39.6	43	45.5	54.6	47.2	51.6	137.6	127.6	77.3	37.5	52.4
1981	51.1	45.7	54.8	66.3	63.1	61.8	61.2	111.2	66.3	36.4	26.1	40.9
1982	50.7	44.8	68.6	86.2	42.4	73.7	51.8	44.2	22.4	49.6	16.7	14.9
1983	10.4	14.2	16.6	18.7	21.7	23.1	27	39.8	22.1	13	15.8	19.4
1984	19.5	17.5	19.9	23.1	20.1	15.4	20	22.5	11.9	8.7	14.3	11.1
1985	25	13.8	17	15.5	16.8	35.4	50.4	59.8	12.4	10.7	15.1	28.8
1986	34.5	0	0	27.6	22.9	41.2	71.5	139.4	93.6	52.6	44.9	50.9
1987	56.5	49	51.1	52.2	57.5	76.3	131.1	187.3	89.8	81.1	77.7	75.3
1988	75.6	36.3	47.7	46.8	49.2	48.4	47.1	260.8	451.6	395.1	128.1	19
1989	0	47.2	59	87.8	204.9	194.2	145.8	163.9	570.2	230.8	86.3	77.4
1990	80.8	81.8	118.5	101.8	92.7	81.1	68.2	94.5	108.2	119.6	99	89.3
1991	89.9	81.5	89.6	67.8	70.6	16.4	0	62	275.6	0	0	0
1992	0	0	0	76.4	89	76	134.6	142.4	245.6	190.3	142.8	184.1

Table A6.2: **Monthly runoff in the Challawa River at Challawa Gorge million cubic metres**

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971	0	0	0	0	0	6.5	56.9	270.5	172.9	1.6	0	0
1972	0	0	0	1.4	12.8	52.6	39.2	275.1	15.3	1.6	0	0
1973	0	0	0	0	0	15.5	142.4	129.7	47.7	0.2	0	0
1974	0	0	0	-	-	-	-	-	-	-	-	-
1975	0	0	0	0	1.5	18.5	215.5	350.7	210.9	2.6	0.1	0
1976	0	0	0	0.3	4.4	47.6	72.5	72.3	40.7	32.6	2.9	0
1977	0	0	0	0	14.7	61.7	65.9	324.2	121.4	5.5	0.1	0
1978	0	0	0	1	43.1	41	118.7	119.6	94.3	4.2	0.3	0.2
1979	0	0	0	0	37.2	122.5	157.3	135.6	40.9	2		0
1980	0	0	0	0	38.8	31.1	34	122.5	23.7	0	0	0
1981	0	0	0	3.1	16.7	24.9	90.2	66.3	58.8	0	0	0
1982	0	0	0	0	9.4	42.1	44.7	64.6	47.3	6.4	0	0
1983	0	0	0	0	16	53.9	111.9	137.8	49.9	0.5	0	0
1984	0	0	0	0	35.6	28.2	61.2	70.8	70.2	28.2	2.5	0
1985	0	0	0	0	11.8	73.2	129.1	128	51.8	0.3	0	0
1986	0	0	0	0	6.7	17.5	69.2	219.7	62.3	1.3	0	0
1987	0	0	0	0	0	65.9	43.4	100.4	15.7	8.5	0	0
1988	0	0	0	0.9	2.4	70.1	23.1	376.3	137	1.5	0	0
1989	0	0	0	0	1.8	6.3	46.8	123.2	19.1	9.7	0	0
1990	0	0	0	0	36.9	17	118.5	43.3	36.4	0	0	0
1991	0	0	0	0	51.7	58	56.2	110.1	33.5	0.7	0	0

Table A6.3: Monthly runoff in the Jama'are River at Bunga in million cubic metres

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1964	0	0	0	0.0	0.0	148.4	344.2	1435.0	1082.0	70.3	9.0	0.4
1965	0.0	0.0	0.0	2.2	6.2	126.7	196.8	610.1	688.6	25.0	3.0	0.7
1966	0.2	0.1	0.0	5.0	75.6	173.6	141.3	851.3	1217.0	99.0	9.4	2.8
1967	0.9	0.2	0.1	0.2	2.1	31.4	232.9	805.6	730.0	50.5	6.5	1.8
1968	0.4	0.2	0.1	11.2	96.1	280.8	576.0	746.8	254.0	29.4	0.9	0.7
1969	0.8	1.0	1.1	6.8	10.2	34.0	422.9	834.6	965.7	185.0	19.9	4.2
1970	1.4	0.9	1.0	1.1	10.4	26.5	179.9	1074.0	784.5	39.4	5.4	1.2
1971	0.4	0.3	0.4	2.8	34.4	51.5	264.8	1661.0	772.0	30.6	4.2	1.1
1972	0.2	0.0	0.0	3.4	23.7	50.2	146.9	502.5	214.9	31.0	1.6	0.4
1973	0.4	0.4	0.3	7.1	8.8	25.7	194.3	649.2	119.4	13.1	0.7	0.4
1974	0.3	0.1	0.1	0.0	72.2	29.9	150.0	820.3	706.1	110.8	7.7	1.9
1975	0.7	0.2	0.1	0.2	19.7	17.1	259.7	761.1	1222.0	64.6	7.4	4.5
1976	0.6	0.3	0.1	0.7	27.4	61.0	338.7	467.8	413.1	92.0	16.7	3.4
1977	1.7	0.1	0.1	0.1	4.1	44.0	142.6	1021.0	690.1	34.0	3.6	0.9
1978	0.3	0.2	0.2	7.1	74.1	110.3	313.5	617.8	397.3	61.0	15.4	2.3
1979	0.7	0.2	0.1	0.1	23.6	50.8	374.9	733.3	520.8	75.1	5.8	1.0
1980	0.3	0.2	0.1	0.2	43.7	57.0	526.8	909.6	243.2	33.7	3.9	0.7
1981	0.2	0.1	0.1	0.0	46.5	58.8	477.9	464.3	430.5	40.1	3.3	0.8
1982	0.4	0.2	0.2	0.7	21.2	55.3	199.7	695.0	289.8	61.5	4.3	1.0
1983	0.2	0.2	0.2	0.7	6.7	49.2	168.9	336.7	245.7	17.6	1.3	0.3
1984	0.1	0.1	0.0	0.1	19.5	47.5	121.8	163.9	93.2	3.2	0.5	0.2
1985	0.1	0.0	0.0	0.1	12.4	89.7	265.8	299.2	289.7	17.6	0.7	0.2
1986	0.0	0.0	0.0	0.1	13.0	67.2	625.1	535.7	576.2	49.6	3.0	0.5
1987	0.2	0.1	0.0	0.0	9.1	90.2	58.2	134.8	80.2	42.5	0.0	0.0
1988	0.0	0.0	0.0	7.6	7.8	48.5	174.1	1,252	698.7	73.4	3.3	0.6
1989	0.2	0.1	0.0	0.0	29.9	78.5	202.2	588.6	434.5	119.6	5.7	1.0
1990	0.1	0.1	0.0	0.0	54.5	79.1	235.1	384.6	379.2	28.3	1.6	0.3
1991	0.0	0.0	0.0	0.5	137.8	118.2	428.9	1103.0	295.4	16.6	0.9	0.0
1992	0.0	0.0	0.0	0.0	0.0	6.6	28.5	68.5	21.6	1.4	17.3	0.1
1993	0.0	0.0	0.0	0.0	32.2	184.4	294.9	730.4	619.4	14.3	0.0	0.0
1994	0.0	0.0	0.0	39.2	28.6	130.0	277.5	1,727	1,438	316.2	23.3	0.0
1995	0.0	0.0	0.0	0.0	76.0	117.3	329.6	646.7	301.3	175.1	6.2	0.0

Appendix 7: Meteorological Parameter

Name of file: Temp.txt
(Temeperature (Temp) in °C and relative humidity (rhum) in %)

KANO	TEMP	RHUM
1974	1978	
1	20	20
2	23.5	12
3	27.5	14
4	33	37
5	30	54
6	29.5	55
7	25.5	76
8	25.5	77
9	25.5	72
10	25	52
11	23	20
12	21.1	19
1	18.5	18
2	24	12
3	26.5	11
4	26.5	30
5	30.5	51
6	28.5	60
7	25.5	74
8	25	76
9	26	74
10	25.5	44
11	24	20
12	21.1	21
1	20	16
2	25.5	16
3	27.5	15
4	30.5	32
5	30.5	50
6	27.5	65
7	25	74
8	25.5	76
9	25.5	69
10	26	65
11	22.5	28
12	21.5	16
1	21	15
2	22	12
3	25.5	12
4	29	18
5	31	43
6	27.5	61
7	25.5	68
8	25.2	78
9	25	72
10	24.5	54
11	19.5	25
12	18.5	29

Appendix 8: Details of dams and users in KYB

Table A8.1: Overview of dams and other major water uses in the Hadejia sub-basin upstream of Hadejia

Sites	Type of use	References
Tiga Dam (1974) and Ruwan Kanya Reservoir on Kano River	live storage 1,845 $10^6 m^3$; large scale irrigation (13,300 ha, 1997) for Kano River Irrigation Project (KRIP), Kano City Water Supply (KCWS), fishing	HJRBDA; Adams (1991); Adams *et al*. (1993); Afremedev (1999d); Diyam (1986, 1996); IUCN (1999); Oyebande (2003); Oyebande and Nwa (1980); Simon (1997)
Tudun Wada Dam (1977) on Kano River	live storage 18 $10^6 m^3$; irrigation	KSMWR; WRECA (1980)
Bagauda small dam (1970) on a tributary to Kano River	live storage 21 $10^6 m^3$; Kadawa Irrigation Scheme; domestic water supply	KSMWR; Diyam (1996); Oyebande and Nwa (1980); WRECA (1980)
Marashi Dam (1980) on Challawa River	live storage 6 $10^6 m^3$; irrigation	KSMWR; Diyam (1986, 1996); WRECA (1980)
Challawa Dam (1992) on Challawa River	live storage 904 $10^6 m^3$; Kano City Water Supply (KCWS), fishing	HJRBDA; Diyam (1996); IUCN (1999)
Pada Dam (1980) on Challawa River	live storage 10.5 $10^6 m^3$; irrigation	KSMWR; Diyam (1986, 1996); WRECA (1980)
Karaye Dam (1971) on a tributary to Challawa River	live storage 16 $10^6 m^3$; urban water supply (Gwarzo, Karaye, Keru and others)	KSMWR; Diyam (1996); Oyebande and Nwa (1980); WRECA (1980)
Magaga Dam (1980) on Challawa River	live storage 17 $10^6 m^3$; irrigation	KSMWR; Diyam (1986, 1996); WRECA (1980)
Gunguzu Dam (1979) on a tributary to Challawa River	live storage 22 $10^6 m^3$; small scale irrigation; domestic water supply (Garo, Gude)	KSMWR; Diyam (1986, 1996); WRECA (1980)
Watari Dam (1980) on Watari River (tributary to Challawa River)	live storage 93 $10^6 m^3$; irrigation	KSMWR; Diyam (1986, 1996); WRECA (1980)
Kafin Chiri (1976) small dam near Wudil on tributary to Hadejia River	live storage 24.6 $10^6 m^3$; domestic water supply, irrigation	KSMWR; WRECA (1980)
Wudil	domestic water supply Wudil (tubewells in the river bank), Gari irrigation project	KSWB; KSMWR
Hadejia Barrage	Hadejia Valley Irrigation Project (3,000 ha, gross; 2,200 ha net. in 2003), fishing	HJRBDA; Diyam (1996)
floodplains along the Hadejia River	small scale irrigation in floodplains using surface and shallow groundwater, groundwater recharge, cattle, domestic uses	ADP and WB Kano and Jigawa states
cities and some villages in the uplands of Kano and Jigawa states	rural and urban water supply, and irrigation(?) using groundwater from 1st aquifer	WB and Ministries of Agriculture of Kano and Jigawa states

Table A8.2: Dams on smaller rivers that are probably not directly draining into the Hadejia and/or Jama'are rivers

Sites	Type of use	References with information
Dambo small dam on Gari River near Kazaure	irrigation	MA Jigawa State; Muslim and Umar (1995)
Gari Marke small dam (1980) on Gari River near Kazaure	live storage 203 $10^6 m^3$; irrigation	MA Jigawa State; KSMWR; Muslim and Umar (1995); WRECA (1980)
Mohammad Ayuba Dam (1975) on Watari River near Kazaure	live storage 4.3 $10^6 m^3$; irrigation; domestic water supply	MA Jigawa State; WRECA (1980)
Ibrahim Adamu Dam (1974) near Kazaure	live storage 7.4 $10^6 m^3$; domestic water supply, irrigation	KSMWR; WRECA (1980)
Tomas Dam (1976) on Tomas River near Kunya	live storage 57 $10^6 m^3$; irrigation	KSMWR; WRECA (1980)
Jakara Dam (1976) on Jakara River near Kano	live storage 54 $10^6 m^3$; irrigation	KSMWR; WRECA (1980)
Warwade small dam on Warwade River near Dutse	live storage 9.7 $10^6 m^3$; irrigation, domestic water supply	MA Jigawa State; Muslim and Umar (1995); WRECA (1980)

Table A8.3: Overview of major water uses in the Jama'are sub-basin upstream of Katagum

Sites	Type of use	References with information
cities and some villages in the uplands of Yobe and Bauchi states	rural and urban water supply and irrigation(?) using groundwater from 1st aquifer	WB for Bauchi and Yobe states
the floodplains along the Jama'are River	small scale irrigation using surface and shallow groundwater, groundwater recharge, livestock, fisheries	ADP for Bauchi and Yobe states
Kafin Gana/Iggi embankment (Kano-Maiduguri road)	Irrigation	MA Jigawa State; Muslim and Umar (1995)
Birin Kudu Dam (1970) on Dogwala River tributary to Jama'are	live storage 1 $10^6 m^3$; irrigation, domestic water supply	MA Jigawa State; Diyam (1986, 1996); Muslim and Umar (1995); WRECA (1980)
Galaga Dam (1985) on Galaga River tributary to Jama'are	live storage 20 $10^6 m^3$	HJRBDA; Diyam (1986, 1996); Ben-Musa and Abubakar (1995)
Tsohowar Gwaram on a tributary to Jama'are		Jigawa State
Dogola Dam on a tributary to Jama'are		Jigawa State
Katagum Irrigation Project (no dam)	Irrigation, active?	HJRBDA; BaSMWR

Table A8.4: Overview of the major water uses in the Hadejia-Nguru Wetlands (Hadejia and Jama'are rivers)

Sites	Type of use	References with information
Hadejia River, Marma Channel and Burum Gana River	small scale irrigation in the floodplain using surface and shallow groundwater	ADP for Bauchi, Jigawa and Yobe states; Acharya and Barbier (2000); Chiroma (1996); Goes (1999); IUCN (1999); Prat *et al*. (1997)
HNW	domestic water uses, livestock uses, groundwater recharge, ecological uses	WB for Bauchi, Jigawa and Yobe states, Chiroma (1996); Chiroma and Polet (1996); Goes (1999); IUCN (1999); Okali and Bdliya (1998a & b)
Wachakal on Burum Gana River	formal irrigation project (70 ha)	YSADP; Adams *et al*. (1993)

Table A8.5: Overview of the major water uses in the Komadugu sub-basin

Sites	Type of use	References with information
cities and some villages in the uplands of Yobe and Bauchi states	rural and urban water supply and irrigation(?) using groundwater from 1st aquifer	YSWC and RUWASA, BaSWB and Ministry for Rural Development
the floodplains along the Komadugu river	small scale irrigation (less than along Yobe River), livestock, fisheries, groundwater recharge	ADP for Bauchi and Yobe states; NEAZDP

Table A8.6: Overview of the major water uses in the Yobe sub-basin

Sites	Type of use	References with information
cities and some villages in the uplands of Yobe and Borno states	rural and urban water supply (usually ~100 m deep wells) and irrigation(?) using groundwater from 1st aquifer	Yobe and Borno State Water Boards and Ministries of Agriculture; NEAZDP (1990); Carter and Alkali (1996)
the floodplains along the Yobe River	small scale irrigation using surface water and shallow groundwater; YSADP has drilled 4892 shallow (max.~12 m) tube-wells that use ~239 $10^6 m^3 y^{-1}$ (July 2005); at Abadam ~200 ha (CBDA), groundwater recharge, livestock, fishing	Yobe and Borno State Ministries of Agriculture and ADP's; CBDA; NEAZDP Village Water Supply; NEAZDP (1990); Carter and Alkali (1996); Diyam (1996); Wardrop (1993)

Sites	Type of use	References with information
Diffa Irrigation Project (Niger)	1,200 ha (1997)	relevant authorities in Niger, LCBC, IUCN (1999)
Magura (150 ha), Bolorum (100 ha), Bululu (100 ha YSADP ~20 ha CBDA), Laba (~20 ha), Gashua (142 ha, 1997), Kellori/Balle (50 ha, 1997), Geidam (50 ha, 1997), Damasak (40 ha, 1997), Duji (500 ha, 1997), Yau	formal irrigation projects along the Yobe River (many projects are no longer active during past 5 years due to reduced flow quantity and flow period)	YSADP, BSADP, CBDA, IUCN (1999)
Baga Polder Project, water from Lake Chad	formal irrigation, problems with water supply, now concentrating on recession farming	UNEP (2004)
South Chad Irrigation Project (SCIP), water from Lake Chad	formal irrigation, problems with water supply, not functioning (2004), dried up irrigation canals are taken over by *Typha*	CBDA; Adams (1991); Adams *et al.* (1993); IRIN (2003); UNEP (2004)

Table A8.7: Overview of possible expansions of currents water uses and proposed water uses

Sites	Sub-basin	Type of use	References with information on quantities
KRIP	Hadejia	expansion from 13,300 ha to 20,300 ha (Phase 1) and 62,000 ha (Phase 1 and 2)	HJRBDA; IUCN-HNWCP (1999); Simon (1997)
HVIP	Hadejia	expansion to 7,000 ha (Phase 1)	HJRBDA
Kunza Dam on Kano River (proposed)	Hadejia		Hollis and Thompson (1993)
Shimar Dam on Kano River (proposed)	Hadejia		Hollis and Thompson (1993)
Garanga Dam on Kano River (proposed)	Hadejia		Hollis and Thompson (1993)
Kango Dam on Challawa River (proposed)	Hadejia		Hollis and Thompson (1993)
Kafin Zaki Dam (proposed, suspended)	Jama'are	capacity 2,700 $10^6 m^3$, irrigation of 84,000 ha	HJRBDA; Adams *et al.* (1993); Schultz (1976)
Kawali Dam (proposed)	Jama'are		Schultz (1976); Diyam (1986, 1996)
Kiyako River Dam (proposed)	Jama'are		Diyam (1986, 1996)
Iggi River Dam (proposed)	Jama'are		Diyam (1986, 1996)
Dogwala River Dam (proposed)	Jama'are		Diyam (1986, 1996)
Marra Dam (proposed)	Jama'are		Hollis and Thompson (1993)
Kafin Gana Dam (proposed)	Jama'are		Hollis and Thompson (1993)
Kukuri	Komadugu	formal irrigation (50 ha), contract has been handed out in mid 2005	YSADP
Missau Dam (proposed)	Komadugu		HJRBDA
Gulka Dam (proposed) in Giade LGA	Komadugu	urban water supply for Jama'are, Azare and Misau, proposed capacity 48 $10^6 m^3$	BaSWB
Balle/Kellune and others (see above)	Yobe	revitalisation of formal irrigation projects	YSADP, BSADP
in the vicinity of all rivers	the whole basin	expansion small-scale floodplain farms using shallow groundwater and surface water	ADP's from the states; Diyam (1987); Wardrop (1993); JSMWR (2000)
Formal irrigation on shores of Lake Chad	Lake Chad	revitalisation of SCIP and Baga Polder irrigation projects (if Lake Chad expands again)	CBDA; Adams (1991); Adams *et al.* (1993); IRIN (2003); UNEP (2004)